INSTRUCTION MANUAL

SINKER EDM

MACHINING TECHNIQUES

1708-202305V1

PRECAUTIONS

1. The matters which are not covered inside this manual will not be guaranteed.
2. The notes provided in this manual must be observed. Otherwise, the function may not be executed correctly or the system could be adversely affected.
3. Specifications are subject to change for improvement without notice.
4. Please contact us if you have any uncertainty about the manual.

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1. ELECTRODE DESIGN AND ELECTRODE REDUCTION

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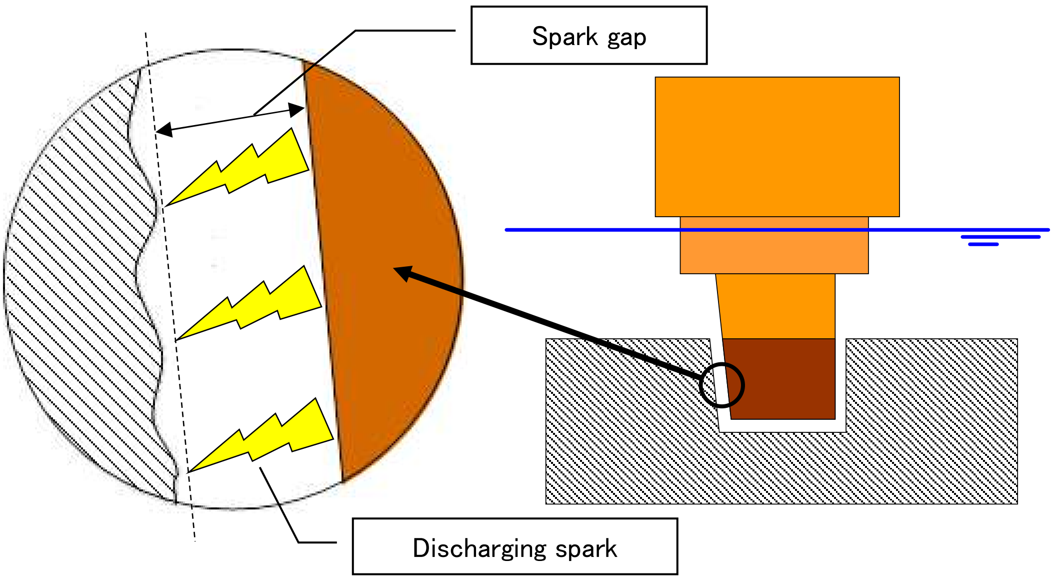
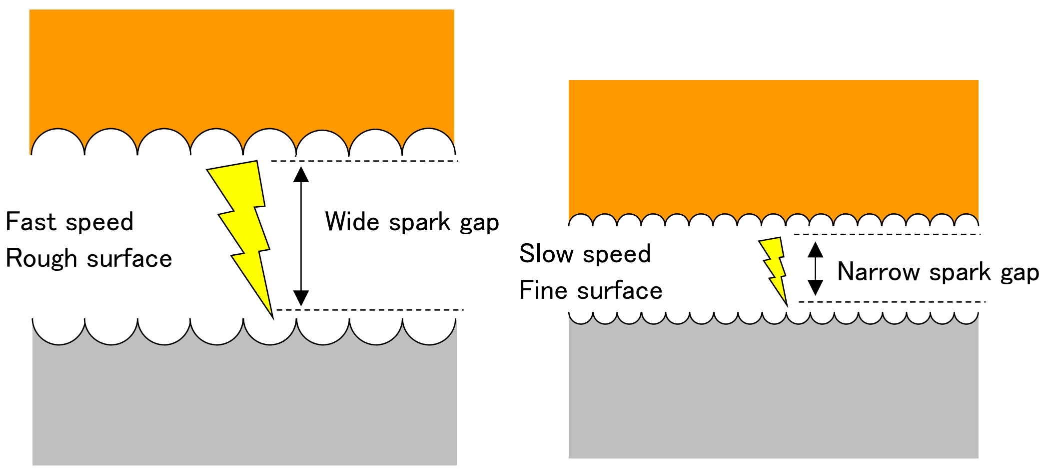
In this chapter, we explain about the concept of “electrode reduction”, which is important in sinker EDM, and its deciding method.
For achieving the maximum performance of sinker EDM, it is necessary to decide “electrode reduction” based on the requirements such as machining time and shape accuracy.

1.1 Relation between spark gap, orbit and electrode reduction

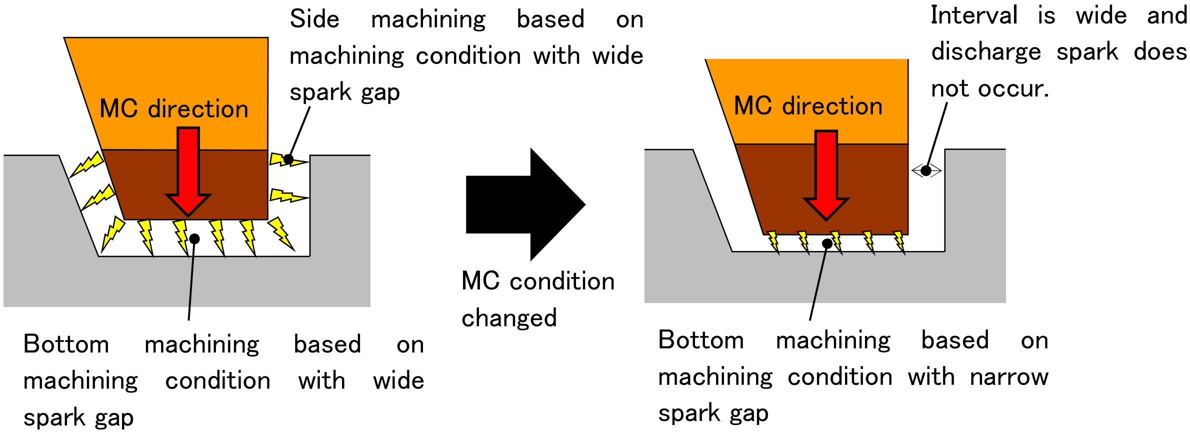
Sinker electrical discharging is a machining method that generates discharge spark from an electrode to a workpiece, and transfers the electrode shape to workpiece. The “transferred” electrode shape, calculated by adding the electrode dimension and the length of discharge spark, is bigger in dimension than the original electrode shape. Therefore, it is necessary to fabricate the electrode to a smaller dimension than the target dimension. The length of this discharge spark is generally called a “spark gap”.



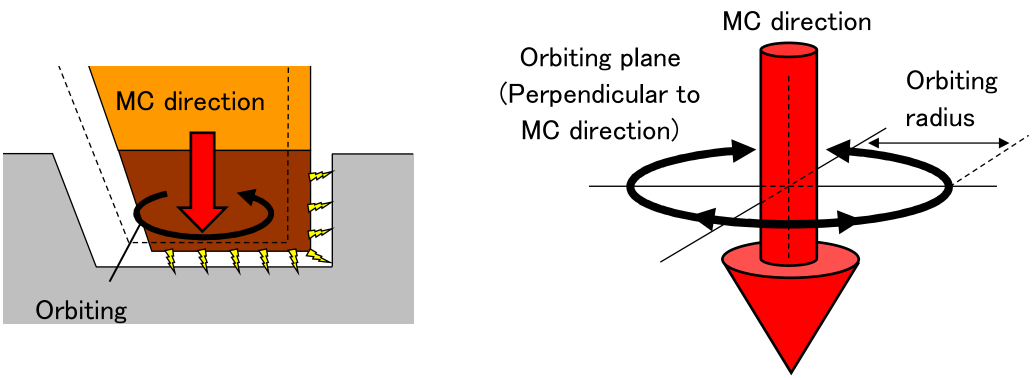
The “spark gap” changes according to the type of machining condition.
When machining speed is fast, and machining condition has rough surface roughness, spark gap becomes wide.
When machining speed is slow, and machining condition has fine surface roughness, spark gap becomes narrow.



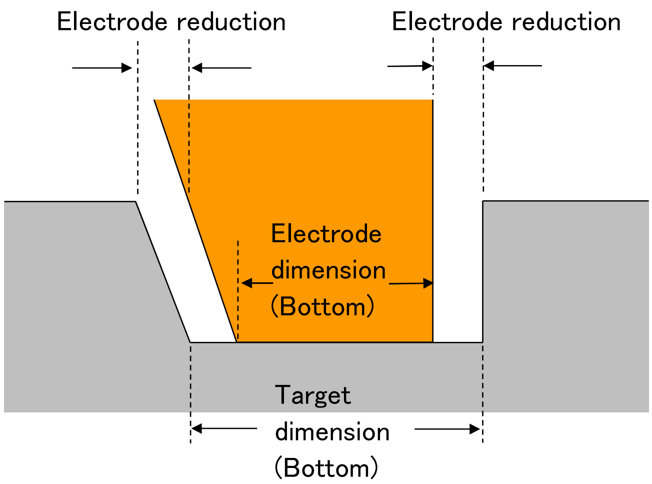
For making fine surface roughness, after machining condition with wide spark gap, simply changing to machining condition with narrow spark gap and machining will give finishing by feeding into the depth of bottom. However, finishing is incomplete as the narrow spark gap does not reach the side walls.



Therefore, in sinker EDM having X, Y, and Z axes, with the motion that swings the electrode on the plain surface that is perpendicular to the machining method, simultaneous finishing of bottom and side is possible. This motion is generally referred to as "orbiting". Half of an orbiting width is called an "orbiting radius".



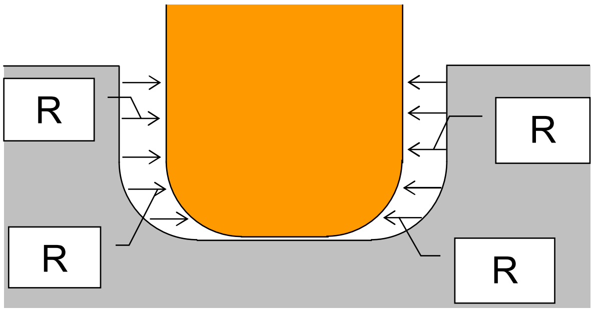
The reduced part of the electrode dimension where "spark gap" and "pattern radius" are considered is referred to as an "electrode reduction". Usually, "electrode reduction" refers to the reduction of per–side dimension. Therefore, the radial dimension of the electrode is reduced twice of "electrode reduction".

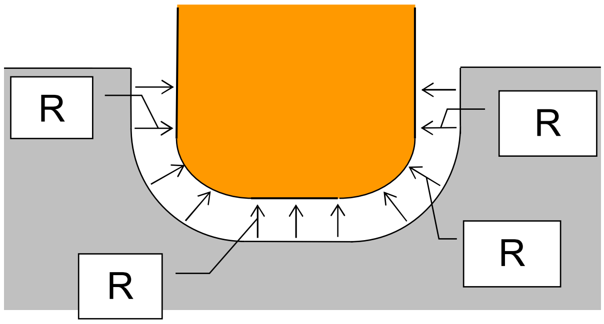


1.2 2D reduction and 3D reduction

There are two types of reduction method of electrode, namely, “2D reduction” and “3D reduction”.

2D reduction	3D reduction
Only XY directions are reduced	All XYZ directions are equally reduced



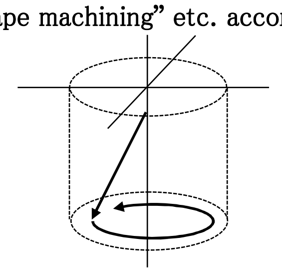


“2D reduction” and “3D reduction” have following features and they are separately used based on the application.

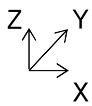
Reduction		Feature	Purpose	Example
2D	Merit	Bottom corner can be accurately machined Orbiting motion is simple and machining efficiency is high	General MC High accuracy right-angled shape	Rib Connector
	Demerit	In 3D shape, shape error becomes large Electrode bottom is always machined to flat surface		
3D	Merit	In 3D shape, shape error can be made small Uniform finishing and machining of all surfaces is possible	3D shape machining	Mobile phone
	Demerit	Corner would have radius R that is equal to or more than electrode reduction Orbit is complex and machining efficiency is low Introduction of 3DCAD is required		

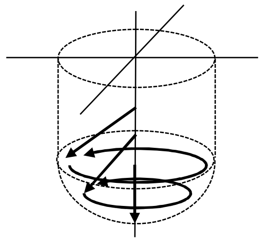
•It is common to machine 2D reduction electrode using model plan (G101).
Regarding how to use it, refer to Chapter 2.

•In 3D reduction electrode, select irregular shape machining “sphere-shape machining” “column-shape machining” etc. according to electrode shape using model plan (G102).



Orbiting path for 2D reduction

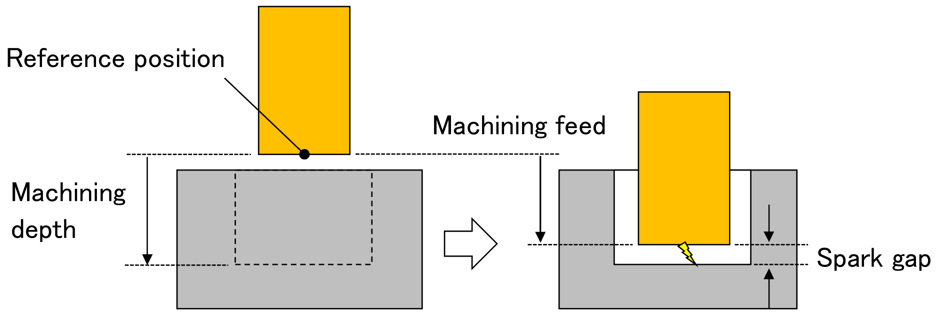




Orbiting path for 3D reduction

1.2.1 Reference position in the case of 2D reduction and 3D reduction

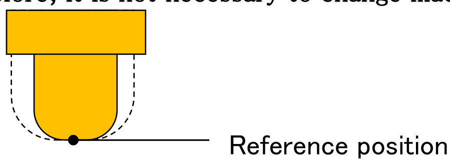
For transfer machining of electrode shape as per the target depth, it is necessary to give machining depth command after measuring the reference position given on the electrode. There is no need to consider reduction in the machining depth axis as it is automatically done based on the spark gap data.



However, in the case of 3D reduction, by deciding the reference position on electrode, machining depth to be instructed changes. Refer to the following figure below for the change of machining depth command value.

① For 2D reduction

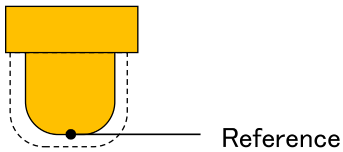
If reference position is placed on the flat part of electrode tip, position of the height direction will not change. Therefore, it is not necessary to change machining depth.



② For 3D reduction

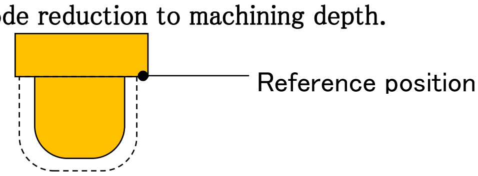
(a) When keeping reference position at the reduced place

Keeping reference position at the reduced place will change the position in height direction due to electrode reduction. However, it will be automatically corrected, and it is not necessary to change machining depth.



(b) When keeping reference position at the place that is not reduced

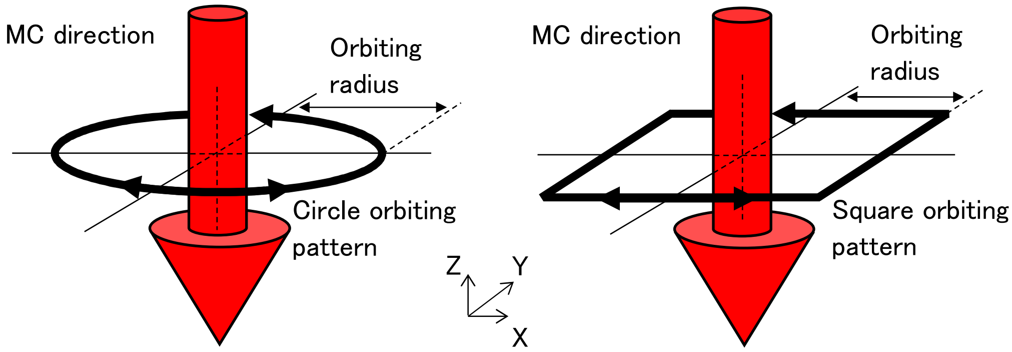
Keeping reference position at the place that is not reduced, will keep the position in the height direction unchanged. However, for balancing out correction, it is necessary to add electrode reduction to machining depth.



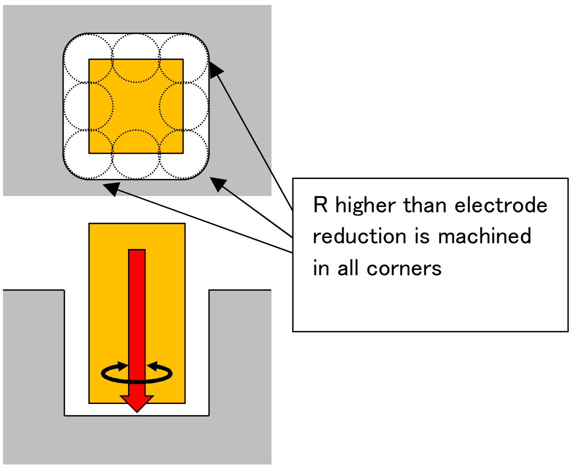
Ex) When machining depth −5.0mm, and electrode reduction 0.2mm,
Change to machining depth −5.2mm.

1.3 Changing machining shape with orbiting pattern

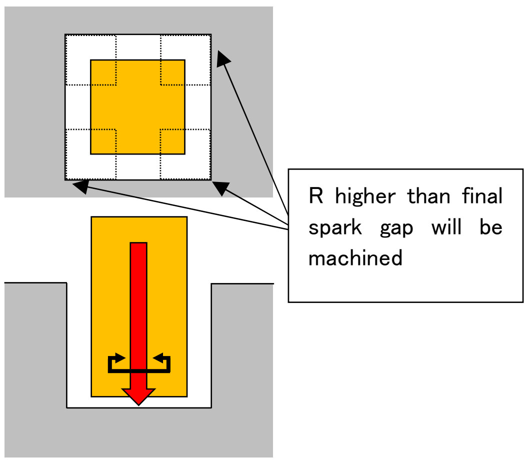
The shape of "Orbiting" motion is called "orbiting pattern". In most of the cases, "orbiting pattern" is either a "Circle" or "Square". Therefore, the effect of machining shape is explained focusing on "Circle" and "Square".



・When machining prismatic electrode with "Circle orbiting" and "Square orbiting"

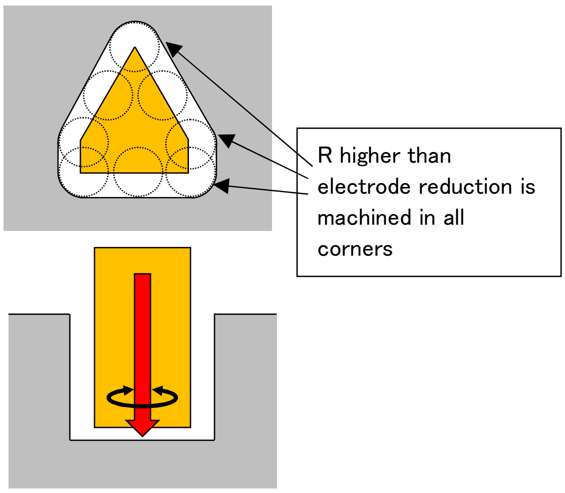


Circle orbiting

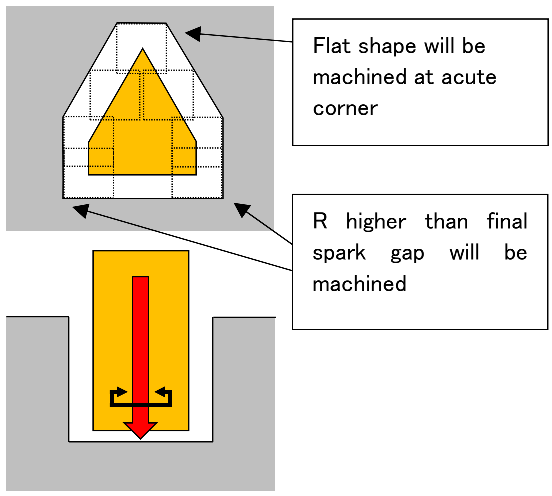


Square orbiting

・When machining electrode having acute corners with "Circle orbiting" and "Square orbiting"



Circle orbiting



Square orbiting

1.4 Setting method of electrode reduction

1.4.1 Effect on machining time following the changes in electrode reduction

The following table shows the effect of electrode reduction and spark area on machining time.

Reduction (mm)	Machining time		
	Spark area □10	Spark area □50	Spark area □100
0.3	45 min. (Unstable)	4 hours	26 hours
0.25	45 min.	7 hours	40 hours
0.2	45 min.	10 hours	63 hours
0.15	2 hours	20 hours	127 hours
0.1	3 hours	58 hours	—
0.07	13 hours	127 hours	—

Machining data
Cu(copper)−St(steel)
No pre milling
Machining depth 10mm
Machining generator 30A

The larger the electrode reduction (spark gap), the shorter the machining time.

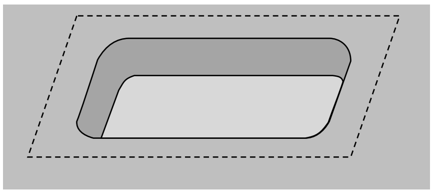
When spark area is □10 and electrode reduction is 0.2mm～0.3mm, machining time doesn't change at 45minutes. Therefore, when spark area is small, it is not necessary to make electrode reduction large.

When spark area is □10 and electrode reduction is 0.3mm, it would depend on the setting of jump etc.; however, discharge will become unstable and abnormal discharge may occur in some cases.

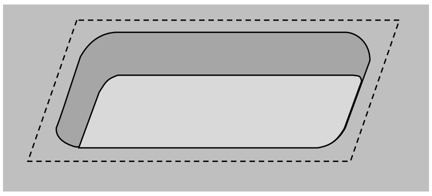
When electrode reduction is 0.1mm or below, a very long machining time is applied. Therefore, it is necessary to shorten it more by pre-machining. (limitation:this doesn't apply when machining amount is small.)

Even if it is other material electrode such as Gr material, this tendency remains the same.

For total machining time shortening, it is desirable to remove as much volume as possible with pre-machining through mechanical cutting, and reduce the machining volume of discharge machining.



Machining allowance of discharge machining is large

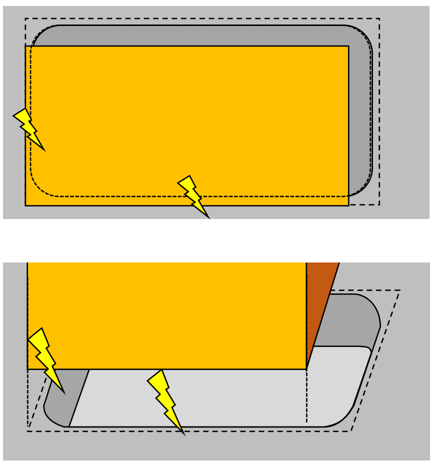


Machining allowance of discharge machining is small

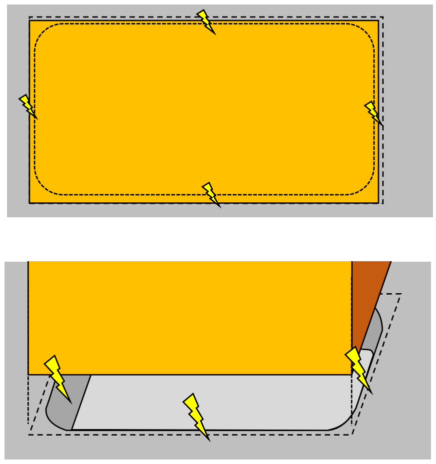
However, if machining allowance of discharge machining is too small, due to the following reasons, longer total machining time may occur.

•Electrode reduction is large → Discharge occur on only per-side and machining efficiency declines

•Electrode reduction is small → Discharge occurs on all circumferences. However, machining capacity declines.

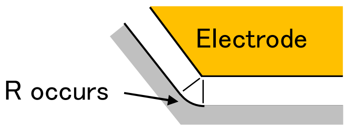


Machining allowance is too small and electrode reduction is large

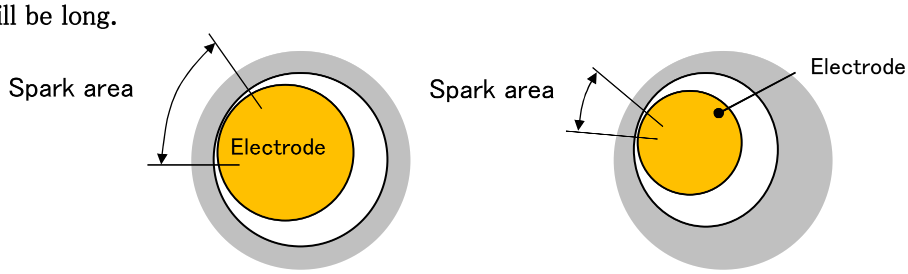


Machining allowance is too small and electrode reduction is small

In circle orbiting, R more than or equal to electrode reduction occurs in the corner. Reducing electrode reduction reduces R, however too much will result in long machining time.



When pattern radius is extremely large (Example: groove machining in the interior part of cylindrical workpiece) For making spark area smaller as shown in the following figure, machining time will be long.



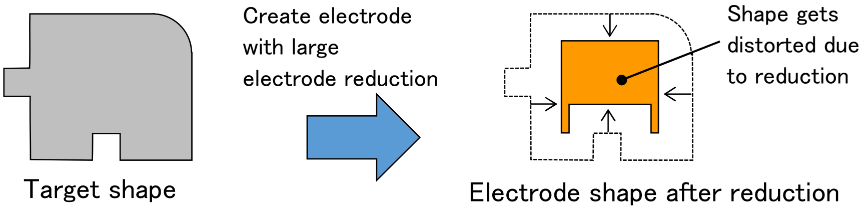
Efficient

Inefficient

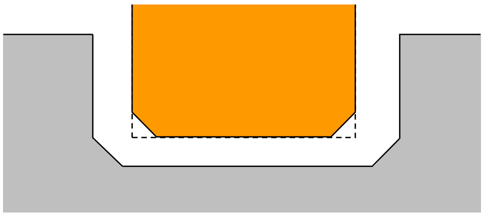
1.4.2 Effect on shape accuracy following the change in electrode reduction

Setting of electrode reduction may lead to worsening of shape accuracy as shown below.

① Reduction itself distorts electrode shape.



② If electrode reduction is large, electrode wear of the corner tends to increase.



R of the bottom edge occurs due to bottom corner electrode wear.
The stronger (wide spark gap) machining condition of a large electrode reduction increases the tendency of this corner electrode wear. In small area machining, usually it is required to reduce R of the bottom edge. Therefore, do not increase electrode reduction beyond what is necessary.

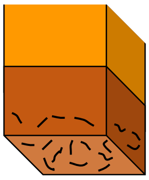
③ If electrode reduction is small (0.15 mm or less), electrode wear ratio tends to become high.

Ex) In the case of Cu-St small area machining (-□5)

Electrode reduction(mm)	0.10	0.08	0.06	0.05	0.04	0.03
Electrode wear rate(%)	0.1	0.1	0.2	0.3	1.0	2.0

Note) Effect on electrode wear ratio due to electrode reduction differs by machining condition.
For increasing shape accuracy, it is necessary to decide electrode reduction after understanding the electrode wear ratio of machining condition.

④ Roughness occurs on the discharge plane of electrode, and the workpiece is subjected to transfer machining.

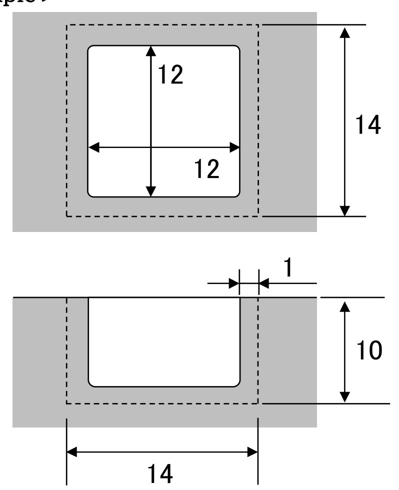


Note) If general copper electrode material “Tough pitch copper” and “Oxygen-free copper” are compared, “Oxygen-free copper” tends to have smaller roughness of electrode.

1.4.3 Method of selecting electrode reduction from spark area

At a place with narrow spark area, forcefully applying machining condition with large electrode reduction worsens machining efficiency, and in some cases, it may cause abnormal discharge. Therefore, method of selecting appropriate electrode reduction from spark area is shown here.

＜Example＞



Electrode Cu(Copper)

Workpiece S55C

When a machining allowance of 1 mm on one side remains due to pre-machining based on mechanical cutting

Entrance area　　14×14－12×12 ＝ 52(mm^2) ≒ □7

Refer to instruction manual data book, and select model data (machining condition number and depth required for rough-finishing machining, collection of orbiting data) corresponding to spark area □10 and Cu-St.

In this example, model data 21 (applicable area □5 ~ 15) is applicable.

Next, refer to the "Minimum spark area" field in the model data table.

"Minimum spark area" refers to minimum spark area that doesn't result in the decline of abnormal discharge or machining efficiency, and a different value for each process number is set. For example, in the case of model data21 process No.3, it is □11. Therefore, it can be interpreted that process No.3 can be used when spark area □11 or more.

Model data 21 (Spark area) □5 ~ 15

Process No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Roughness		55	45	40	35	25	20	16	14	10	8	6	4	3	2
μmRa		10.0	9.0	7.0	5.6	4.5	4.0	3.2	2.5	1.7	1.6	1.1	0.7	0.6	0.4
VDI No.		40	39	37	35	33	32	30	28	25	24	21	17	16	12
Condition No.		248	247	246	245	244	243	242	307	306	305	304	303	332	331
Average current		10	8	7	5	4	3	2							
Electrode wear		0.2	0.2	0.2	0.2	0.2	0.2	0.2	1	2	4	8	11	26	29
Bottom remain		280	237	197	161	132	107	85	68	55	38	28	20	13	8
Side remain		185	154	129	109	93	78	67	56	45	31	23	16	10	7
Min. Spark area		□14	□11	□9	□7	□6	□5	□4							
Time cont. area										□17	□11	□11	□9	□8	□6
After pre milling		195	165	140	120	100	90	80							
Min. reduct. (per side) 2mm		195	165	140	120	100	90	80							
Min. reduct. (per side) 10mm		250	210	180	160	140	120	110							
Min. reduct. (per side) 20mm		290	245	210	190	170	145	130							

Minimum spark area

Entrance of machining example spark area is calculated as □7. Therefore, searching a value less than this will make “□7” of process number5 becoming applicable.

Model data 21 (Spark area) □5 ~ 15

Process No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Roughness			55	45	40	35	25	20	16	14	10	8	6	4	3	2
μmRa			10.0	9.0	7.0	5.6	4.5	4.0	3.2	2.5	1.7	1.6	1.1	0.7	0.6	0.4
VDI No.			40	39	37	35	33	32	30	28	25	24	21	17	16	12
Condition No.			248	247	246	245	244	243	242	307	306	305	304	303	332	331
Average current			10	8	7	5	4	3	2							
Electrode wear			0.2	0.2	0.2	0.2	0.2	0.2	0.2	1	2	4	8	11	26	29
Bottom remain			280	237	197	161	132	107	85	68	55	38	28	20	13	8
Side remain			185	154	129	109	93	78	67	56	45	31	23	16	10	7
Min. Spark area			□14	□11	□9	□7	□6	□5	□4							
Time cont. area											□17	□11	□11	□9	□8	□6
After pre milling			195	165	140	120	100	90	80							
Min. reduct (per side)	2mm		195	165	140	120	100	90	80							
	10mm		250	210	180	160	140	120	110							
	20mm		290	245	210	190	170	145	130							

If we look at the “electrode reduction” field below, electrode reduction in the “After pre milling” field is mentioned as “0.12 mm”.

Min. Spark area			□14	□11	□9	□7	□6	□5	□4	
Time cont. area										
After pre milling			195	165	140	120	100	90	80	After pre milling
Min. reduct (per side)	2mm		195	165	140	120	100	90	80	Without pre milling
	10mm		250	210	180	160	140	120	110	
	20mm		290	245	210	190	170	145	130	

Electrode reduction (per side) ≧ 0.12mm

Therefore, electrode will be made with the aforementioned settings.

1.4.4 Other selection method of electrode reduction

When the selection of electrode reduction becomes difficult due to reasons such as a change in the manufacturer (brand) of electrode material or machining a new electrode shape, approximate spark area and conduct machining test. During testing, check machining efficiency. At the machining program side, you can adjust the discharge state to some extent. The shape of the electrode need not necessarily be aligned. The most important thing is to observe discharge state when it occurs. Therefore, benefits can be expected by checking, even for a few minutes.

Refer to Chapter 2 for the adjustment method of discharge state with machining program.

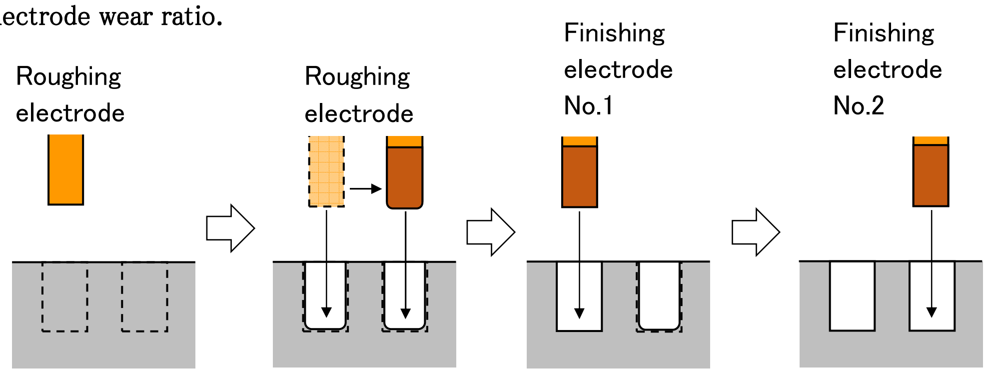
1.5 About number of electrodes

In sinker electrical discharge machine, mostly two electrodes, namely 1 roughing electrode and 1 finishing electrode are machined. The number of electrodes that satisfies the required machining time, shape accuracy, surface roughness, and cost requirement are usually 2 in most of the cases. When machining multiple holes, adjust the number of electrodes using the following method.

<Example Two-hole discharge machining>

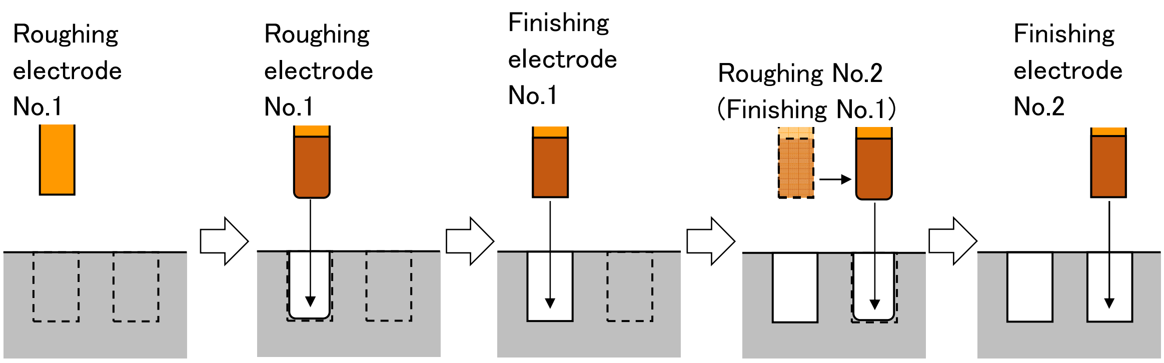
① Machining all positions with 1 roughing electrode

You can individually set electrode reduction for rough machining and finishing machining according to the target. For rough machining, select machining condition with low electrode wear ratio.



② Assign used finishing electrode to the next roughing electrode

This method can reduce the dimension difference between holes. However, roughness and finishing electrode reduction are almost same. Therefore, machining speed is inferior to even ①.



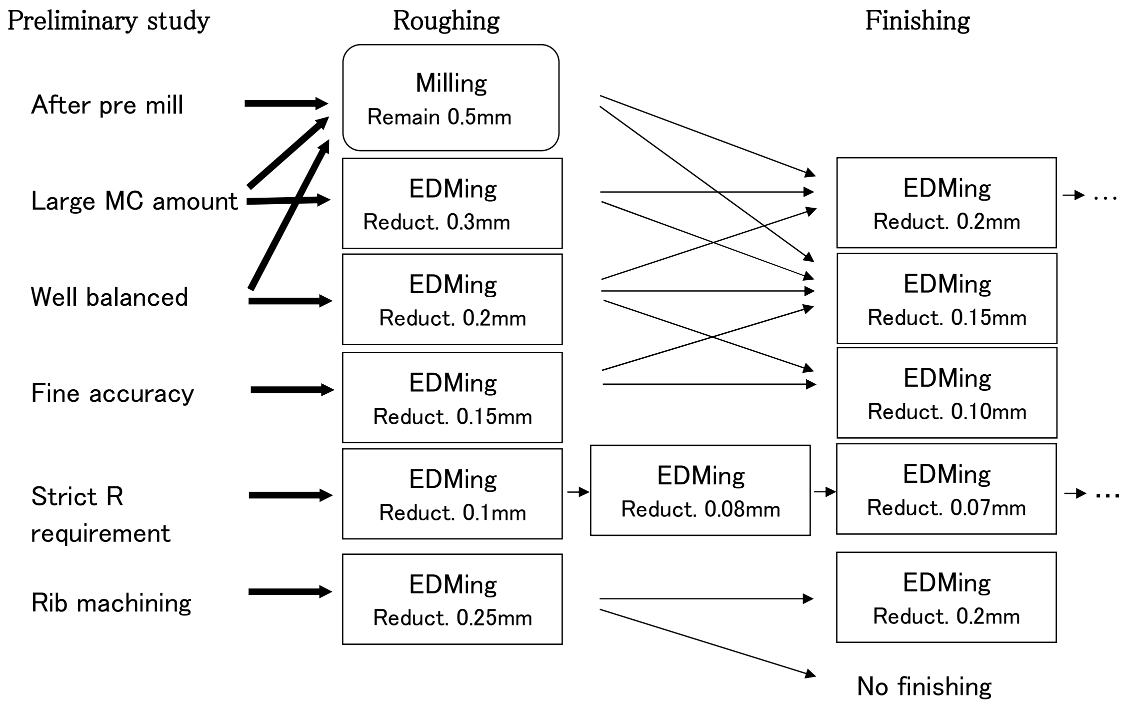
In the case of following machining details, the number of electrodes may increased or decreased.

Amount of electrode	Machining content
1	In rib machining, shape accuracy and surface roughness requirement are loose Machining the screw shape in steel workpiece material Engraving (imposition) machining Contour machining
3 or more	In connector machining, bottom edge R requirement is strict In gear machining etc., shape accuracy requirement is strict Machining the high workpiece material of electrode wear ratio (Carbide etc.) Machining depth is extremely deep Surface roughness needs be finished less than Rz1 μm

1.6 Setting example of electrode reduction

Setting example of electrode reduction according to machining purpose is shown in the flowchart.

<Example of setting electrode reduction>



Setting electrode reduction is important for achieving the balance of machining speed and machining accuracy. However, because of the following reasons, there are cases where roughness and finishing electrode reduction are kept same.

•Pre-machining accuracy using cutting machine, improving electrode making accuracy
•Improving the accuracy of positioning of discharge machining equipment
•Reducing the cost of electrode making and management

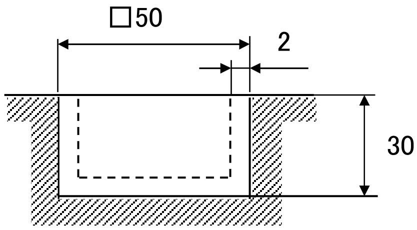
For improving production efficiency, it is important to optimize electrode reduction by accumulating actual machining data.

1.7 Supplementary Explanation: Method of deciding electrode reduction from current density

Here, we explain the method of deciding electrode reduction for rough machining from current density.

This method of deciding from current density is valid only for spark area □10～50, workpiece material St.

＜Example＞



Electrode　Cu(copper)
Workpiece SK-5

When a machining allowance of 2 mm on one side remains due to pre-machining based on mechanical cutting

Machining volume(mm^3) ＝ 50×50×30－46×46×28 ≒ 16000

Letting the specific gravity of iron be 7.8(g/cm3), machining weight is calculated as follows.

Machining weight(g) ＝ 16000÷1000×7.8 ＝ 124.8(g)

Next, estimate machining time from "machining speed" mentioned in instruction manual "Machining condition".

Condition No.	Roughness (μmRmax)	MC speed (g/min)	Estimated machining time (h)
E164	50	0.11	124.8÷0.11÷60 ≒ 19
E165	60	0.15	124.8÷0.15÷60 ≒ 14
E166	70	0.21	124.8÷0.21÷60 ≒ 10
E167	80	0.31	124.8÷0.31÷60 ≒ 7
E168	90	0.48	124.8÷0.48÷60 ≒ 4

・Condition No. E164:19 hours
・Condition No. E168:4 hours

Because there is a lot of time difference, we want to select E168 as rough machining condition. However, as mentioned earlier, forcefully applying fast machining condition to narrow spark area worsens machining efficiency, and it may cause abnormal discharge in some cases.

“Spark area” in this machining example is calculated as follows.

Entrance area ： $(50\times50-46\times46)\div100=3.84(cm^2)$

Bottom area ： $50\times50\div100=25(cm^2)$

Next, refer to the “average current value” of each machining condition mentioned in instruction manual “Machining condition”.

Average current value

E number		160	161	162	163	164	165	166	167	168	169
Machining state	Voltage (%)			20	20	20	15	15	20	20	
	Current (A)			6.5	8	9	11	14	20	24	
Removal rate	Jump (g/min)			0.044	0.075	0.11	0.15	0.21	0.31	0.48	
	machining (mm^3/min)										
	Pre-machined hole										
	flushing/suction										
Bottom face roughness	Rmax (μm)			30	40	50	60	70	80	90	
	Ra (μm)										
Side face roughness	Rmax (μm)										
	Ra (μm)										
Electrode wear (%)				0.5	0.2	0.2	0.2	0.2	0.2	0.2	
One-sided exit gap (mm)				0.045	0.055	0.06	0.065	0.075	0.085	0.100	
Duty Factor (%)				80	79	80	79	79	80	80	

Spark area of the entrance part is the smallest. Therefore, calculate currency density of the entrance part with the following expression.

$$\text{Currency density } (A/cm^2) = \frac{\text{Average current value (A)}}{\text{Spark area } (cm^2)}$$

Condition No.	Roughness (μmRmax)	Ave.current (A)	Entrance currency density (A/cm^2)
E164	50	9	$9\div3.84=2.3$
E165	60	11	$11\div3.84=2.9$
E166	70	14	$14\div3.84=3.6$
E167	80	20	$20\div3.84=5.2$
E168	90	24	$24\div3.84=6.3$

＜Appropriate currency density＞

Appropriate currency density changes depending on whether machining control is there or not. Therefore, decide depending on the situation.

Electrode material	Workpiece material	Appropriate currency density
Cu(copper)	St(steel)	15(A/cm^2) or less
Gr(graphite)	St(steel)	15(A/cm^2) or less

Current density of machining condition calculated this time is completely within the suitable range. Therefore, basically selecting any machining condition will not be a problem.

Here, for example, if the following additional requirements are added,

Rough machining can be completed with nighttime machining, and we want to avoid the occurrence of abnormal discharge as much as possible.
We want to keep roughness of bottom surface and electrode wear of corner part as small as possible.

Machining time: It can be judged that E165 machining condition calculated as 14 hours is appropriate.

Next, read "electrode reduction" of E165 machining condition from the instruction manual "Data Book" model data table.

Model data 23 (Spark area) □15 ~ 50

Process No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Roughness		90	80	70	60	50	40	30	23	16	12	9	7	4.5	3.0	2.0
μmRa		14.0	13.0	11.0	10.0	9.0	7.0	5.0	4.5	3.2	2.2	1.6	1.1	0.8	0.56	0.40
VDI No.		43	42	41	40	39	37	34	33	30	27	24	21	18	15	12
Condition No.		168	167	166	165	164	163	162	338	337	336	335	334	333	332	331
Average current		24	20	14	11	9	8	6.5								
Electrode wear		0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	3	7	14	19	16	26	29
Bottom remain		487	409	337	278	229	189	147	113	77	54	40	27	17	9	4
Side remain		284	246	209	178	151	128	101	82	59	40	28	18	11	5	2
Max. spark area														□80	□50	□30
Time cont. area								□70	□60	□40	□35	□30	□20	□15	*	*
After pre milling		320	270	235	200	170	145	115								
Min. reduct. (per side)	2mm	320	270	235	200	170	145	115								
	10mm	430	335	285	245	205	175	140								
	20mm	490	385	330	280	240	200	160								

Note. "Minimum reduction" in model data table may change to larger side due to the difference of electrode shape or fluid processing method.

"Minimum electrode reduction" in the case of "With pre-machining" is mentioned as 200 μm. Therefore, it is decided as follows.

Electrode reduction for roughing ＝ 0.2 mm

2. SELECTION METHOD OF MODEL DATA AND PROCESS NO.

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This chapter explains about using model data when doing rough to finish machining.

Model data refers to a table where numerical data required for discharge machining is summarized. By using model data without any complex calculations, it is possible to finish the target dimension shape to any surface roughness.

Electrode material / Workpiece material / Spark area / Model data No.

Cu (Copper) – St (Steel)

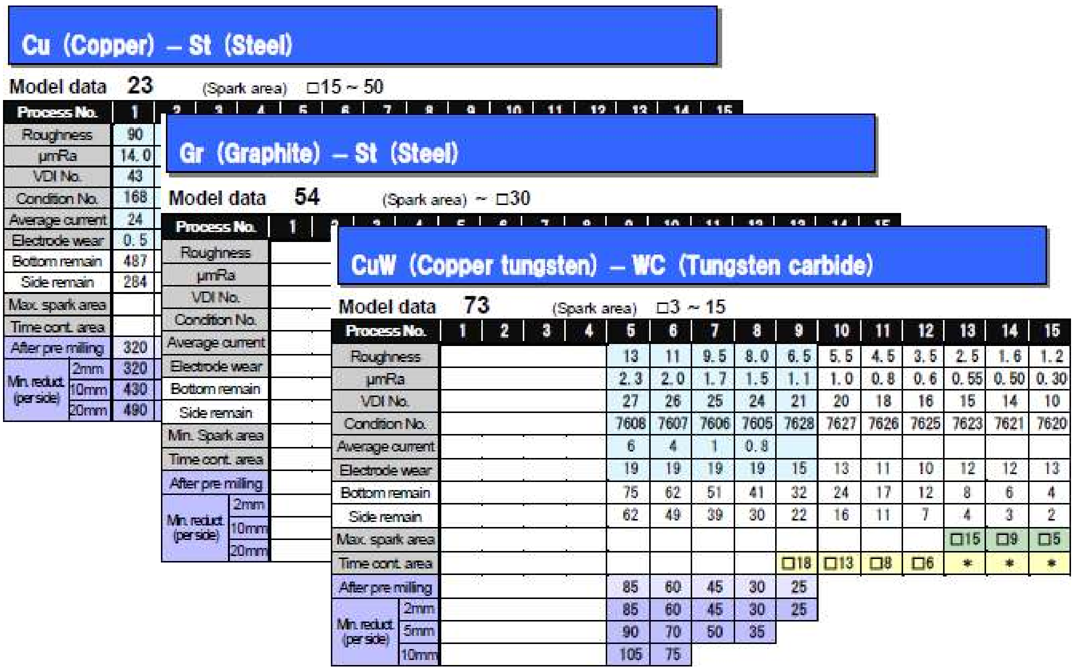
Model data 21 (Spark area) □5 ~ 15

Process No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Roughness			55	45	40	35	25	20	16	14	10	8	6	4	3	2
μmRa			10.0	9.0	7.0	5.6	4.5	4.0	3.2	2.5	1.7	1.6	1.1	0.7	0.6	0.4
VDI No.			40	39	37	35	33	32	30	28	25	24	21	17	16	12
Condition No.			248	247	246	245	244	243	242	307	306	305	304	303	332	331
Average current			10	8	7	5	4	3	2							
Electrode wear			0.2	0.2	0.2	0.2	0.2	0.2	0.2	1	2	4	8	11	26	29
Bottom remain			280	237	197	161	132	107	85	68	55	38	28	20	13	8
Side remain			185	154	129	109	93	78	67	56	45	31	23	16	10	7
Min. Spark area			□14	□11	□9	□7	□6	□5	□4							
Time cont. area											□17	□11	□11	□9	□8	□6
After pre milling			195	165	140	120	100	90	80							
Min. reduct. (per side)	2mm		195	165	140	120	100	90	80							
	10mm		250	210	180	160	140	120	110							
	20mm		290	245	210	190	170	145	130							

Unique numbers are assigned to model data for each "Electrode material" and "workpiece material", and various machining details can be accommodated by separately using these numbers.

＜Example＞

- Electrode：Cu Workpiece：St Spark area □20 … Model data No.23
- Electrode：Gr Workpiece：St Spark area □25 … Model data No.54
- Electrode：CuW Workpiece：WC Spark area □10 … Model data No.73



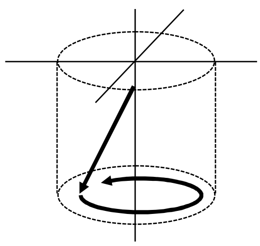
2.1 Electrode reduction system and model plan selection based on machining shape

Model data can be used with model plan "Machining Model" G101–104.

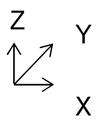
Menu	Detailed menu	Code	Contents
Machining	SINGLE MC	G100	Single machining with a MC condition
	BOTTOM STOPPED–SIMPLE	G101	MC for single axis with model data
	BOTTOM STOPPED–COMPLEX	G102	MC with complex shaped bottom
	THROUGH MC	G103	Through MC such as screw MC
	CORNER MC	G104	Corner MC
	PACKAGE		

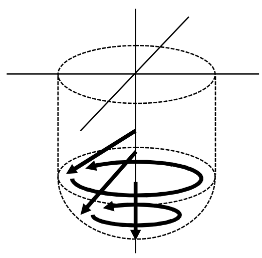
Machining model where model data can be used

Refer to "2D reduction" and "3D reduction" flowcharts for electrode reduction given in chapter 2.2 and 2.3, and select appropriate machining model according to the respective machining shape.

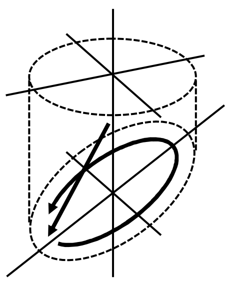


2D reduction
3–axis finishing

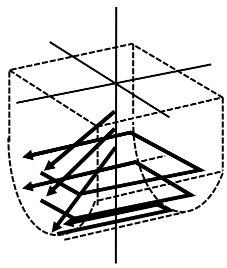




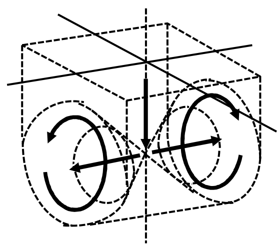
3D reduction
Sphere–shape machining



2D reduction
Bottom inclined
machining

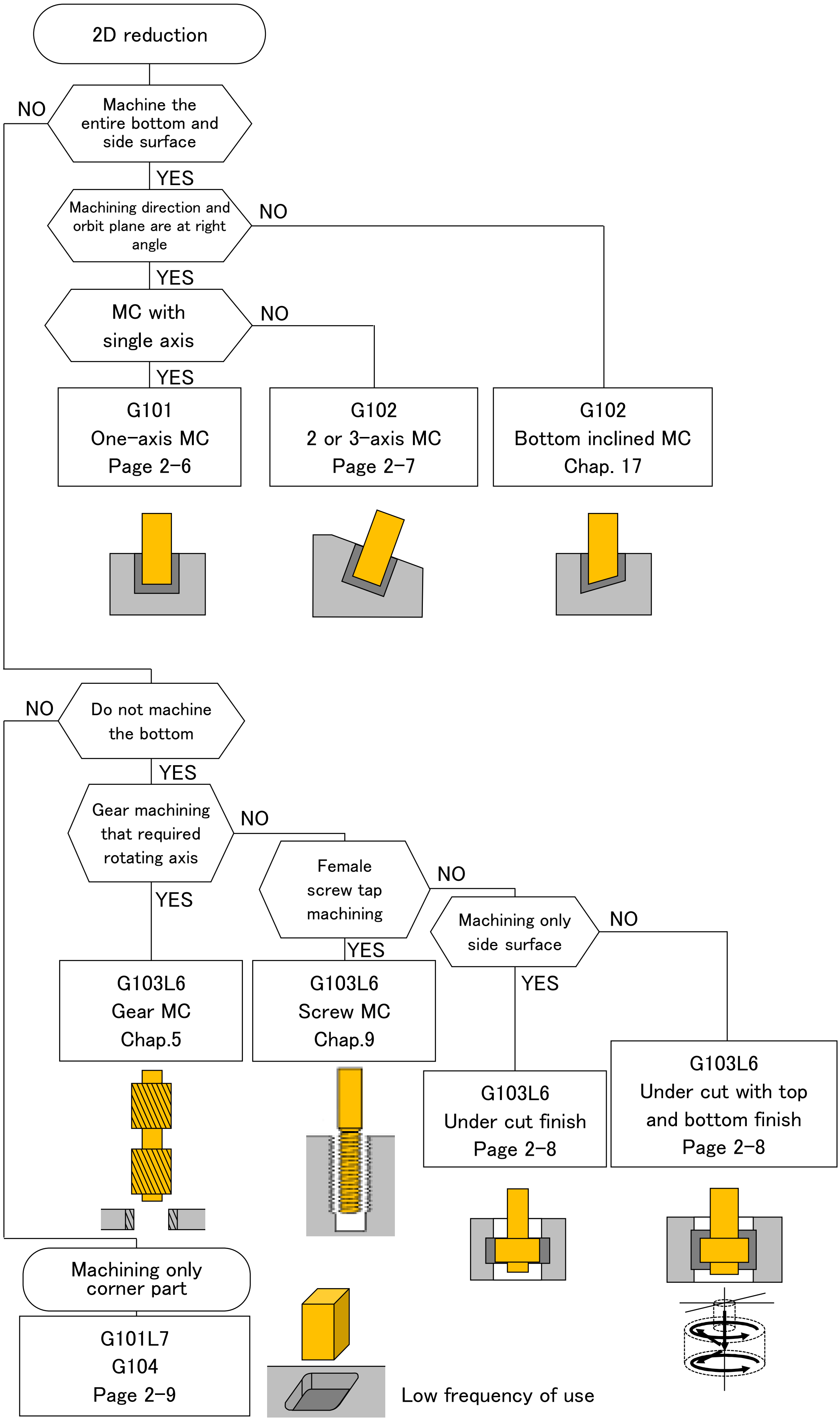


3D reduction
Column–shape
machining

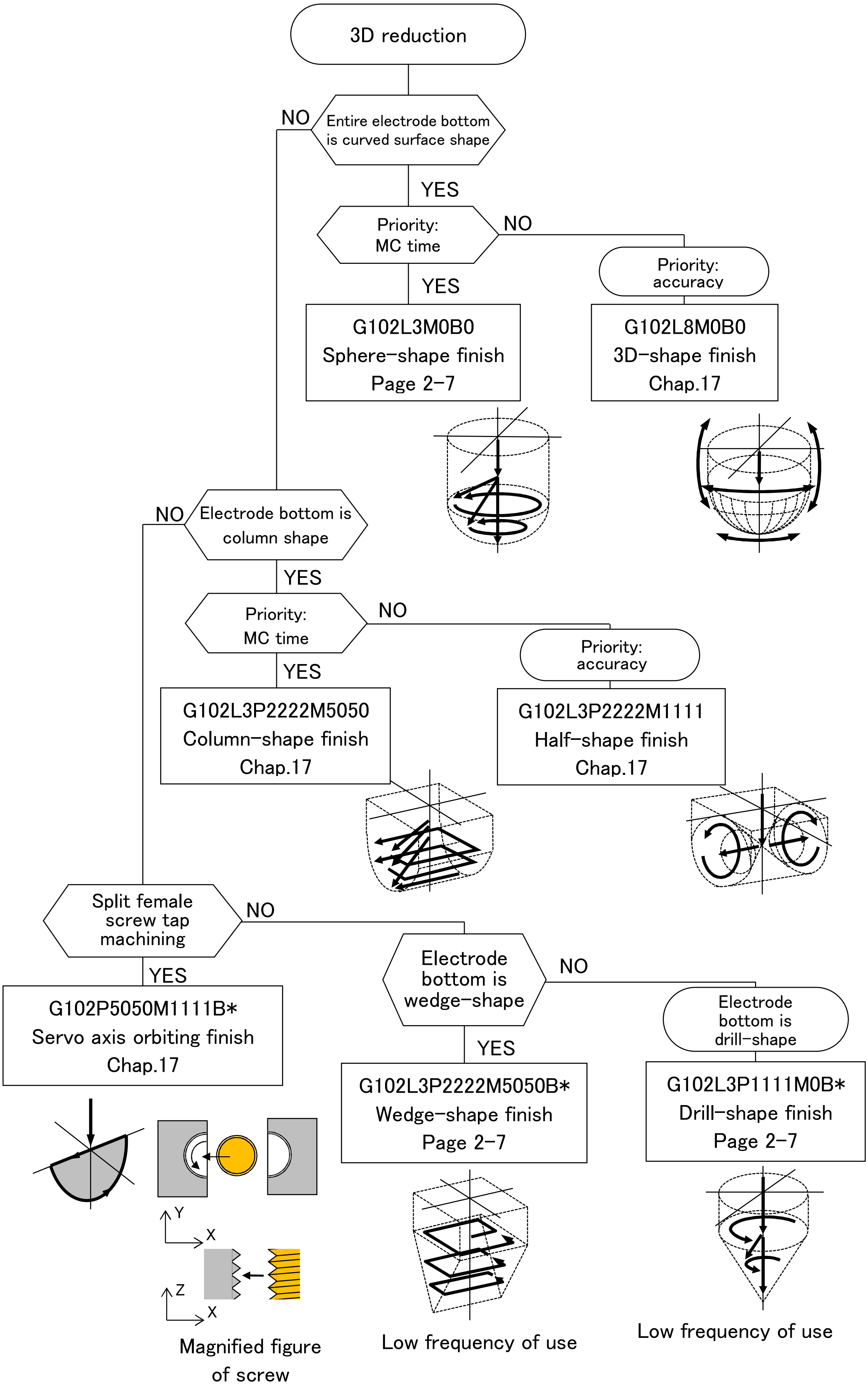


3D reduction
Half–shape machining

2.2 Machining model selection method in the case of 2D reduction



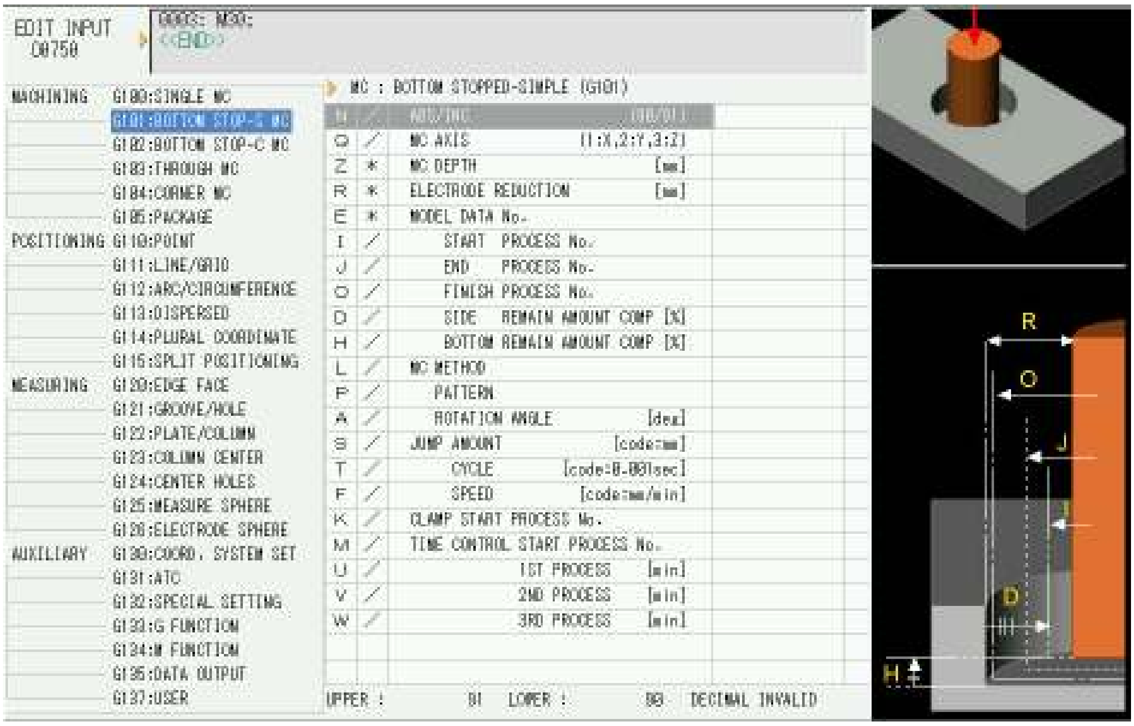
2.3 Machining model selection method in the case of 3D reduction



2.4 Features of each machining model

2.4.1 Machining model G101: BOTTOM STOPPED-SIMPLE

G101 is used in linear one way machining (XYZ axis) based on 2D reduction electrode that has flat part in the bottom.



Furthermore, with G101 it is possible to set minute process management time with the following items.

Item U: 1ST PROCESS

Item V: 2ND PROCESS

Item W: 3RD PROCESS

It is desired to use G101 where machining time is relatively long, and in the case of large area machining where setting of process management time is important.

<Example>

- Machining on large spark area (□100 or more)
- Glazed machining
- HQSF machining
- IC mold machining (Flower pattern)

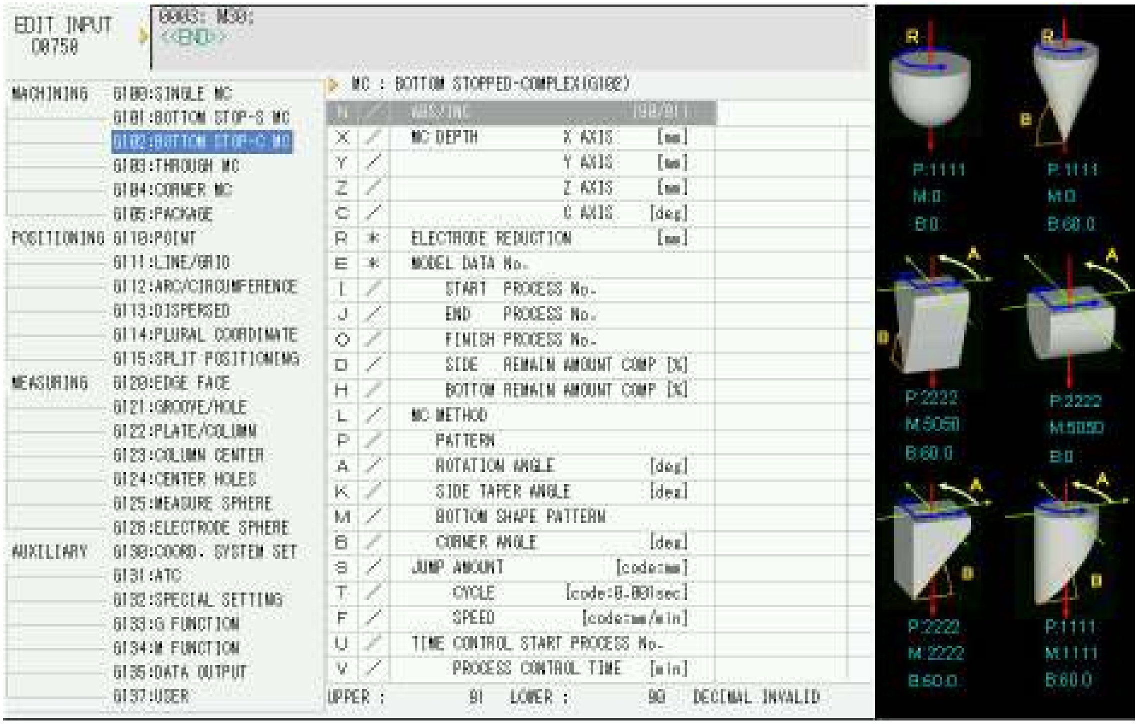
Item L: Basically, select the following machining method, and change the 2nd digit as and when required.

- Item L: = 13 : High accuracy 3-axis machining
- Item L: = 23 : Standard 3-axis machining

Depending on the machining shape, command of item L:machining method=1: one way finishing may be given.

2.4.2 Machining model G102 : BOTTOM STOPPED–COMPLEX

Use BOTTOM STOPPED–COMPLEX (G102) in the case of one to three way machining (XYZ axis).
In the case of machining with base in inclined direction, use BOTTOM STOPPED–COMPLEX (G102).



Bottom complex (G102) can be separately used for 2D reduction and 3D reduction electrode depending items K, M, B.

① In the case of 2D reduction electrodes … Use with item K, M, B = Blank.
In this case, it will function in almost same manner as bottom simple (G101).

② In the case of 3D reduction electrodes: Basically use "Sphere finish" :Item K = Blank, Item M = 0, Item B = 0. In the case of a special machining shape, refer to the flowchart in chapter 2.4, and set items K, M, and B. Refer to Chapter 18 for details.

Item L: Basically, select the following machining method, and change the 2nd digit as and when required.

- Item L: = 13 : High accuracy 3–axis machining
- Item L: = 23 : Standard 3–axis machining

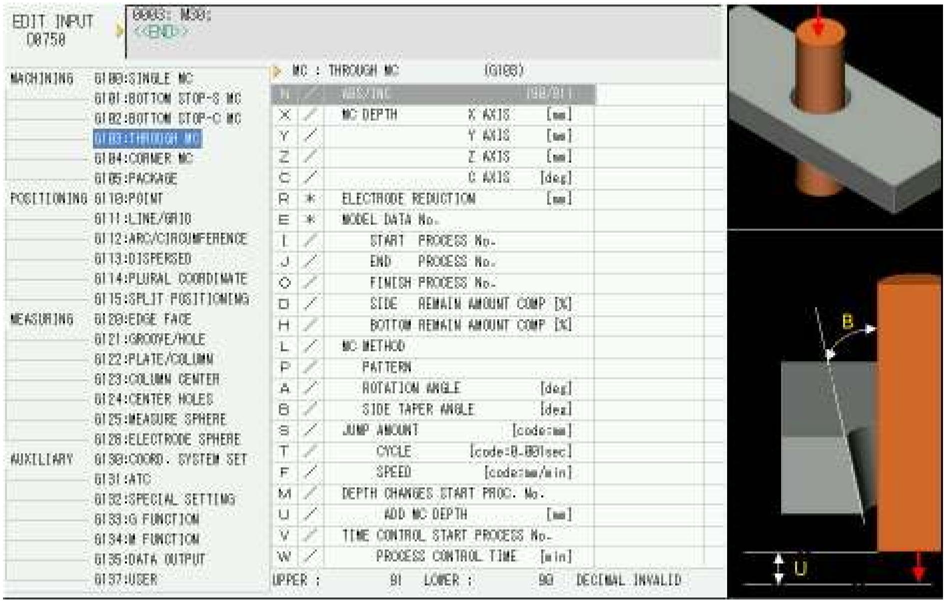
Depending on the machining shape, command of item L:machining method=1: one way finishing may be given.

2.4.3 Machining model : G103 THROUGH MC

Through MC (G103) is used when you want to finish only side face.

After moving up to the command position of bottom face direction, for orbit machining of the side face direction, you can discharge efficiency using the entire side face of electrode. Moreover, for shortening machining time, fluid flushing/suction unit is widely used.

＜Example of use＞
- ･Female screw tap machining　　･Seal groove machining of rubber mold
- ･Shape machining of through hole side face
- ･Helical, warm gear machining (Z,C simultaneous two way machining)
- ･Expansion machining of through hole diameter



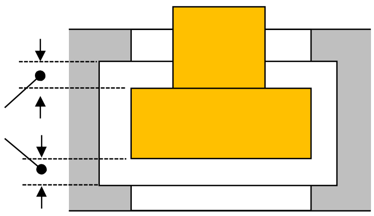
In Through MC (G103), with item L:machining method 3rd digit pattern offset and offset data No.21～29, in addition to side face of the shaped part, you can also finish top and bottom face.

1. In case of 2D reduction electrode: Do not enter item L:machining method 3rd digit pattern offset
2. In case of 3D reduction electrode: Use item L, enter electrode reduction of height direction in the corresponding offset dataNo.21～29, and instruct under cut top and bottom surface finishing.

Offset data No.21～29

NO.	DATA
21	0.0000
22	0.0000
23	0.0000
24	0.0000
25	0.0000
26	0.0000
27	0.0000
28	0.0000
29	0.0000

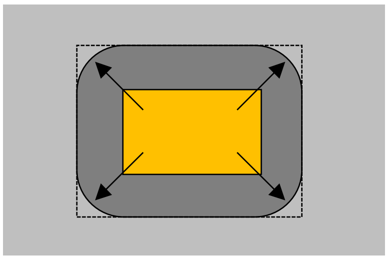
Electrode reduction of height direction

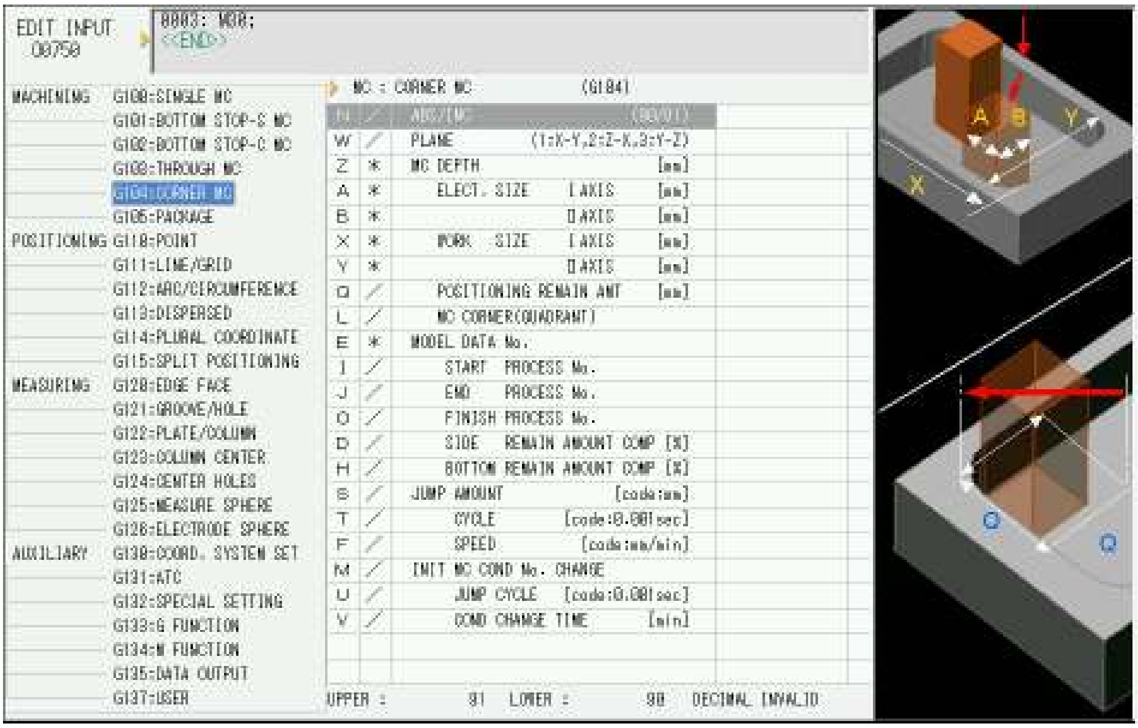


For item L: machining method, basically select L= 16 : high accuracy under cut finishing, and change the 2nd digit as required. Moreover, ensure to instruct orbit OFF for item 1:start process No. 3rd digit = 1** : start process depth machining, ensure that discharge trace is not added to any unwanted place while approaching.

2.4.4 Machining model : G104 CORNER MC

Corner MC (G104) is only used when machining corner R that remained after mechanical cutting. While linear and efficient machine is possible, it tends to have poor uniform finishing across the surface. Therefore, use it according to the situation.





Furthermore, in bottom simple (G101) and bottom complex (G102), instructing item L:machining method=7, you can achieve similar corner finishing as Corner MC (G104). In the case of corner finishing, you can machine with almost same program as machining with bottom.

2.5 Selection of model data

When the machining model is decided, select model data number.
Refer to the instruction manual "data book" and select model data number corresponding to "Electrode material", "workpiece material" and "spark area".

The following table shows main model data numbers mentioned in data book.

Model data No.	Electrode material	Workpiece material
19～28,1001,1002	Cu(Coppper)	St(Steel)
29	Cu(Coppper)	St(Steel)※Glazed
34,39,1043～1046 1051～1057	Gr(Graphite)	St(Steel)
59,62～67,1060	CuW(Coppper tungsten)	St(Steel)
69～74	CuW(Coppper tungsten)	WC (Tungsten carbide)
68	CuW(Coppper tungsten),Cu	CuW, Cu
86	Cu(Coppper)	Cu-Copper Alloy
88	Cu(Coppper)	CuBe(Beryllium copper)
1082	Gr(Graphite)	Cu-Copper Alloy

In instruction manual "Machining condition" Chapter 7, various model data other than the above are mentioned. Using the information in the following table as reference, use them depending on the condition.

Model data No.	Electrode	Workpiece	Comments
5,6,8,10,11,15	Cu	St	Low electrode wear, but discharge may become unstable. Take precaution when using it.
16,17,18	Cu	St	Having glazed machining condition, surface can be finished to fine roughness.
75,76,77,78	Cu	St	Surface roughness up to Rz1 μm
40～47	Gr	St	Use when electrode tip has deteriorated and discharge has become unstable.
48,49	Gr	St	Low electrode wear

2.6 Selection of Start / End / Finish process No.

Next, the selection method for Start / End / Finish process differs depending on the number of electrodes, electrode material, etc. Therefore, refer to the following explanation, and select the appropriate process number.

MC : BOTTOM STOPPED-SIMPLE (G101)

N	/	ABS/INC (90/91)	
Q	/	MC AXIS (1:X,2:Y,3:Z)	
Z	*	MC DEPTH [mm]	
R	*	ELECTRODE REDUCTION [mm]	
E	*	MODEL DATA No.	
I	/	START PROCESS No.	
J	/	END PROCESS No.	
O	/	FINISH PROCESS No.	

Item I: Start process No.
… Specify process number for starting the machining.
This item has the highest impact on machining time.

Item J: End process No.
… Specify process number for ending the machining.
It mainly affects shape accuracy and machining time.

Item O: Finish process No.
… Specify process number of target surface roughness value.

2.6.1 Reading and interpreting model data table

In the model data table, select process number from the data covered inside the box below.

(a) Min. reduct. … Selecting start process No.

(b) Min. spark area … Selecting start process No.

(c) Electrode wear … Selecting start and end process No.

(d) Roughness … Finish process No.

(d) Roughness

Process No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Roughness		55	45	40	35	25	20	16	14	10	8	6	4	3	2
μmRa		10.0	9.0	7.0	5.6	4.5	4.0	3.2	2.5	1.7	1.6	1.1	0.7	0.6	0.4
VDI No.		40	39	37	35	33	32	30	28	25	24	21	17	16	12
Condition No.		248	247	246	245	244	243	242	307	306	305	304	303	332	331
Average current		10	8	7	5	4	3	2							
Electrode wear		0.2	0.2	0.2	0.2	0.2	0.2	0.2	1	2	4	8	11	26	29
Bottom remain		280	237	197	161	132	107	85	68	55	38	28	20	13	8
Side remain		185	154	129	109	93	78	67	56	45	31	23	16	10	7
Min. Spark area		□14	□11	□9	□7	□6	□5	□4							
Time cont. area										□17	□11	□11	□9	□8	□6
After pre milling		195	165	140	120	100	90	80							
Min. reduct. (per side) 2mm		195	165	140	120	100	90	80							
Min. reduct. (per side) 10mm		250	210	180	160	140	120	110							
Min. reduct. (per side) 20mm		290	245	210	190	170	145	130							

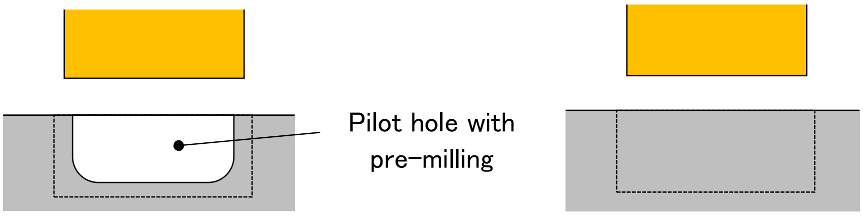
(c) Electrode wear

(b) Min. spark area

(a) Min. reduct.

2.6.2 (a) Reading and interpreting fields of Minimum reduction

The field to be referenced will differ when doing discharge machining for pre-milled or solid workpieces.



＜After pre milling＞ ＜Without pre milling＞

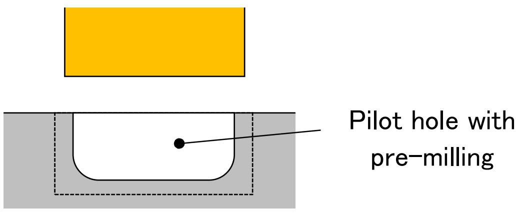
After pre milling

Process No.		1	2	3	4	5	6	7	8
After pre milling			195	165	140	120	100	90	80
Min. reduct. (per side)	2mm		195	165	140	120	100	90	80
	10mm		250	210	180	160	140	120	110
	20mm		290	245	210	190	170	145	130

Without pre milling

① After pre milling

From the “Aft. Pre mill”, search a smaller numerical value than electrode reduction, then select process number.



Ex.) In the case of electrode reduction 0.150mm

No.3 : 0.165 ＞ 0.150 ··· Minimum electrode reduction is larger than electrode reduction, and therefore it cannot be used. Using it forcefully will make rough finishing on the side face

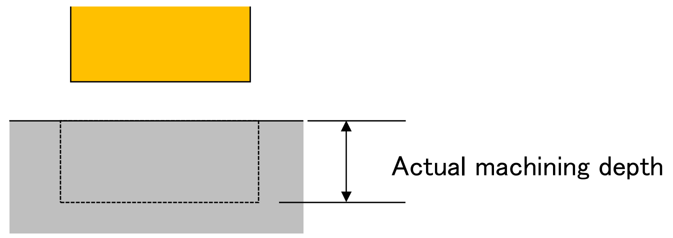
No.4 : 0.140 ≦ 0.150 ··· Minimum electrode reduction is smaller than electrode reduction, therefore it can be used.

× ○

Process No.		1	2	3	4	5	6	7	8
After pre milling			195	165	140	120	100	90	80
Min. reduct. (per side)	2mm		195	165	140	120	100	90	80
	10mm		250	210	180	160	140	120	110
	20mm		290	245	210	190	170	145	130

② When pre-machining is not done

From “2mm” “10mm” and “20mm” fields, focus on the rows containing numerical values higher than “machining depth”, and select process number corresponding to the fields containing numerical values lower than electrode reduction. This machining depth is the actual machining depth. Not that it may differ from the machining depth command value of the program.



Process No.		1	2	3	4	5	6	7	8
After pre milling			195	165	140	120	100	90	80
Min. reduct. (per side)	2mm		195	165	140	120	100	90	80
	10mm		250	210	180	160	140	120	110
	20mm		290	245	210	190	170	145	130

Ex.1) In the case of electrode reduction 0.200mm, machining depth 20.0mm

No.4 : 0.210 ＞ 0.200 … Minimum electrode reduction is larger than electrode reduction, and therefore it cannot be used.

No.5 : 0.190 ≦ 0.200 … Minimum electrode reduction is smaller than electrode reduction, therefore it can be used.

× ○

Process No.		1	2	3	4	5	6	7	8
After pre milling			195	165	140	120	100	90	80
Min. reduct. (per side)	2mm		195	165	140	120	100	90	80
	10mm		250	210	180	160	140	120	110
	20mm		290	245	210	190	170	145	130

Ex.2) In the case of electrode reduction 0.160mm, machining depth 15.0mm

From minimum electrode reduction of 10mm and 20mm, calculate minimum electrode reduction when machining depth is 15mm.

Process No.	5	6
10mm	160	140
15mm(Calculated)	175 = (160+190)/2	155 = (140+170)/2
20mm	190	170

No.5:0.175 ＞ 0.160 … Minimum electrode reduction is larger than electrode reduction, and therefore it cannot be used.

No.6:0.155 ≦ 0.160 … Minimum electrode reduction is smaller than electrode reduction, therefore it can be used.

In the model data table, there are process numbers where minimum electrode reduction is not set. They are not suitable for the start process of roughing electrode because of the reasons such as slow machining speed and large electrode wear.

Cu (Copper) – St (Steel)

Model data 21 (Spark area) □5 ~ 15

Process No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Roughness		55	45	40	35	25	20	16	14	10	8	6	4	3	2
μmRa		10.0	9.0	7.0	5.6	4.5	4.0	3.2	2.5	1.7	1.6	1.1	0.7	0.6	0.4
VDI No.		40	39	37	35	33	32	30	28	25	24	21	17	16	12
Condition No.		248	247	246	245	244	243	242	307	306	305	304	303	332	331
Average current		10	8	7	5	4	3	2							
Electrode wear		0.2	0.2	0.2	0.2	0.2	0.2	0.2	1	2	4	8	11	26	29
Bottom remain		280	237	197	161	132	107	85	68	55	38	28	20	13	8
Side remain		185	154	129	109	93	78	67	56	45	31	23	16	10	7
Min. Spark area		□14	□11	□9	□7	□6	□5	□4							
Time cont. area										□17	□11	□11	□9	□8	□6
After pre milling		195	165	140	120	100	90	80							
Min. reduct. (per side) 2mm		195	165	140	120	100	90	80							
Min. reduct. (per side) 10mm		250	210	180	160	140	120	110							
Min. reduct. (per side) 20mm		290	245	210	190	170	145	130							

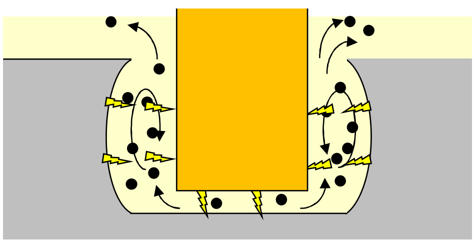
Suitable for the start process of roughing electrode

NOT suitable for the start process of roughing electrode

＜Relation between machining depth and electrode reduction＞

In the case of “Without pre milling”, as machining debris become more and as machining depth increases, discharge efficiency of machining debris due to jump reduces, and machining debris concentration in the hole keeps on increases. As a result, discharge spark reaches farther than the regular distance, and dimension of the machining hole also widens.

Because of these reasons, when pre-machining is not done, it is necessary to set electrode reduction larger according to machining depth.



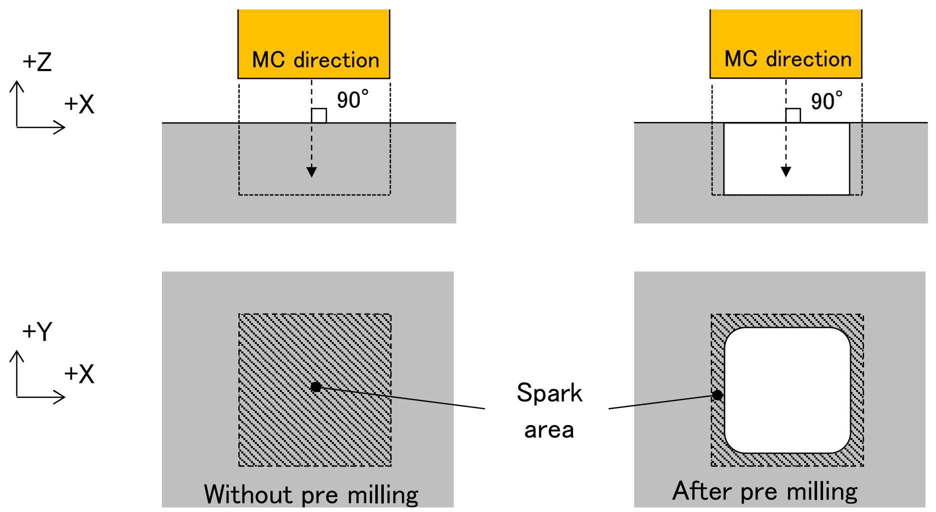
2.6.3 (b) Reading and interpreting applicable minimum area field

In discharge machining, even if machining is done at a small process number (fast machining speed) with respect to narrow spark area, machining speed may rather slow down and abnormal discharge may occur. Therefore, in the (b) column, minimum applicable spark area for each process number is shown.

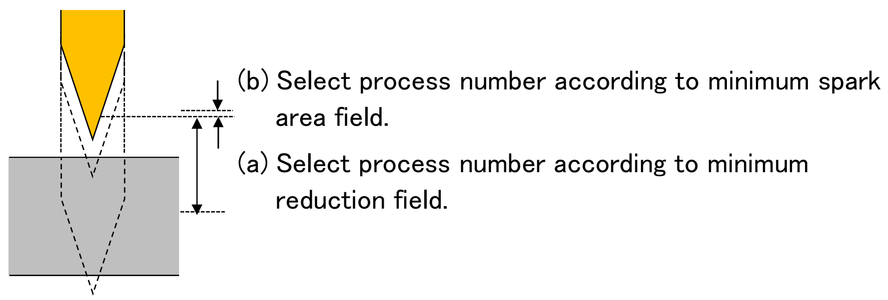
Ex.) Process No.3 in the following table shows that it is not suitable to machining where spark area□11 or below.

Process No.	1	2	3	4	5	6	7	8
Min. Spark area		□14	□11	□9	□7	□6	□5	□4

Note. Spark area refers to facing area of electrode and workpiece shown with shaded area in the following figure.



In the shape where spark area becomes wide as the machining progresses, process number is basically selected from the largest spark area. However, as a result of this selection, problems like abnormal discharge may occur when discharge takes place. In such case, divide machining program when discharge occurs and subsequent stages, and by instructing individual process number, you can shorten machining time and control abnormal discharge.



2.6.4 (c) Reading and interpreting the electrode wear field

In the electrode wear field, electrode wear ratio for each process number is mentioned. In sinker electrical discharge machine, machining condition with fine surface roughness (large process number) tends to have high electrode wear ratio. Therefore, if start process of roughing electrode can be made smaller (if electrode reduction can be made large), electrode wear ratio can be reduced and machining allowance of finishing electrode can also be reduced.

Process No.: small ↔ Process No.: large
Electrode wear: small ↔ Electrode wear: large

Process No.		6	7	8	9	10	11	12	13	14	15
Electrode wear		0.2	0.2	0.2	1	2	4	8	11	26	29
After pre milling		100	90	80							
Min. reduct (per side)	2mm	100	90	80							
	10mm	140	120	110							
	20mm	170	145	130							

Low electrode wear

In roughing electrode, continuing machining up to process number with high electrode wear ratio will not reduce the machining allowance of finishing process. Moreover, machining time will end up becoming extremely long. By setting end process as per the following table, you can shorten total machining time.

＜Rough guide of roughing electrode end process＞

MC type	Item J:Input value of end process No.	
Cu-St	Process number with electrode wear ratio 2-8%	
Gr-St	Process number with electrode wear ratio 5-20%	
CuW-WC	Start process' electrode wear ratio 10% or more	Process number with approximate surface roughness Rz4-6 um
Other	Start process' electrode wear ratio less than 10%	Process number with electrode wear ratio 5-20%

Despite of small electrode reduction (high electrode wear ratio), when machining accuracy and surface roughness requirement are high, handle it by increasing the number of electrodes.

2.6.5 (d) Reading and interpreting the surface roughness field

Set the process number having target surface roughness µmRz, µmRa, and VDI number in item O:finish process for roughing ~ finishing electrode program.

Ex.) In the case of target surface roughness 6µmRz, select item O = 12 process.

Process No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Roughness		55	45	40	35	25	20	16	14	10	8	6	4	3	2
µmRa		10.0	9.0	7.0	5.6	4.5	4.0	3.2	2.5	1.7	1.6	1.1	0.7	0.6	0.4
VDI No.		40	39	37	35	33	32	30	28	25	24	21	17	16	12

2.6.6 Selection of Start / End / Finish process No. for steel machining

When the workpiece material is steel, usually the number of electrodes is 2.

Select process number after referring to the following.

Item I: Start process No.

Roughing electrode: Specify process number according to roughing electrode's electrode reduction.

Finishing electrode: Basically, it instructs process number according to finishing electrode reduction. However, specifying process number before 2 ~ 3 processes from end process of roughing electrode will help in efficient machining.

Item J: End process No.

Roughing electrode: Select end process targeting the process number where ELECTRODE WEAR ratio changes greatly (≒machining time applies). Enter the same numerical value as finish process.

Finishing electrode: Enter the same value as finish process No.

Item O: Finish process No.

Roughing and finishing electrode: Specify the process number having the target surface roughness value.

2.6.7 Selection of Start / End / Finish process No. for WC machining

When the workpiece material is carbide material, usually 3 or more electrodes are required.
Select process number after referring to the following.

Item I : Start process No.

Roughing electrode : Specify process number according to roughing electrode's electrode reduction.

Semi-finishing electrode : Select same start process No. as roughing electrode or start process No. with 1-2 processes more.

Finishing electrode : Select start process No. where end process of semi-finishing electrode is reduced by 2 ~ 3 processes. When it becomes smaller than semi-finishing electrode's rough machining condition, specify same start process No. as semi-finishing process.

Item J : End process No.

Roughing electrode : Select process number with approximate surface roughness Rz4-6 um

Semi-finishing electrode : Select process number that is intermediate to roughing electrode and finishing electrode.

Finishing electrode : Enter the same value as finish process No.

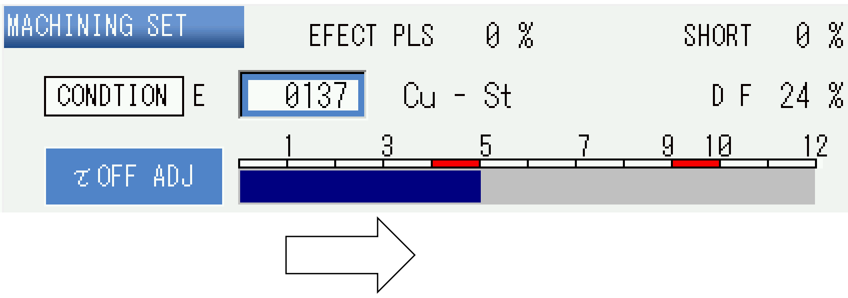
Item O : Finish process No.

ALL electrodes : Specify the process number having the target surface roughness value.

2.7 When machining doesn't progress

Immediately after starting machining, if discharge becomes unstable and machining doesn't progress, it is possible that the selected process number is too small (power is too strong). Try the following measures.

① During machining, open machining condition[F6]–MACHINING SET [L1] screen. Extend the τOFF ADJ bar displayed at the top of the screen, and lower machining power. After that, observe the discharge state for some time.



When discharge has stabilized, return the τOFF ADJ bar to the original setting, and continue machining.

② If the situation doesn't improve even after attempting the measures, abort machining and check the discharge places of electrode. If any error is found during progress, replace the electrode or polish using abrasive paper.

③ Increase start process No. of machining program by 1 process (lower machining power), and conduct the machining once again.

3.INSTALLATION OF A LARGE ELECTRODE

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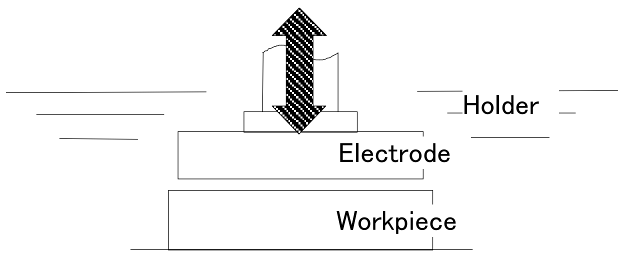
3.3 Note on using universal holder ······································ 3－6

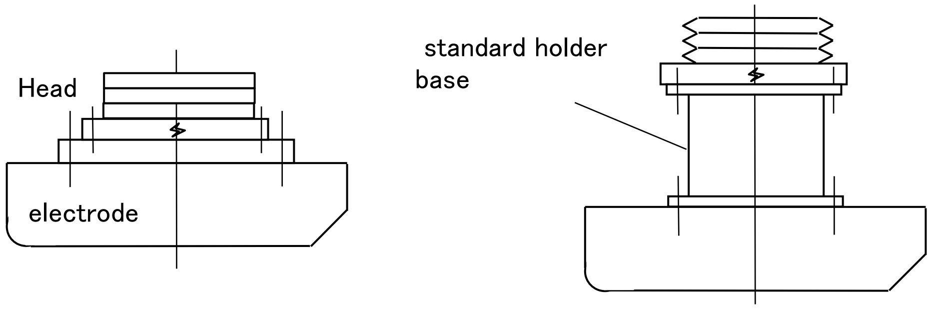
Installation of electrode and workpiece requires the most extreme care to ensure better machining.
Unlike mechanical cutting, electrical discharge machining is taken place in non-contact state. It may therefore be thought that the stress applied to the electrode and workpiece during machining is small.
In fact, large stresses are applied. The electrode approaches very closely to the workpiece and the face-to-face contact is made. In the space between them, the viscous dielectric fluid generates a very large stress when the electrode moves up and down repeatedly at very high speed.
This stress reaches several to ten times the stress produced during vertical movement in the air.



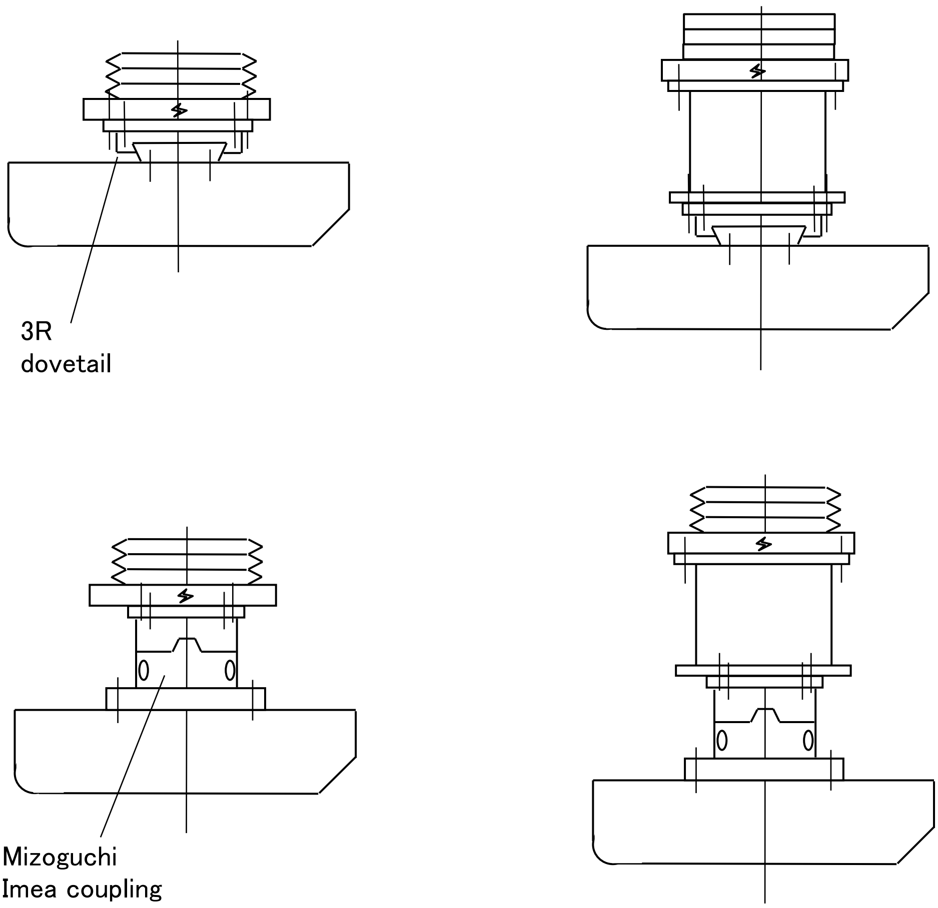
In addition, this stress varies with the discharge gap and the contact area of electrode and workpiece, i.e., the discharge area. The stress becomes the largest when a small discharge gap machining condition is used in a large discharge area machining.
In general, the larger electrode (the larger discharge area) or the finer finish machining (the smaller discharge gap) requires the stronger installation of electrode and workpiece.
Weak installation of electrode and workpiece makes machining unstable, causing a trouble in machining speed, accuracy or surface roughness.
For the electrode installation, various fixtures are available, the fixture should be selected from a viewpoint of rigidity as well as work efficiency.
Moreover, when workpiece height is low, it is better to pile up workpiece and the electrode should be shortened for rigidity.

3.1 Examples to install a large electrode

a) Strong direct installation



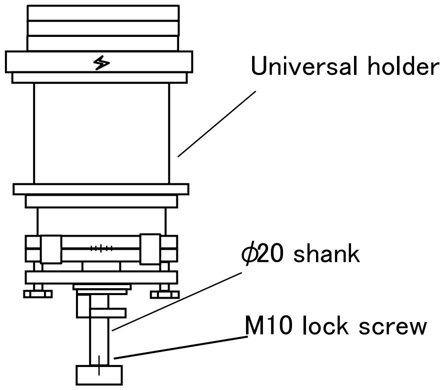
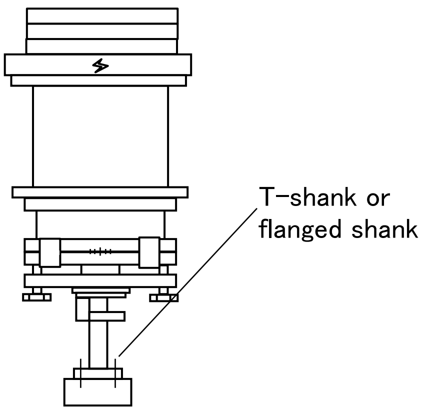
b) Strong installation with high rigid fixture

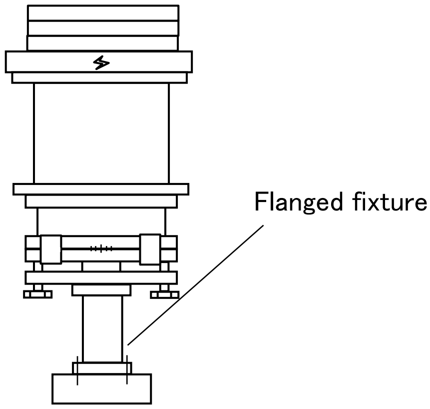
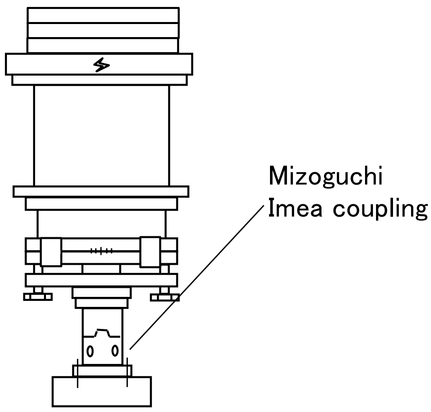
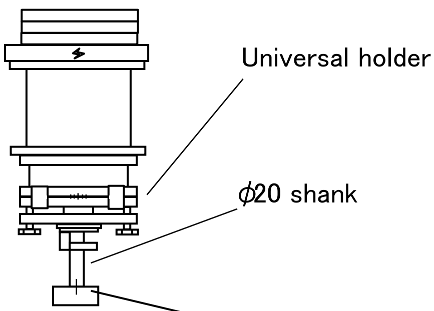


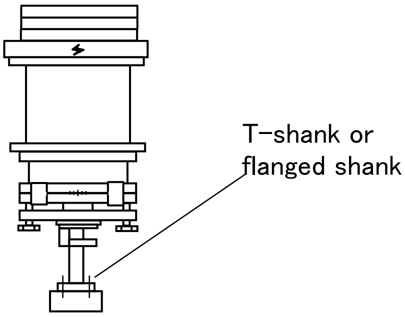
3.2 Installation with high efficient fixture

There are various fixtures to improve work efficiency, however, these fixtures has, in general, small rigidity and they should not be used for a large electrode. Otherwise, poor machining accuracy or unstable machining will result.

The maximum electrodes (discharge area) for each fixture are as listed below, though they will vary depending on the machining condition used.

Fixture	Max. electrode (discharge area)
Universal holder for EDNC6,8,10,15,20 	□50
	□80

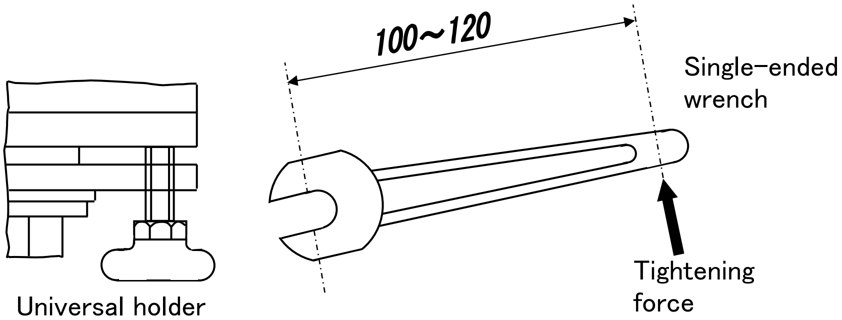
	□100
	□100
Universal holder for EDAC1,EDAF2,3 	□50

	□70

Take care of rigidity of fixture when using a large electrode, though description of additional fixtures is omitted.

3.3 Note on using universal holder

The adjuster screw on the universal holder is tightened by the hand, but it may be tightened with a wrench only if a large electrode is used. In this case, however, do not tighten it extremely. Too strong tightening can damage the universal holder.
The maximum tightening force is as listed below.



Universal holder for EDNC6,8,10,15,20	7kgf max.
Universal holder for EDAC1,EDAF2,3	4kgf max.

4. SL MACHINING BY GRAPHITE ELECTRODE

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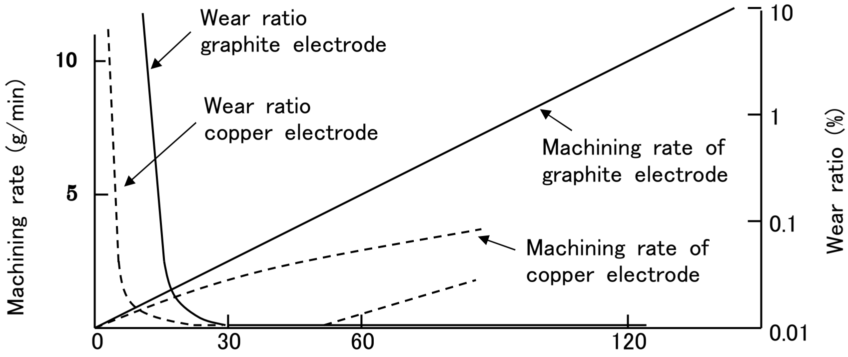
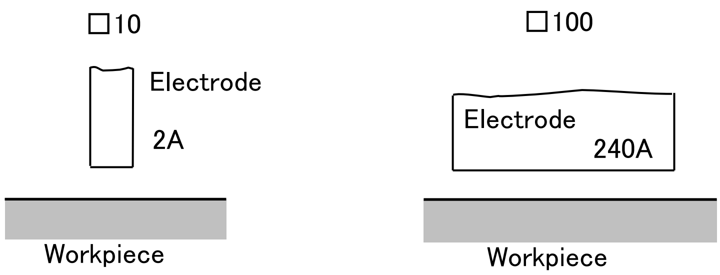
Graphite electrodes are now becoming increasingly prevalent. It features short manufacturing time, light weight, little distortion caused by thermal expansion, etc.
Unlike copper electrodes, graphite electrodes have the following three characteristics.

- Superior machining characteristics in a larger area and a larger current
- Inducing an arc in a smaller area and a larger current
- Greater wear in finishing than copper electrode

Next, we describe these characteristics in more details.
The below figure shows the change in the machining rate and wear ratio when the machining current is increased.

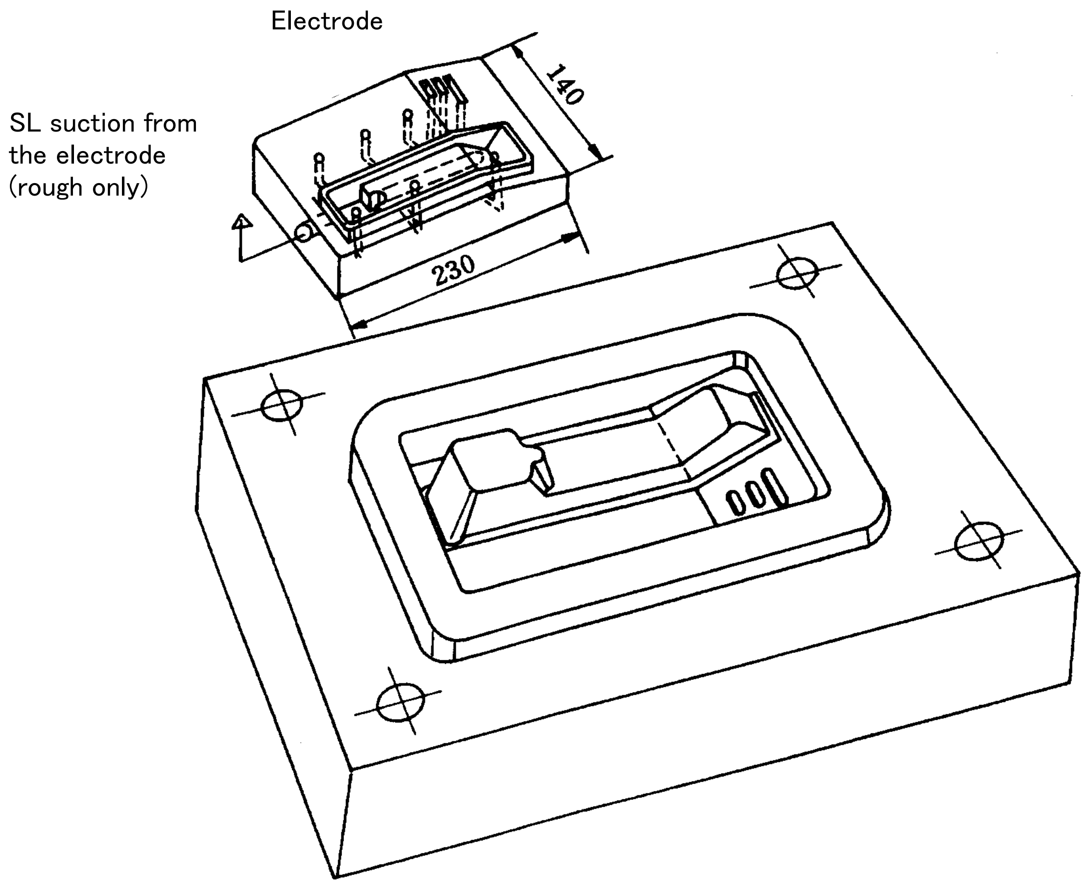


The above figure indicates that, if a discharge area is not small, a larger current flowing through the graphite electrode increases its machining rate, while even a current of 30A or more flowing through the copper electrode does not increase machining rate as much. Also, the figure shows that the graphite electrode wears more than the copper electrode under the machining condition of small current. Accordingly, the graphite electrode should be used under the machining condition where the electrode reduction and the current area are large. The graphite electrode generally arcs in response to a larger current flowing through a small area. In other words, the optimum current for the machining area stabilizes the machining.



Machining example 1

Name of workpiece		Telephone
Workpiece dimensions		230mm × 140mm
Depth of machining		30mm
Premachining		None
Mold material		S50C
Use of SL		Used in rough, not used in finish(no suction hole)
Electrode Material	Rough	ED−3 reduction 0.8mm on one side
	Finish	ED−3 reduction 0.3m on one side
Machiningtime	Rough	12H30M(max. current 120A)
	Finish	14H (roughness 12 μ mRz)
	Total	26H30M



4.1 Designing of electrode reduction

Machining data

[Rough electrode] [finish electrode]

Machining Current	Discharge area	Machining rate	Electrode reduction per side	Electrode reduction per side
240A	□ 150 MIN.	20 g/min	1.3 MIN.	0.3 MIN.
120A	□ 100 MIN.	10 g/min	0.8 MIN.	
60A	□ 50 MIN.	5 g/min	0.6 MIN.	
30A	□ 10 MIN.	2.5g/min	0.5 MIN.	

＊The machining rate is for SL machining.

The following explains how to design electrode reduction in the case of machining example 1 (telephone)

(a) Machining weight calculation

$23cm \times 14cm \times 3cm = 966cm^3$

$966cm^3 \times 7.8g/cm^3$ (steel gravity) = 7500g

The time required for machining at 120A is obtained by the following formula.

7500g ÷ 10g/min ≒ 750min ≒ 13 hour

(where 10g/min is the SL rough machining rate at 120A)

This formula indicates that finishing an even finer surface by the rough electrode takes more or less 15hr.

This is the optimum time in which starting roughing on one day enables the finish electrode to be applied on the next day.

(b) confirmation of the machining area

The minimum of 100mm square in machining at 120A satisfies the electrode dimensions limit of 230mm × 140mm.

When machining at 120A according to (a) and (b), the rough electrode reduction is 0.8mm and that of the finish electrode is 0.3mm per side.

4.2 Suction hole boring

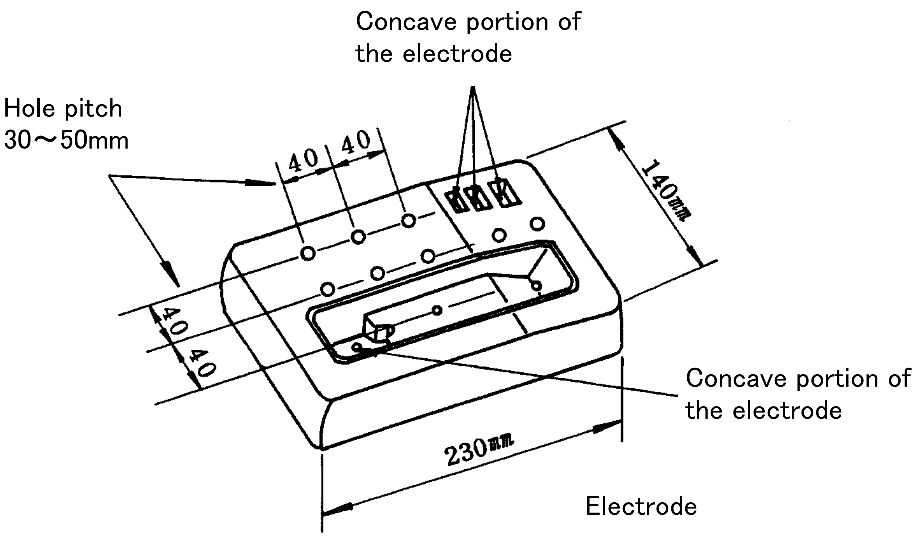
The following conditions specify the suction hole boring method.

(a) The suction hole pitch is 30～50mm.

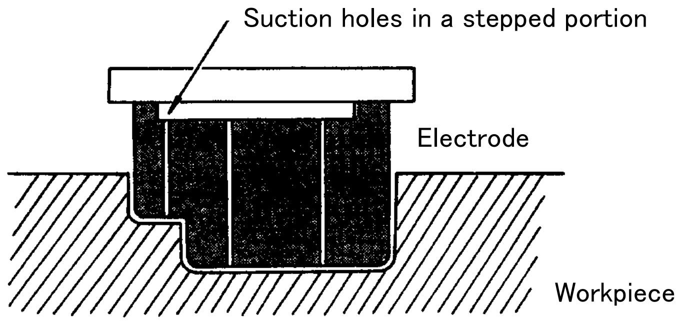
(b) Be sure to bore suction hole in the concave part of the electrode.

(c) Bore suction holes in the part where the electrode touches the workpiece first, or the convex part of the electrode as much as possible.
These principles prescribe that suction holes have been bored at 14 spots in the figure.
The top part of the electrode is the rib for the cradle; however, its thinness did not necessitate hole boring.

(d) The hole diameter is 3mm. When the depth of hole is deep, bore a large diameter hole to the half depth from the opposite side.



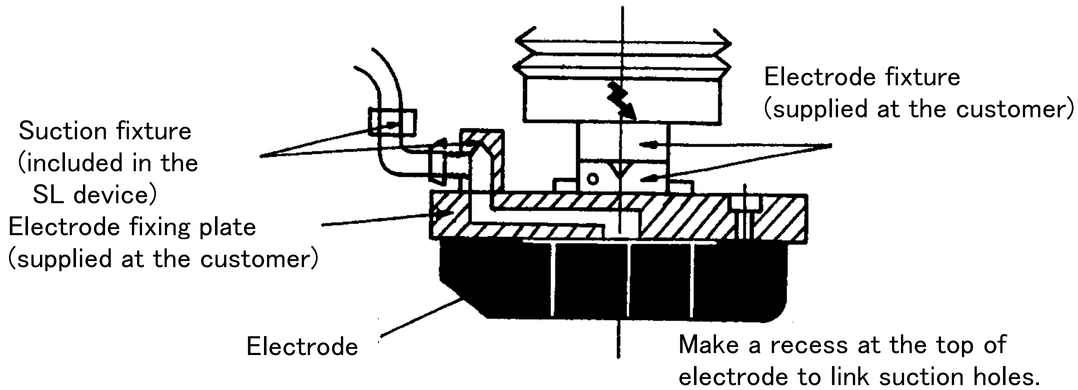
(e) Further, a stepped portion needs suction holes.



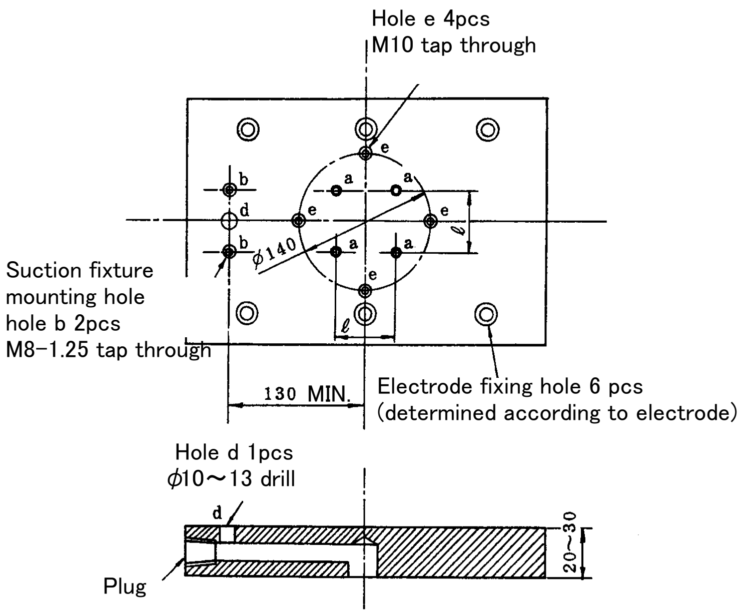
(f) Although no suction hole is required for the finish electrode because SL machining is not taken place, a gas bleeding hole should be made one for each concave portion where it is difficult to remove gas and chip.

4.3 Electrode fixture designing

Without the high rigidity of the electrical discharge machine, the electrode fixing plate, and the electrode, powerful SL suction causes the electrode swinging and unstable machining. The electrode fixing plate integrates suction holes to execute suction and also serves as a medium between the electrode and the electrical discharge machine.



[Design example of electrode fixing plate]



Holes in electrode fixture

Electrode fixture	ℓ mm	Holes
3R dovetail	59.4	Hole a M6-P1
Mizoguchi Imea 222	55	Hole a M6-P1
Mizoguchi Imea 322	78.5	Hole a M8-P1.25
Spacer(standard accessory)	-	Hole e M10

- The 3R dovetail is directly fixed to the face plate on the machine. (a fixture required)
- Mizoguchi Imea can be attached either directly to the machine or to the universal holder.(a fixture required)
- If a spacer (standard accessory) is used, drill ϕ11 holes additionally at the hole e position (normal screw holes).

[Notes on designing]

(a) Powerful suction requires sufficient rigidity and light weight. (e.g., hard aluminum)

(b) Use an electrode fixture of high rigidity, such as 3R-27.2, Mizoguchi Imea 222 or 322, or fix the electrode directly to the electrode fixing plate of the electrical discharge machine.

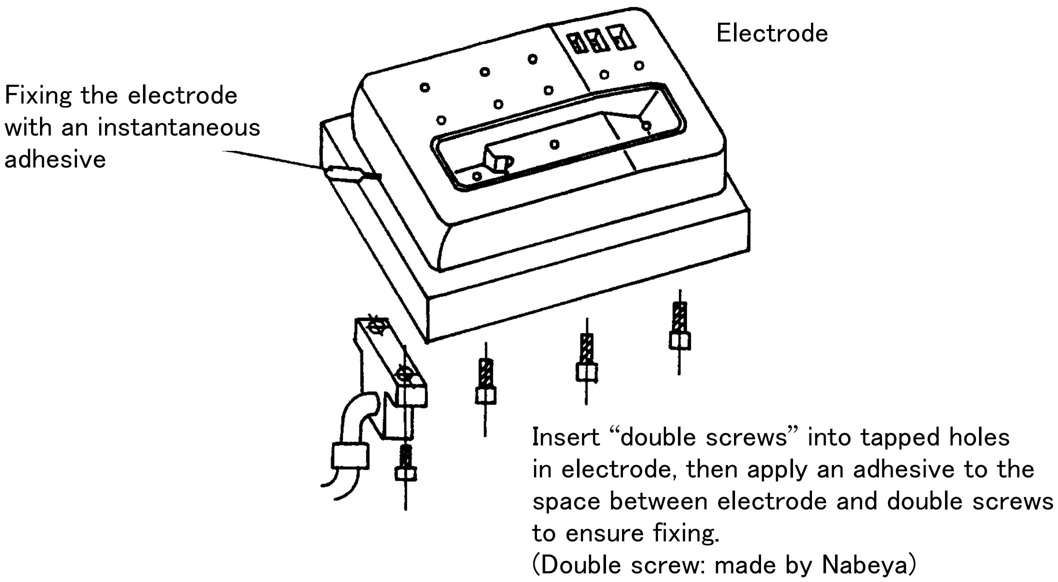
(c) Use an electrode fixing plate of a large diameter as much as possible and increase the number of clamping bolts 1.5 times that of copper electrode. Further, tap the plates as deeply as possible.

4.4 Fixing electrode to the electrode fixing plate

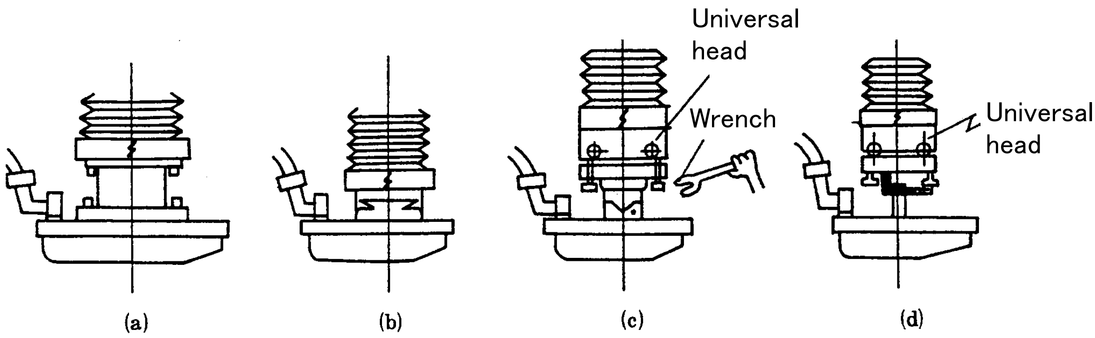
Since graphite is fragile, taps soon become unavailable and because its friction coefficient to steel is small, the electrode is likely to be dislocated. Therefore, utmost care should be taken of fixing an electrode.

Bolts alone cannot prevent dislocation of electrode. After fixing the electrode with bolts, pour an instantaneous adhesive around the electrode to fix it to the plate.

Adhesive reinforcement would also go a long way toward preventing parts of the electrode from falling off unexpectedly.



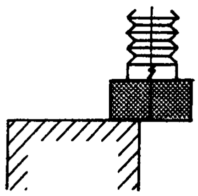
[Fixing the electrode fixing plate to the electrical discharge machine.]



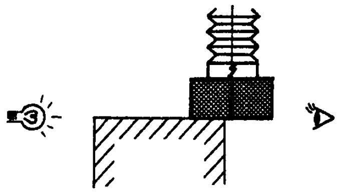
The method (d) swings the electrode and invites unstable machining. The use of the universal head in (c) requires that electrode alignment and inclination be adjusted by fixing bolts with a wrench. Tightening bolts just by hand would result in loose bolts.(However, too strong tightening can damage the universal holder.)

4.5 Positioning

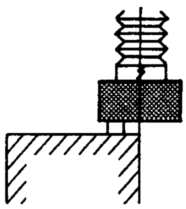
The graphite electrode with powder adhering to its surface impedes high accuracy touch sensing; therefore, care should be taken of its positioning. Especially in the case of touch sensing on a large surface, the touch state is provided in spite of a gap of approximately 0.1mm between the electrode and the surface.
To prevent this trouble, clean the touch surface first, and then position the electrode according to the procedure (a) ～ (f) below.



(a) Touch the electrode to the surface in the smallest possible area.

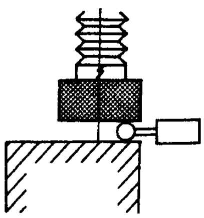


(b) Light the electrode and the surface from the opposite side and confirm that there is no gap between them.

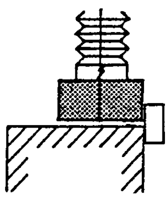


(c) Insert a reference block and execute touch sensing.

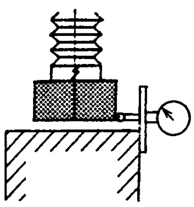
(Turn on the INTERRUPT sw to disable touch sensing, and lower the electrode by 10 μ m inching operation to confirm the touch condition of reference block.)



(d) Insert a spindle ball between the electrode and the surface and execute touch sensing.



(e) Use a block.



(f) Use a depth gauge.

4.6 Large-scale roughing(SL machining)

After the machining position is determined, start machining in the MDI mode.

Of rough machining, initial machining is referred to as “large-scale roughing”

Machining process by a rough electrode

Large-scale roughing	——	Large current machining
Rough to medium machining	——	Medium finishing machining

The large-scale roughing uses the “Single MC” menu.

Set approximate value to “MC DEPTH”.

Machining current	Setting of MC DEPTH
240A	1.3mm before finish dimension
120A	0.8mm before finish dimension
60A	0.6mm before finish dimension

⇩

Machining menu : Single machining(G100)

Address	Attri.	Talk items		Set value	
N	/	ABS/INC	(90/91)		
X	/	MC DEPTH	X AXIS[u, t]		
Y	/		Y AXIS[u, t]		
Z	/		Z AXIS[u, t]	-29.2	← 0.8mm before finish dimension
C	/		C AXIS[rot./ANGLE]		
W	/	AUTO DEPTH MAX.TRAVEL	[u, t]		
L	/	MC LAST STOP	(1:ON)		
E	*	MC COND No.		4417	← Machining at 120A
U	/	REMAIN AMOUNT	[u, t]		
R	/	PATTERN RADIUS	[u, t]	50	
P	/	MODE/PATTERN		1111	
A	/	ROT.ANGLE	[deg]		
B	/	CIRCUIT SPEED	[m, i/min]		
S	/	JUMP AMOUNT	[code:u, t]	}	← Determined according to machining profile.
T	/	CYCLE	[code:0.001sec]		
F	/	SPEED	[code:m, i/min]		
I	/	CLAMP AMOUNT	[u, t]		
H	/	TIME CONTROL TIME	[min]		
M	/	START MC COND.No	(DF[%])	0	← P pulse “ON”
D	/	START J.CYCLE	[code:0.001sec]		
V	/	START MC REMAIN AMOUNT	[u, t]		

・P pulse

The P pulse is turned on by the following setting.

The P pulse sets proper machining conditions according to the machining.

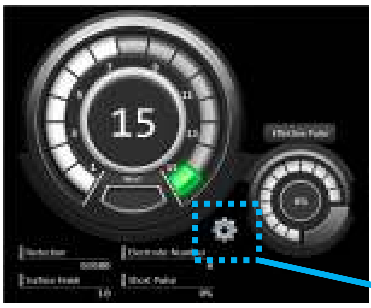
It maintains stable machining at the start of machining where the discharge area becomes small temporarily.

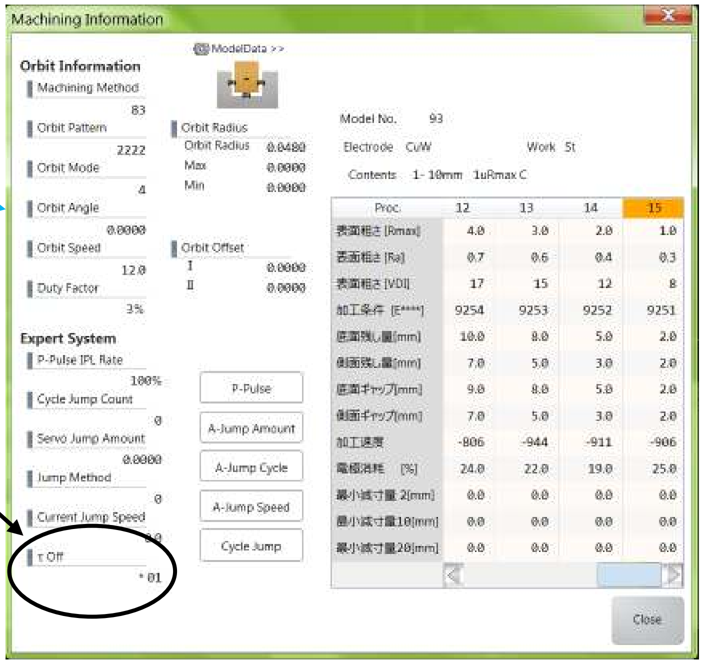
Machining menu : Single machining(G100)

U	/	REMAIN AMOUNT [u,t]	
R	/	PATTERN RADIUS [u,t]	
P	/	MODE/PATTERN	
A	/	ROT.ANGLE [0.001deg]	
B	/	CIRCUIT SPEED[m,i/min]	
S	/	JUMP AMOUNT [code:u,t]	
T	/	CYCLE [code:0.001sec]	
F	/	SPEED [code:m,i/min]	
I	/	CLAMP AMOUNT [u,t]	
H	/	TIME CONTROL TIME [min]	
M	/	START MC COND.No (DF[%])	0
D	/	START J.CYCLE [code:0.001sec]	
V	/	START MC REMAIN AMOUNT [u,t]	

P pulse "ON"
0:Current and OFF time is set.
(For large current)
1:OFF time is set.

COND MC SET SCREEN



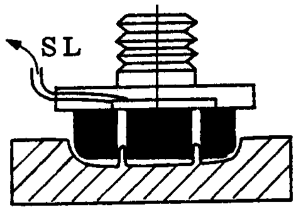


Set value by P-pulse

※ If P pulse is not used, change the machining condition and τ OFF ADJ by manual operation according to the discharge area.

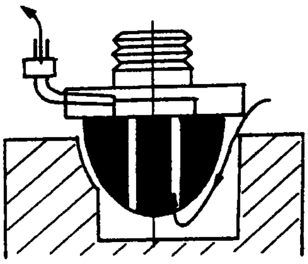
・Suction condition of SL unit and setting of jump

The jump function must be used if the suction condition by SL unit is not good.



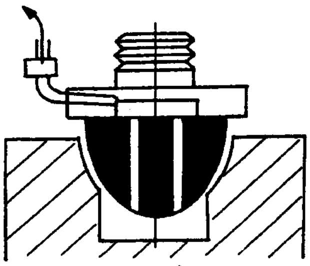
(a)

(a) Jump off is most effective in whole electrode discharge with SL suction.



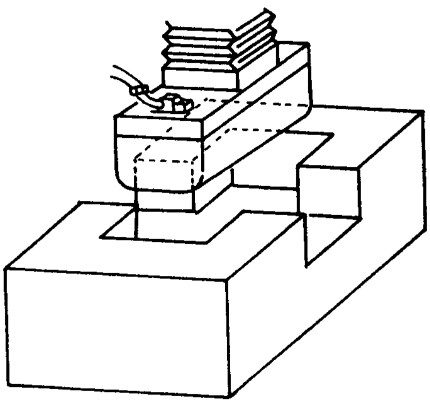
(b−1)

(b−1) The electrode does not touch the whole workpiece in pre−machining.
Jump off is impossible because a liquid flows into the opening as shown in the left figure and there is little liquid on the discharge surface.
The jump cycle 10 ～ 12 is essential.



(b−2)

(b−2) The electrode touches the whole workpiece in machining including pre−machining.
Same as (a), jump off is allowed.



(c) A sliding part is provided.
Jump off is not allowed because of the same reason as (b−1).
The same kind of jump as in (b−1) is essential.

SL suction enables jump with neither chips accumulated on the bottom face or a bottom arcing in a longer jump cycle.

4.7 Program preparation

Prepare a program when a large-scale roughing started and machining is stabilized.

[Program for rough electrode]

M70L1; ← SL large "on"

G100Z-29.0E4417S0M0; ← Large-scale roughing

G113X0Y0Z5.0;

[Program for middle electrode]

AUX :.Special setting (G132) ← Medium finishing

Address	Attri.	Talk items	Set value
D	/	STARTING COND. No.	
H	/	τoff ADJ SETTING	
C	/	HQSF μSC DENSITY [g/l]	
Q	/	EXP P-PULSE	1
A	/	A-JUMP	
E	/	F-JUMP	
K	/	STEP ANGLE [deg]	
S	/	SUPER SPARK	
M	/	CYCLE JUMP MODE	
R	/	NO.OF JUMP	
U	/	JUMP AMOUNT [code,u,t]	
V	/	CYCLE [code,0.001sec]	
W	/	NUMBER OF TIMES	
O	/	DISCHARGING JUMP (1:ON)	
P	/	SERVO JUMP AMOUNT [u,t]	
L	/	JUMP METHOD	
X	/	ARBITRARY JUMP X AXIS [u,t]	
Y	/	Y AXIS [u,t]	
Z	/	Z AXIS [u,t]	
T	/	SETTING FOR FINE MATTE FINISH	
B	/	POLARITY REVERSE CYCLE [min]	

↓

Machining menu : Bottom stopped–complex(G102)

Address	Attri.	Talk items	Set value
N	/	ABS/INC (90/91)	
X	/	MC DEPTH X AXIS [u,t]	
Y	/	Y AXIS [u,t]	
Z	/	Z AXIS [u,t]	-29.85
C	/	C AXIS [rot./ANGLE]	
R	*	ELECTRODE REDUCTION [u,t]	0.65
E	*	MODEL DATA No.	30
I	/	START OF PROCESS No.	2
J	/	END OF PROCESS No.	5
O	/	FINISH PROCESS No.	14
D	/	SIDE REMAIN AMOUNT COMP [%]	
H	/	BOTTOM REMAIN AMOUNT COMP [%]	
L	/	MC METHOD	23
P	/	PATTERN	1111
A	/	ROT. ANGLE [deg]	
K	/	SIDE TAPER ANGLE [deg]	
M	/	BOTTOM SHAPE PATTERN	0
B	/	CORNER ANGLE [deg]	0
S	/	JUMP AMOUNT [code:u,t]	0
T	/	CYCLE [code:0.001sec]	
F	/	SPEED [code:m,i/min]	

0.15mm allowance to final depth 30mm.

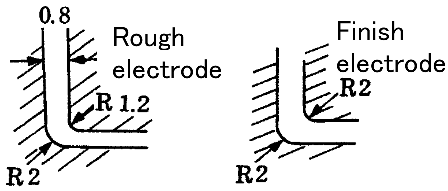
0.15mm allowance to rough elec. reduction 0.8mm.

Specify "sphere-shape machining" to reduce the overcut at the corner.

G113X0Y0Z5.0;

M30;

The “sphere-shape machining” of bottom stopped – complex is used because manufacturing an electrode in a three dimensional program of an automatic program or in a copy machining diminishes the bottom face R, resulting in excessive corner formation in roughing.
For the finish electrode, on the other hand, the bottom stopped-simple menu is used to make the corners with the R as final profile.



[Program for finish electrode]

AUX :.Special setting (G132) ← Finish machining

Address	Attri.	Talk items	Set value
D	/	STARTING COND. No.	
H	/	τoff ADJ SETTING	
C	/	HQSF μSC DENSITY [g/l]	
Q	/	EXP P-PULSE	1
A	/	A-JUMP	
E	/	F-JUMP	
K	/	STEP ANGLE [deg]	
S	/	SUPER SPARK	
M	/	CYCLE JUMP MODE	
R	/	NO.OF JUMP	
U	/	JUMP AMOUNT [code,u,t]	
V	/	CYCLE [code,0.001sec]	
W	/	NUMBER OF TIMES	
O	/	DISCHARGING JUMP (1:ON)	
P	/	SERVO JUMP AMOUNT [u,t]	
L	/	JUMP METHOD	
X	/	ARBITRARY JUMP X AXIS [u,t]	
Y	/	Y AXIS [u,t]	
Z	/	Z AXIS [u,t]	
T	/	SETTING FOR FINE MATTE FINISH	
B	/	POLARITY REVERSE CYCLE [min]	

↓

Machining menu : Bottom stopped–simple(G101) ←Finish machining

Address	Attri.	Talk items	Set value
N	/	ABS/INC (90/91)	
Q	/	MC AXIS	
Z	*	(1:X,2:Y,3:Z)	-30.0
R	*	MC DEPTH [u,t]	0.3
E	*	ELECTRODE REDUCTION [u,t]	30
I	/	MODEL DATA No.	4
J	/	START OF PROCESS No.	14
O	/	END OF PROCESS No.	14
D	/	FINISH PROCESS No.	
H	/	SIDE REMAIN AMOUNT COMP [%]	
L	/	BOTTOM REMAIN AMOUNT COMP [%]	23
P	/	MACHINING METHOD	1111
A	/	PATTERN	
S	/	ROT. ANGLE [0.001deg]	
T	/	JUMP AMOUNT [code:u,t]	
F	/	CYCLE [code:0.001sec]	
		SPEED [code:m,i/min]	

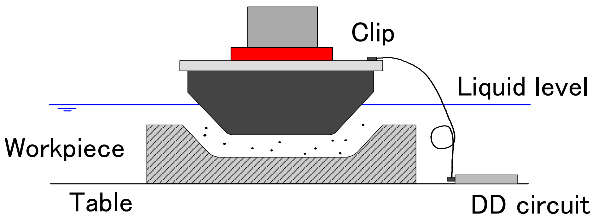
G113X0Y0Z5.0;
M30;

※ Refer to item 19.8 “3-D machining” when you use three dimension electrode made by three dimensions CAD・CAM.

※ When the electrical discharge area is large, the machining depth and the amount of the side expansion are shallower than the schedule or become small. Therefore, set the machining depth and electrode reduction deeply or largely according to the electrical discharge area.

※ Use DD circuit when the electrical discharge area is □200 or more.

・Installation of DD circuit

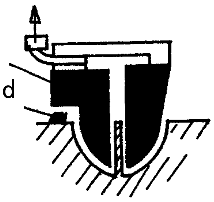


Fix the DD circuit on the table, and connect the DD circuit terminal with the power cable of electroforming electrode. Sink the DD circuit in the liquid because there are a lot of heat.

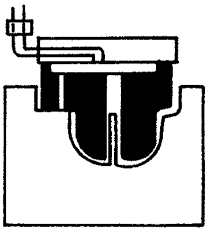
The machining chips piles up on the DD circuit. Please clean the connector sometimes.

4.8 Other instructions

(a)

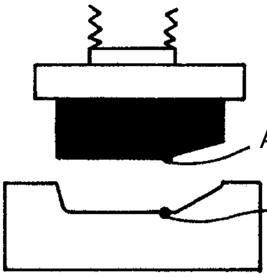


When SL machining is executed with an electrode of the shape as in the left figure, chips accumulated at the parting of the electrode's recessed part and the workpiece surface may cause an arc.



In this case, bore a hole in the recessed part or execute jump.

(b)



When an arc is generated
When increasing τ OFF or the jump amount does not eliminate unstable discharge, an arc protrusion is generated at the tip of the electrode. File this part and also the part of the workpiece that fits this protrusion because this part has turned black. Then, restart machining from E5308. When the electrode arcs several times, the arc protrusion has spread and it is necessary to file it by a wide margin.

※ E5308 is a machining condition to extend τ off etc. of E4111 and to stabilize the machining better.

5. HELICAL GEAR MACHINING

The Helical gear machining uses synchronizing control on Z axis and C axis for machining. Therefore, one of following mandatory options must be chosen for the Helical gear machining.

Mandatory options: Mi Head MR Head MA Head

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5.2 Electrode length, electrode reduction and model data ···· 5－2

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5.4 Machining example (Using 2 electrodes) ···· 5－7

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5.1 Materials and features of electrode

The different materials such as copper (electrode copper, free-cutting copper), copper tungsten, and brass are used for the electrode of the Helical gear machining. The following table shows features of each material with the three-grade evaluation of A, B, and C.

A:Excellent B:Good C:No good

Materials	Removal Rate	Electrode wear	Material cost	Machin-ability	Evaluation result
Electric copper	A	B	A	C	A
Free-cut copper	A	B	B	A	A
Copper tungsten	B	A	C	A	B
Brass	C	C	A	A	C

5.2 Electrode length, electrode reduction, and model data

① Electrode length

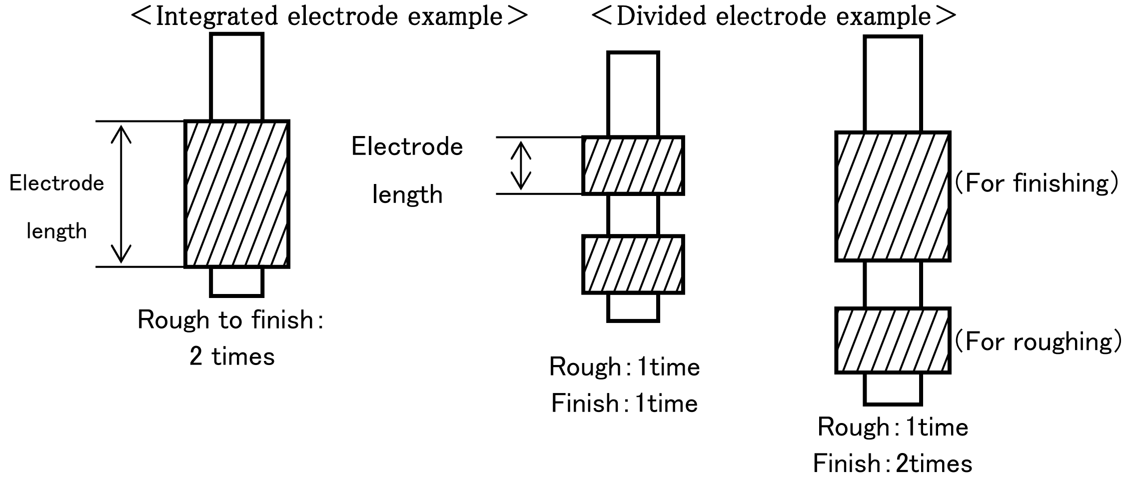
Electrode length is restricted by wear of electrode material and balance with machining plate thickness. Decide the length of electrode after referring to the following data.

Electrode material	Electrode length
Electrode copper	Workpiece thickness × 2. 5
Free-cut copper	Workpiece thickness × 2. 5
Copper tungsten	Workpiece thickness × 1. 3
Brass	Workpiece thickness × 5. 0

(At the time of one spot machining)

Reduction, each electrode length must be more than 1/2 of above data.

＜Integrated electrode example＞ ＜Divided electrode example＞



②Electrode reduction

In case of deciding a larger value on electrode reduction, machining can be started from rough condition and machining time will be reduced.
Since machining swarf emission is very good, stable machining can be achieved. However, electrode wear at the corner will be increased due to the larger value on electrode reduction and the shape becomes structurally weakened.
In contrast, if a smaller value on electrode reduction was decided, machining has to start from weak machining condition, and machining time requires more time. Also machining swarf emission becomes less efficient and machining gets easily unstable. Therefore a well-balanced value suitable for target accuracy should be chosen for the helical gear machining.

Electrode reduction	Machining time	Machining stability	Machining accuracy
Large ↕ Small	Fast ↕ Slow	Stable ↕ Unstable	Fragile ↕ Durable

The electrode reduction values for the helical gear in general are as follows:
Rough electrode reduction value :0.10 ～ 0.15mm(Per side)
Finish electrode reduction value :0.05 ～ 0.10mm(Per side)

③Model data

The model data for the Helical gear machining use is determined by the outside diameter of electrode and the thickness of workpiece.

Ex.) In case of 10mm outside diameter and 5mm thickness.
Model data 21(□5～15)
Model data 77(□5～15)etc,

In case of 20mm outside diameter and 5mm thickness.
Model data 23(□15～50)
Model data 78(□10～25)etc,

5.3 Setting

①Fluid processing

The fluid processing is recommended using a jet vacuum container.

＜Rough machining＞ … Flushing

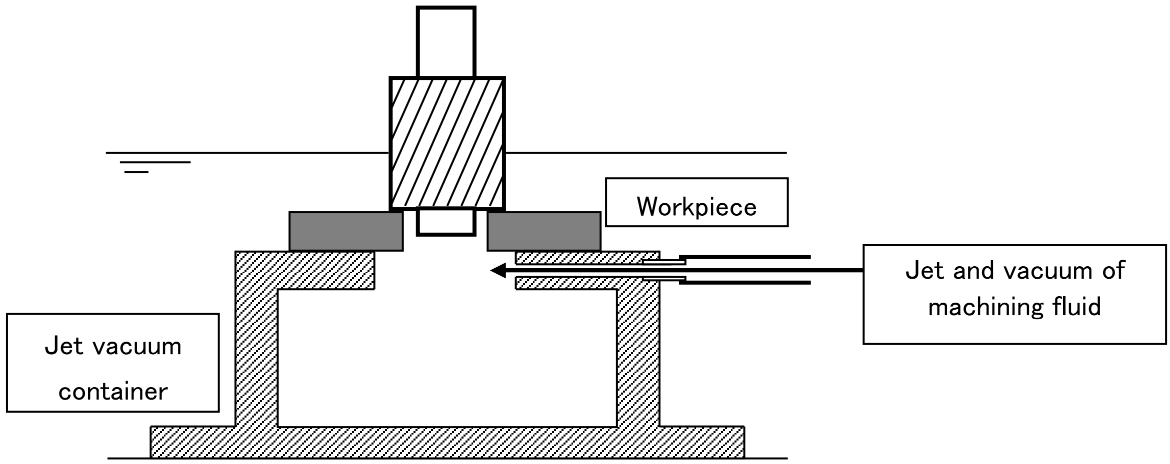
In rough machining, machining amount is large and large amount of machining debris and gas is generated. Therefore, use flushing. Take precaution so that machining debris or gas doesn't accumulate in flushing/suction flange.

The jet pressure should be set around 0.005 to 0.01MP. If the jet pressure setting is too high, the machining becomes easily unstable.

＜Finish machining＞ … Suction

Vacuum will be used at finish machining.

The vacuum usage equalizes discharge gaps and the difference between inlet and outlet diameter of workpiece can be minimized. The vacuum pressure should be around 0.01MPa. The early machining is hard to stable, set the vacuum pressure to low mode until the machining is stabilized.



②Jump

In case of the fluid processing, frequent jump action is not necessary. Set the jump amount between 2 to 4, the jump cycle between 12 to 16, and the jump speed to 1. There is a possibility of damaging the electrode during the Helical gear machining. Make sure to set the jump speed to below 3. With this setting, all axis feed rates including the electrode escape action during the machining are restricted.

When machining is unstable, set large jump and short jump frequency.

Keep the jump speed to 3 or below.

When machining is unstable, it is useful to jointly use "DISCHARGING AMOUNT" in the

SPECIAL SETTING (G132) menu. However, secondary discharge through machining debris will become large. Therefore, it is better to avoid using it when emphasizing surface roughness.

③Machining method.

The through machining (G103) will be used as a machining model. And No.16 will be used as the machining method. With this setting, the Z axis moves to a command value position then orbital expansion towards X and Y axis is performed.

④Side remain amount correction rate

At the Helical gear machining, secondary discharge amount to the side direction becomes larger compare with common shape machining due to inefficiency of machining swarf emission. If the secondary discharge amount is too large, the finish of machining surface may not be able to complete evenly.

Therefore, enter “130 ~ 150” in “D” in the machining menu, and increase side remain between the respective processes.

⑤Time control

The time management must be used all the time.

The process of time management initiation should be set from rough machining condition process rather than common shape machining.

However, do not use the time management from the machining initiation process.

In case of 5mm thickness of workpiece, a measure of the setting time for rough machining should be more than two times the outside diameter of electrode and five times or more for finish machining.

As the workpiece becomes thicker, the setting time should be longer than above setting time. On the contrary, if the workpiece becomes thinner, the setting time should be shorter than above setting time.

＜Ex＞ In case of φ20mm electrode outside diameter and 5mm workpiece thickness.

Rough machining setting time:20 X 2 = 40 minutes or more

Finish machining setting time: 20 X 3 = 60 minutes or more

⑥Orbiting speed

Input "3" to the fifth digit on the "STARTING CONDITION No." in the special machining setting (G132). With this setting, the orbiting speed can be decreased. For helical gear machining, the electrode length is getting longer. If orbiting speed is too fast, the electrode will fan and result in poor machining. Therefore to avoid this, orbiting speed should be set slower.

Special machining setting(G132)

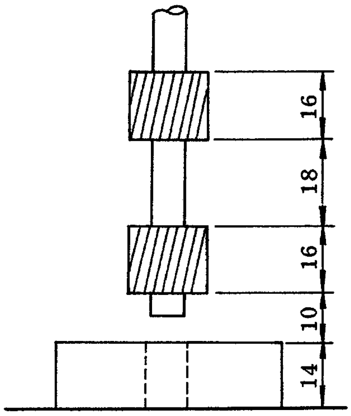
Address	Attri.	Talk items	Range
D	／	STARTING CONDITION No.	3＊＊＊＊ ← Input 3 to the fifth digit.
C	／	HQSF μSC DENSITY [g/l]	
・	・	・	
・	・	・	
・	・	・	

Through machining(G103)

Address	Attri.	Talk items	Range
・	・	・	
・	・	・	
・	・	・	
E	＊	MODEL DATA No.	＊＊
I	／	START OF PROCESS No.	1＊＊ ← Input 1 to the third digit.
J	／	END OF PROCESS No.	＊＊
・	・	・	
・	・	・	
・	・	・	
D	／	SIDE REMAIN AMOUNT COMP [%]	130～150
H	／	BOTTOM REMAIN AMOUNT COMP[%]	
L	／	MC METHOD	16
P	／	PATTERN	1111
・	・	・	
・	・	・	
S	／	JUMP AMOUNT [code, μm]	2～4
T	／	CYCLE [Code, 0.001 sec.]	12～16
F	／	SPEED [code, mm／min.]	1
・	・	・	
・	・	・	
・	・	・	

5.4 Machining example (Finish with two electrodes)

Helical gear machining



Electrode

Material : Copper (Free-cut)

Reduction per side: Rough 0.1mm

Finish 0.05mm

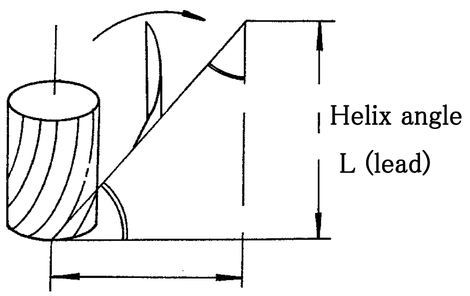
Finish surface roughness

Workpiece

Material :	SKD－11
Module :	0.8
Number of teeth :	16
Helix angle :	20°
Helix direction:	Right

This example explains simultaneous 2-axis machining using Z axis and C axis. A value of the depth of machining on Z axis direction and an appropriate value of the rotation angle on C axis are required.

<Calculation of C axis rotation angle>



Peripheral length of pitch circle

L(lead) = (Pitch circle dia. × 3.14159) × tan(90° − helix angle)

[Pitch circle dia. = Module × No. of teeth ÷ cos (helix angle)]

・ Calculating L (lead) from the above example

Pitch circle dia. = Module × No. of teeth ÷ cos (helix angle)

= 0.8 × 16 ÷ cos20

≒ 13.621

L(lead) = (Pitch circle dia. × 3.14159) × tan (90° − helix angle)

= (13.621 × 3.14159) × tan (90 − 20)

≒ 117.569

Calculating the rotation angle of C axis in relation to the depth of machining on Z axis based on the L (lead) value.

Z axis depth of machining = Workpiece height +
(electrode length – 0.5mm) + MC start point = 14 + 16 − 0.5 + 10 = 39.5

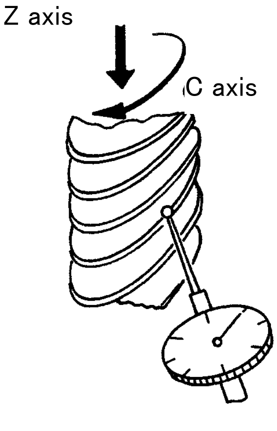
(Machining start point is dimension between workpiece top and electrode)

C axis rotation angle
= Z axis setting value $\times$ −1 $\times$ 360 $\div$ L (lead)
= 39.5 $\times$ −1 $\times$ 360 $\div$ 117.569
≒ −120.950

(−1 is for right helix direction and +1 for left helix direction)

Precautions against machining program creation
•Always use INC (G91) command to set the depth of machining.
Use of ABS (G90) command may cause errors in setting the depth of machining on Z axis and the rotation angle on C axis.

•Before performing actual machining, check the depth of machining on Zaxis and the rotation angle on C axis with following method.



With the electrode attached to the spindle, move the spindle to the safe place where the electrode does not interfere.
Then, as shown to the left, with the indicator touched the tooth surface, execute the following program with the MDI mode.

```
G91;
M19G01Z－25.5C－120. 950;
M30;
```

If the indicator needle moves, review the calculation and the electrode data.

＜Rough machining program＞

G132D30000Q1M2R50U2.0;

G103N91Z−39.5C−120.950R0.09E23I108J11O15D200L16P1111S3T12F1V10W60;

G113X0Y0Z10.0L1A0;

＜Finish machining program＞

G132D30000Q1M2R50U2.0;

G103N91Z−73.5*1)C−225.059*2)R0.05E23I110J15O15D200L16P1111S3T12F1V11W150

G113X0Y0Z10.0L1A0;

M30;

*1)、*2)These values are calculated in the same manner as rough machining program.

5.5 Cautions

①Do not use high speed jump “A3*”
The electrode may be damaged.

②Do not use Super spark.
The surface machining may not be completed.

③Make sure to use the jet vacuum at the time of the jet vacuum container usage. If the jet vacuum container is filled with gas, the risk of explosion will be increased. In case of the explosion, check the workpiece displacement and damages on the electrode and the machine.

④Do not perform “Retract” and “Return” action.
At the helical gear machining, there is a risk of damaging the electrode due to machining swarf stuck in the gap between the electrode and the workpiece.
If a retract is performed to check the machined area, make sure the electrode is free from the workpiece then execute reset and restart.

5.6 Measures against unstable machining

Typical conditions at the time of unstable machining.

- Servo light and Condition light are both OFF.
- No discharge sound at all.

If the above conditions (Short-circuit or abnormal discharge) occurred frequently, perform following procedures.

1. Open Condition F6 and goes to Execute L7 screen.

・Increase "Servo adjustment " value about 2 taps.

Ex) If the current value is 12 then changes it to 14.

・Increase "τ OFF" value.

Set the D.F ratio on the machining condition screen to below 10%.

2. Open Condition F6 and goes to Machining setting L1 screen.

・Increase "Jump amount" value about 2 to 3 taps.

・Decrease "Jump cycle" value about 2 to 4 taps.

3. Lower the jet and vacuum pressure.

However, caution should be taken and make sure not to have gas which was produced by machining inside the jet vacuum container.

6. HQSF（μSC USED）

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6.1 General description

High-Quality-Surface-Finish (HQSF) is a machining method of obtaining fast and stable electrical discharge performance in the finish process by the effect of μSC.

Main electrical discharge performances are shown below.

①The number of electrical discharges increases by a factor of 3～5.
②An extremely light electrical discharges are maintained from the start machining to the end.
③The irregularities on the surface are extremely little, because the electrical discharges are distributed.

Because the electrical discharge performance improves as shown above, the following results are obtained.

①Finished surface is flat and that is polished easily.
②Finish machining time is good.
③Side which comes off is easily.

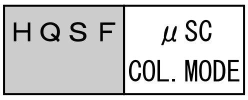
HQSF does not only achieve a glazed surface, but it is also able to machine a uniform satin surface which can be polished easily in post machining.

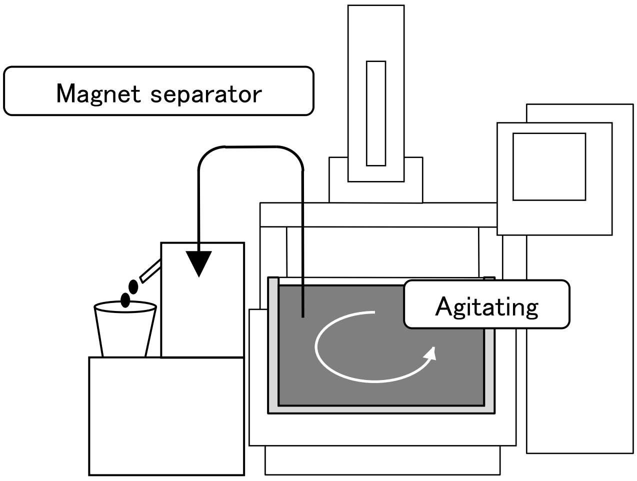
6.2 Main operation of the system

In the HQSF model (S specification), it is necessary to use three kinds of modes properly concerning the circulation of dielectric fluid.
The modes are selected by turning on and off "HQSF" and "μSC COL.MODE" on OPT FUNC – M.CONTROL screen.

①HQSF machining mode

It is a mode with the dielectric fluid by which μSC is added from roughing to finishing. In this mode, the machined chips are removed by the magnet separator without passing the standard filter system.

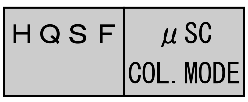


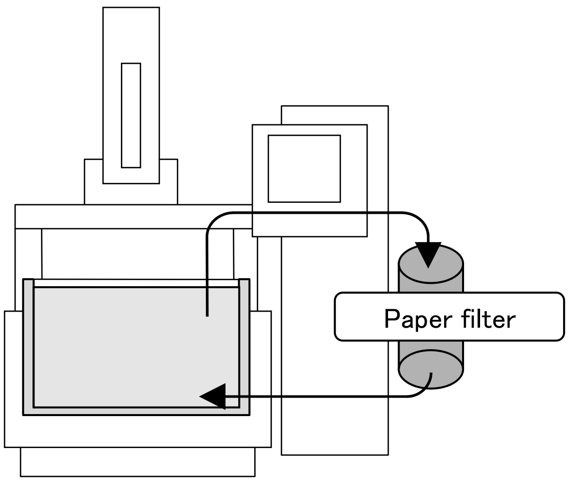


When μSC is used, "HQSF" must be always ON.
"HQSF" is displayed at status display area on CRT screen.
This setting will be hold even after power off.
HQSF can collect 30minutes per 200l.

②μSC collect mode

When μSC becomes used up (HQSF time: 400 hours) or it is weakened the μSC density, μSC in dielectric fluid is collected by the standard filter system.





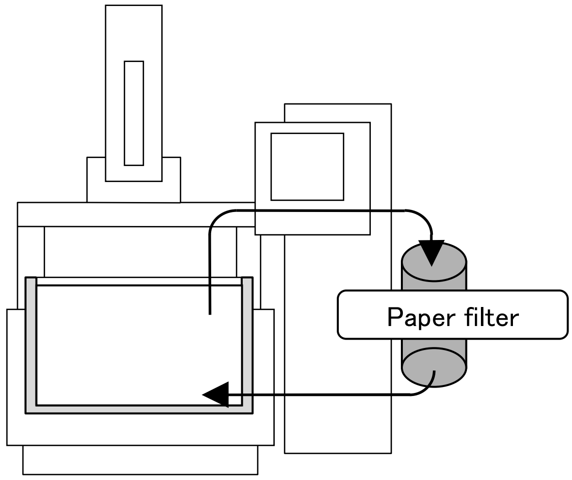
It takes roughly one hour.
No need to collect μSC completely.

③Standard machining mode

Machining without μSC. In this mode, the machined chips are removed from dielectric fluid by using the standard filter system.

HQSF	μSC COL. MODE

When "HQSF" is off, the filter system works normally.
In case "HQSF" is off, μSC will be collected with the machined chips.



Each mode is changed as follows.

HQSF mode

(μSC mixing)

(Density check)

(HQSF machining)

↓

μSC collect mode

(μSC becomes used up.)

↓

Standard machining mode

6.3 Density management of μSC

6.3.1 Outline of density management

The density management of μSC is important in HQSF machining.

To maintain accurate density, inspect the μSC density before machining or every week.

①Proper density

General machining : 1g/ liter

Precise machining : 0.5g/ liter

When the density is too high, the machining is not stable.

The electrical discharge will not be generated when the μSC density exceeds 4g/liter. Collect μSC by changing mode to the μSC collect mode (refer to clause 7.2) few minutes to weakened the density. Oppositely, when the density becomes 0.2g or less/liter, the effect of μSC is lost. Add μSC.

②Method of measuring density

General machining : Method of measuring general density

Precise machining : Method of measuring low density

Refer to clause 6.3.4, 6.3.5.

③Lifetime

It is about one month. (400 machining hours)

It should be used only as a guide.

Lifetime of μSC differs according to the model and machining condition.

Early replacement is recommended in case of hard condition machining or emphasizing surface quality.

④Timing of density measurement

Don't measure the density during rough machining.

It is impossible to measure the density accurately during rough machining due to machined chips.

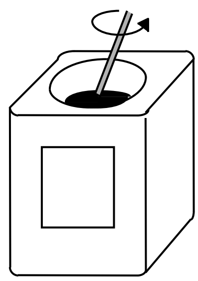
6.3.2 Type of μSC

There are two types of μSC, type 1 and type 2.

Choose either one according to the usage.

Type	Type 1	Type 2
Container	5kg can, 300g can	5kg can
Usage	for precise	for general

6.3.3 How to add μSC into dielectric fluid



It may be difficult to take μSC out of the can. Beforehand, stir and soften it with a stick or a pipe.

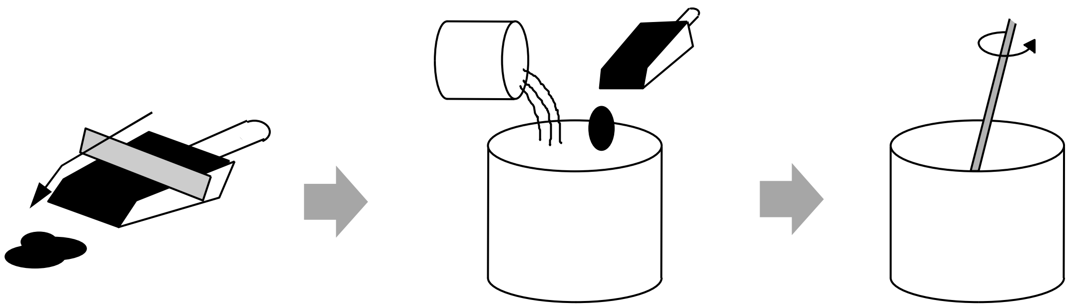
Take μSC out using the attached shovel.

It is about 500g per level shovel.

Put μSC and dielectric fluid, about 5 liters, in another can.

Stir thoroughly until lumps of μSC disappear.

Then pour it into the work tank.



For instance, when you add μSC by 1g/l by the processing liquid gross weight 800l.

The μSC of 1×800=800g is necessary.

And take out half μSC to the shovel about the work of second, please.

The dielectric fluid gross capacities according to the models are shown.

Models	Gross capacities (liters)
EDAF2	300
EDAF3	450
EDNC6	800
EDNC8	1000
EDNC10	1500
EDNC15	4500
EDNC20	6000

Select HQSF mode (refer to clause 6.2) and agitate dielectric fluid when adding μSC.

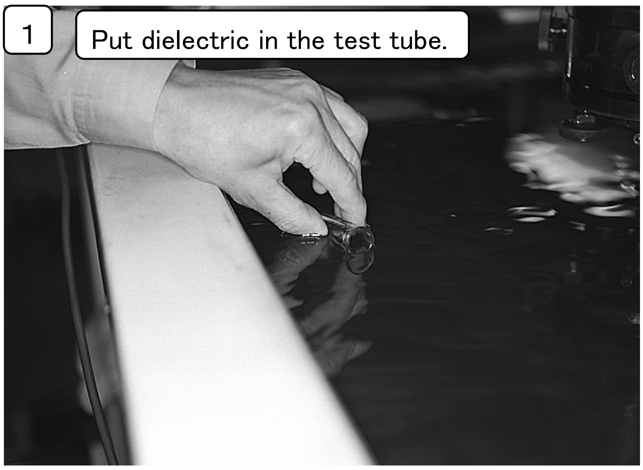
6.3.4 How to measure density of μSC

Use the graduated test tube for density measurement.

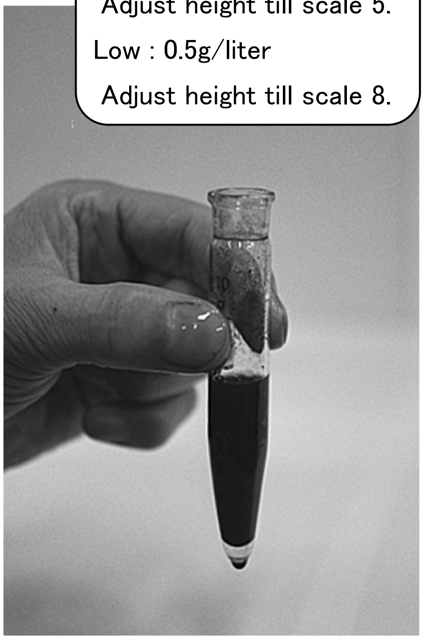
Wash and dry the test tube before measurement.

Measure the density according to the following procedures.

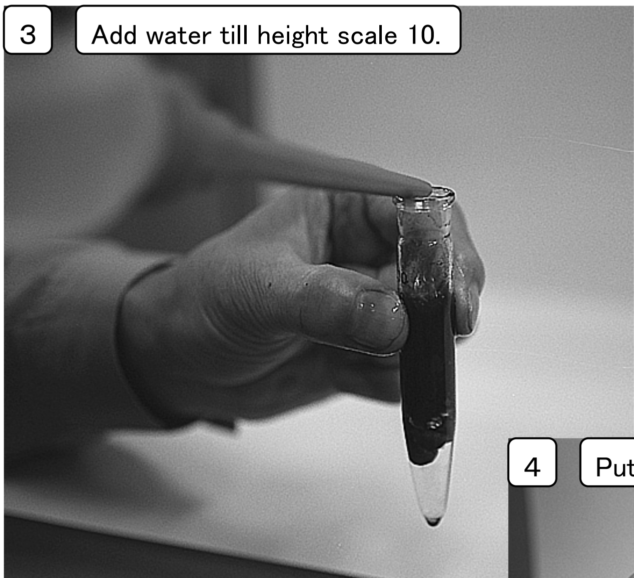
1 Put dielectric in the test tube.



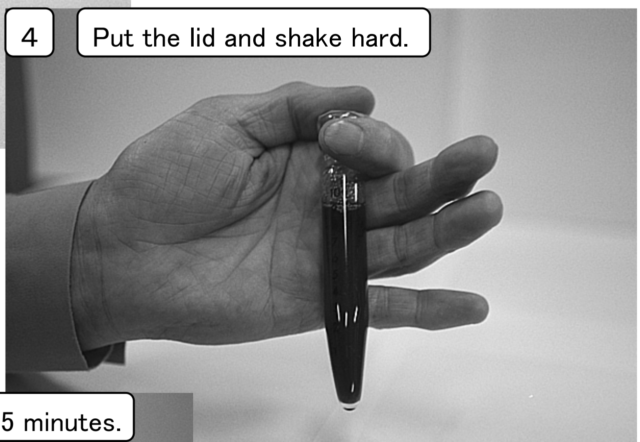
2 General : 1g/liter
Adjust height till scale 5.
Low : 0.5g/liter
Adjust height till scale 8.



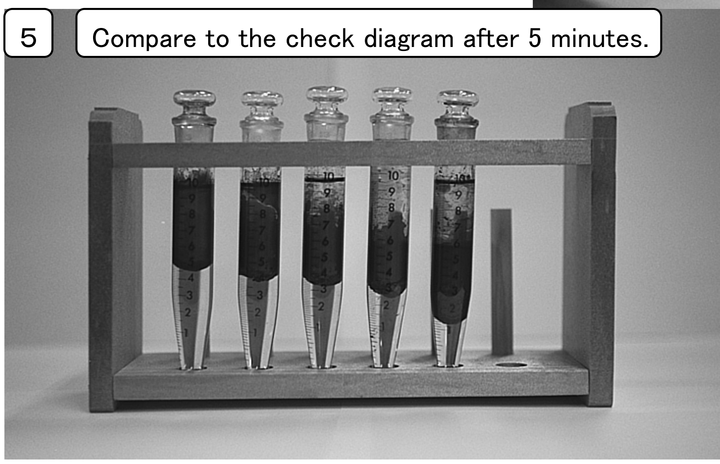
3 Add water till height scale 10.



4 Put the lid and shake hard.



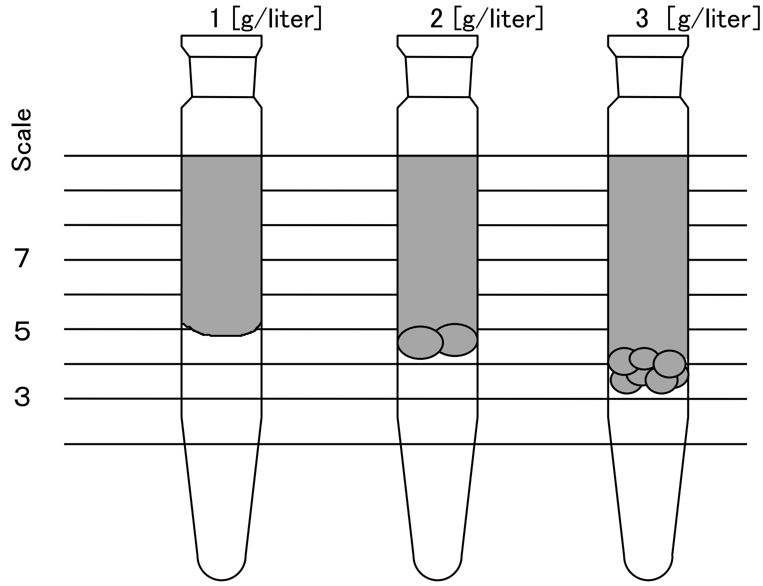
5 Compare to the check diagram after 5 minutes.



6.3.5 Standard of density

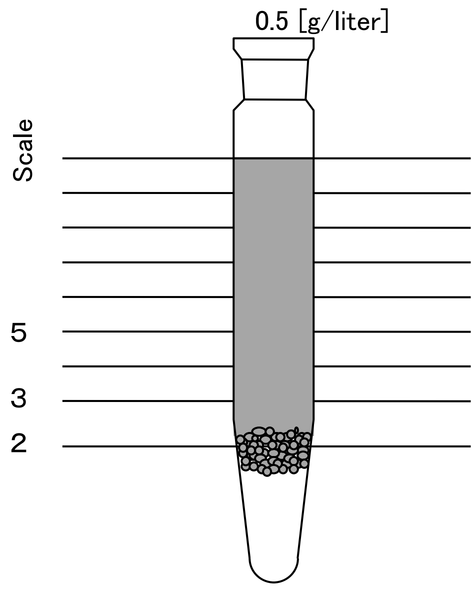
①Method of measuring general density

In the method of measuring general density, make 1–1.5g/liter the standard of the density adjustment. Add or collect μSC so that the boundary part of dielectric fluid and water may become within the range of graduation 4–5 of the test tube.



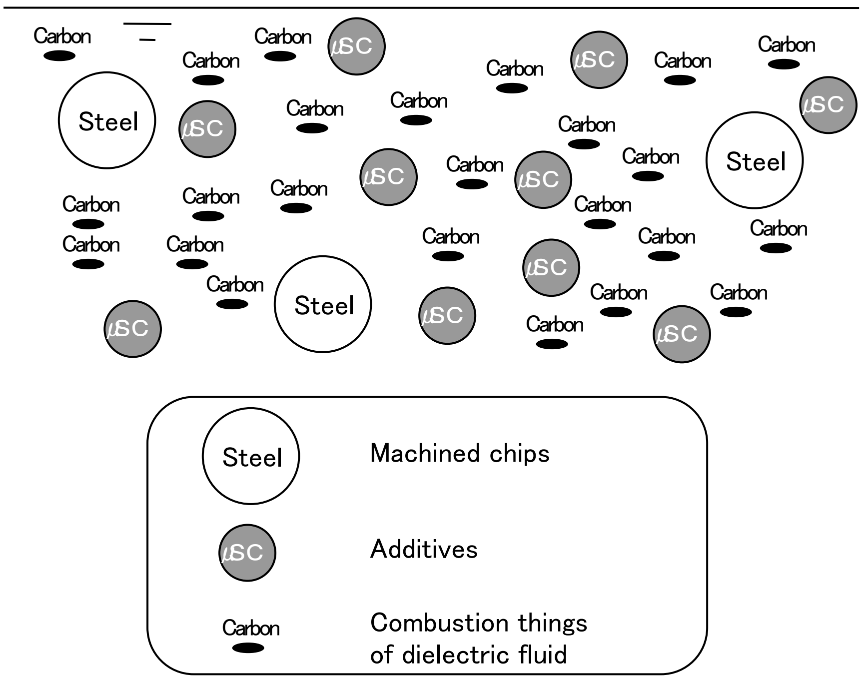
②Method of measuring low density

In the method of measuring low density, make 0.5g/liter the standard of the density adjustment. Add or collect μSC so that the boundary part of dielectric fluid and water may become within the range of graduation 1.5–2 of the test tube.



6.3.6 Notice for density management

If rough machining using 30A or more for a long time, collect and add μSC in order to readjust the density after rough machining.



Imitation of dielectric fluid inside after rough machining

A large amount of carbons are generated in rough machining when the current is 30A or more. The color of dielectric fluid changes from silver to deep-black.
An accurate μSC density cannot be measured by the influence of the carbons when the color of dielectric fluid is deep-black. Moreover, the effect of μSC decreases though the density measurement result is proper.

Readjust the μSC density after rough machining for a long time, even if the machining current is 20A or less.
※ Do not return the liquid in the test tube which measured the density into the tank.
This is because the liquid contains water.
The μSC density sometimes becomes unstable in case of new machine or after μSC resumption or after switching the mode from standard machining. If this is the case, add μSC until the density becomes stable for a certain period of time. The stable period may vary depending on the type of machines and its usage. And as for the machine, especially those of smaller sizes, regularly perform up-and-down movement of the work tank to stabilize μSC density with ease.

6.4 Machining condition table

The machining conditions for HQSF are added after the usual model data.
Make the program which inputs the model data number (“Model data specified function of machining condition table”) corresponding to discharge area as follows.
Refer to clause 6.6 for making the program.

①Cu－St

Applied area ～□30 (Rough to semi-finish : Model data20, 21, 23)

Model data No.	Process No.								
3600	1	2	3	4	5	6	7	8	9
E No.	E3601	E3602	E3603	E3604					
Surface roughness	0.4	0.45	0.5	0.7					
Wear ratio [%]	40	40	30	30					

Applied area □30～□75 (Rough to semi-finish : Model data 23, 24)

Model data No.	Process No.								
3610	1	2	3	4	5	6	7	8	9
E No.			E3614	E3615					
Surface roughness			1	1					
Wear ratio [%]			40	40					

Applied area □75～□150 (Rough to semi-finish : Model data 24, 25)

Model data No.	Process No.								
3620	1	2	3	4	5	6	7	8	9
E No.						E3626			
Surface roughness						1.5			
Wear ratio [%]						50			

Applied area □150～□200 (Rough to semi-finish : Model data 25, 28)

Model data No.	Process No.								
3630	1	2	3	4	5	6	7	8	9
E No.							E3637		
Surface roughness							3		
Wear ratio [%]							50		

Refer to manual “MACHINING CONDITION” for details of each machining condition.

②Gr－St

Applied area ～□30 (Rough to semi–finish : Model data 54, 30)

Model data No.	Process No.								
3700	1	2	3	4	5	6	7	8	9
E No.	E3701	E3702							
Surface roughness	2	4							
Wear ratio [%]	350	250							

Applied area □30～□75 (Rough to semi–finish : Model data 30)

Model data No.	Process No.								
3710	1	2	3	4	5	6	7	8	9
E No.		E3712	E3713						
Surface roughness		3	4						
Wear ratio [%]		350	350						

Applied area □75～□150 (Rough to semi–finish : Model data 34)

Model data No.	Process No.								
3720	1	2	3	4	5	6	7	8	9
E No.			E3723	E3724					
Surface roughness			4	8					
Wear ratio [%]			350	100					

Applied area □150～□200 (Rough to semi–finish : Model data 30)

Model data No.	Process No.								
3730	1	2	3	4	5	6	7	8	9
E No.				E3734	E3735				
Surface roughness				8	11				
Wear ratio [%]				250	70				

As for post satin machining, the surface may be polished easily and uniformly.

Satin machining Applied area □30～□1000 (Rough to semi–finish : Model data 30, 34)

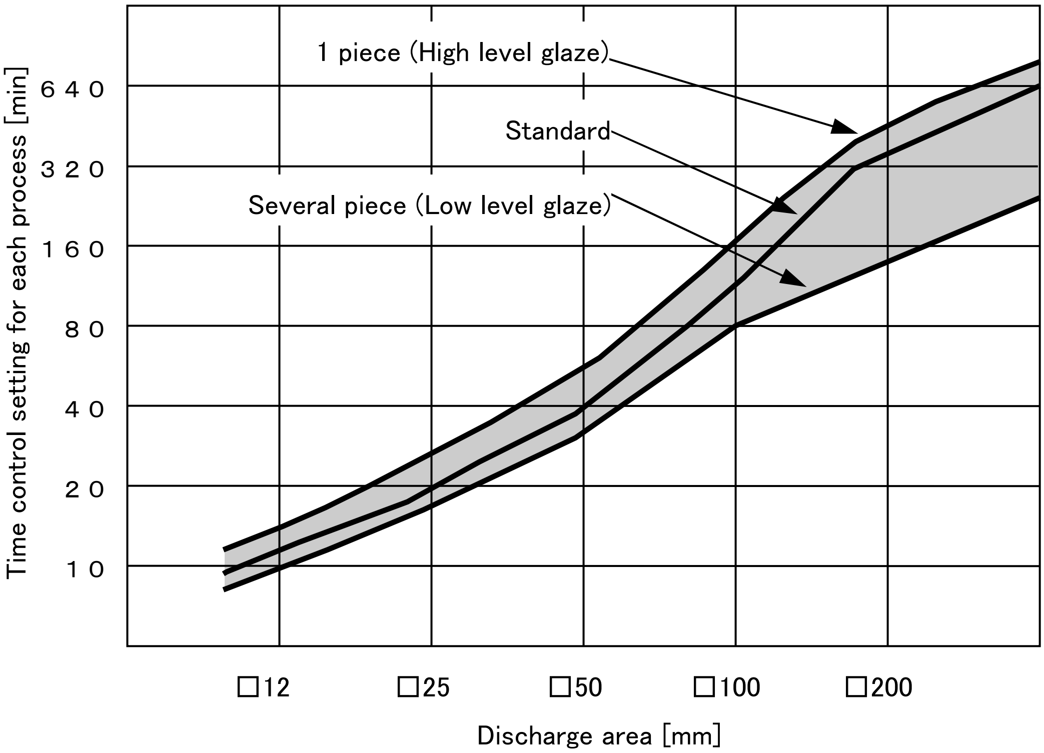
Model data No.	Process No.								
3750	1	2	3	4	5	6	7	8	9
E No.		E3752	E3753	E3754	E3755	E3756	E3757		
Surface roughness		4	5	6	8	10	12		
Wear ratio [%]		300	270	250	230	200	140		

Note: Satin machining circuit is necessary for the satin machining in EDNC8 or more.

Refer to manual "MACHINING CONDITION" for details of each machining condition.

6.5 Guideline of the time control machining

Decide setting the time control according to the discharge area (includes both bottom and side).



The above figure is a standard of the time control setting.
A necessary surface might not be obtained by the machining shape or selected machining method. In that case, lengthen the time setting.

In case of burning several pieces, set the time control shorter to make the electrode wear less.

6.6 Machining program

Program for rough and semi-finish machining are same as ordinary machining.
In case if further improvement is required on surface, add the HQSF machining process.

General finishing

MC : Bottom stopped (Simple) (G101)

N	／	ABS/INC	(90／91)
Q	／	MC AXIS	(1:X, 2:Y, 3:Z)
Z	＊	MC DEPTH	[μ, t]
R	＊	ELECTRODE REDUCTION	[μ, t]
E	＊	MODEL DATA No.	
I	／	START OF PROCESS No.	
J	／	END OF PROCESS No.	
O	／	FINISH OF PROCESS No.	
D	／	SIDE REMAIN AMOUNT COMP	[%]
H	／	BOTTOM REMAIN AMOUNT COMP	[%]
L	／	MC METHOD	
P	／	PATTERN	
A	／	ROT. ANGLE [0.001deg]	
S	／	JUMP AMOUNT	[code, μ, t]
T	／	CYCLE	[code, 0.001sec]
F	／	SPEED	[code, m, i/min]
K	／	CLAMP START PROCESS No.	
M	／	TIME CONTROL MC START PROC. No.	
U	／	1PROCESS	[min]
V	／	2PROCESS	[min]
W	／	3PROCESS	[min]

Enter actual MC depth and electrode reduction.

In HQSF mode, the remain amounts of the model data are changed automatically.
Refer to the model data No.0.

POS : Dispersed (G113) etc.

HQSF finishing

MC : Bottom stopped (Simple) (G101)

N	／	ABS/INC	(90／91)
Q	／	MC AXIS	(1:X, 2:Y, 3:Z)
Z	＊	MC DEPTH	[μ, t]
R	＊	ELECTRODE REDUCTION	[μ, t]
E	＊	MODEL DATA No.	
I	／	START OF PROCESS No.	
J	／	END OF PROCESS No.	
O	／	FINISH OF PROCESS No.	
D	／	SIDE REMAIN AMOUNT COMP	[%]
H	／	BOTTOM REMAIN AMOUNT COMP	[%]
L	／	MC METHOD	
P	／	PATTERN	
A	／	ROT. ANGLE [0.001deg]	
S	／	JUMP AMOUNT	[code, μ, t]
T	／	CYCLE	[code, 0.001sec]
F	／	SPEED	[code, m, i/min]
K	／	CLAMP START PROCESS No.	
M	／	TIME CONTROL MC START PROC. No.	
U	／	1PROCESS	[min]
V	／	2PROCESS	[min]
W	／	3PROCESS	[min]

Add 0.03mm for depth and 0.02mm for electrode reduction.

Setting of start, end and finish process are reversed in "Model data specified function of machining condition table".
Make sure the bigger number, the rougher surface.

Machining method 7 is invalid to use.

Always set the time control machining.

POS : Dispersed (G113) etc.

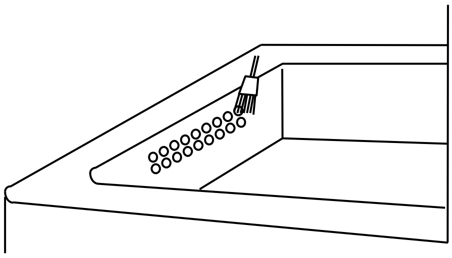
M30;

"Model data specified function of machining condition table" is the function of machining condition table (refer to 6.4) as a model data. The side and bottom remain amount are set at "48:SM" in each machining condition.
Refer to clause 6.8 for machining programs.
E3600～E3999 can be used as this function.

6.7 Notice for the operation

①When clear dielectric is necessary to clean the workpiece up, change mode to the μSC collect mode (refer to clause 6.2). Filter system works as usual in this case and μSC will be collected.

②A large quantity of carbon are produced in dielectric after long rough machining with more than 60A condition.
The carbons adhere to the inner wall and the dielectric outlet is closed occasionally. Clean the work tank inner wall once or more a week.



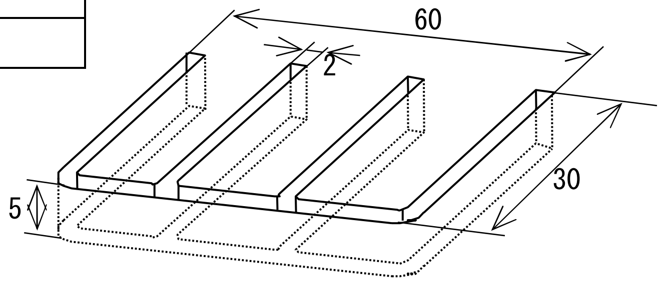
③To remove the dirt from your hand easily, apply cream to your hand in advance.

④Paper filters that collected μSC can be thrown away just as usual filters.

6.8 Machining examples

6.8.1 Chassis

Electrode	Copper
Workpiece	NAK80 (St)
Number of elec.	2 pcs.
Elec. reduction	0.15mm/side
MC depth	−5.0mm
μSC density	2g/liter



Machining program

Rough electrode : Roughing

```
G132 Q22 A32 M2 R20 U20.;
G101 Z-4.95 R0.1 E124 I8 J9 L13 P2222 S7 T4 F8;
G113 X0 Y0 Z10.0;
M30;
```

Finish electrode : Semi-finishing

```
G132 Q2 A32 M2 R20 U20.;
G101 Z-5.00 R0.15 E124 I8 J15 O15 L13 P2222 S7 T4 F8 M12 U40 V40 W40;
G113 X0 Y0 Z10.0;
;
```

Point

HQSF finishing

```
G132 D60 M2 R20 U20.;
G101 Z-5.03 R0.17 E3610 I5 J5 L13 P2222 S7 T4 F8 M5 U40;
G113 X0 Y0 Z10.0;
M30;
```

Point

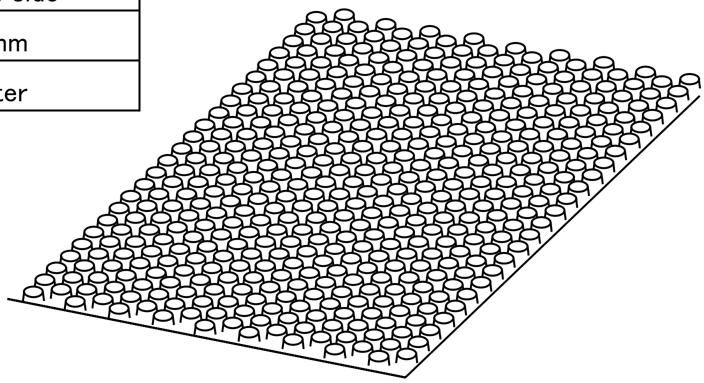
Points

・In HQSF finishing, increase machining depth and electrode reduction.

・In HQSF finishing, use "Model data specified function of machining condition table".

6.8.2 Speaker grill

Electrode	Copper(200×200)
Workpiece	NAK80 (St)
Number of elec.	1 pc.
Elec. reduction	0.15mm/side
MC depth	−1.5mm
µSC density	1g/liter



Machining program

Roughing

```
G132 D60 Q3 A2 M2 R50 U20.;
G100 Z-1.2 E194 R5 P1111 S7 T8 F6;
G113 X0 Y0 Z10.0;
;
```

Semi-finishing

Point

```
G132 D60 Q3 A2 M2 R50 U20.;
G101 Z-1.5 R0.15 E24 I5 J15 O15 L73 P1111 S8 T10 F6 M12 U180 V180 W180;
G113 X0 Y0 Z10.0;
;
```

HQSF finishing

Point

```
G132 D60 M2 R50 U20.;
G101 Z-1.53 R0.18 E3620 I6 J6 L73 P1111 S8 T10 F6 M6 U240;
G113 X0 Y0 Z10.0;
M30;
```

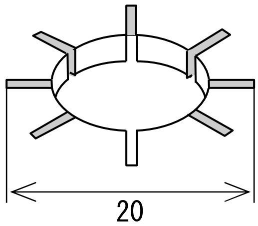
Point

Points

- Side machining area is wide, so it is difficult to finish.
- Use machining method 73.
- In HQSF finishing, increase machining depth and electrode reduction.

6.8.3 Small shape

Electrode	Copper
Workpiece	STAVAX (St)
Number of elec.	1 pc.
Elec. reduction	0.15mm/side
MC depth	−4.0mm
μSC density	1g/liter



Machining program

Semi-finishing

```
G132 Q2 A32 M2 R20 U20.;
G101 Z-4.0 R0.15 E323 I6 J15 O15 L13 P1111 S7 T4 F8 M13 U15 V10 W10;
G113 X0 Y0 Z5.0;
;
```

Point Point

HQSF finishing

```
G132 D60 M2 R20 U20.;
G101 Z-4.03 R0.18 E3600 I4 J3 L13 P1111 S7 T4 F8 M4 U10 V10;
G113 X0 Y0 Z5.0;
M30;
```

Points

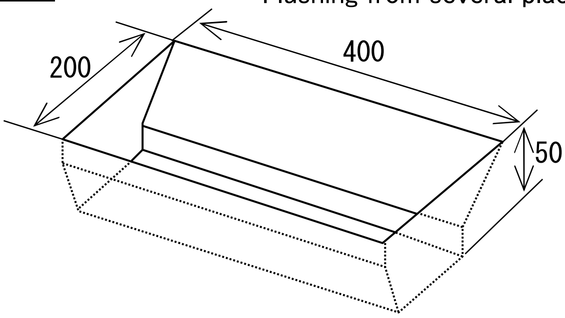
- In "Model data specified function of machining condition table", setting number of start, end and finish process are reversed.
- Set a shorter time for the time control machining.

6.8.4 Panel

Electrode	Graphite (400×200)
Workpiece	S55C (St)
Number of elec.	2 pcs.
Elec. reduction	0.8(Rough), 0.3(Finish)
MC depth	−50.0mm
µSC density	1g/liter

Pre-machined

Flushing from several places



Machining program

Rough electrode : Roughing

```
G132 Q22 A2 M2 R50 U50.;
G102 Z-49.95 R0.8 E34 I5 J9 O15 L18 P1111 M0 B0 S8 T14 F2;
G113 X0 Y0 Z10.0;
M30;
```

Point

Finish electrode : Semi-finishing

```
G132 Q2 A2 M2 R50 U50.;
G102 Z-50.0 R0.3 E34 I8 J15 O15 L18 P1111 M0 B0 S8 T16 F2 U13 V300;
G113 X0 Y0 Z10.0;
;
```

Point

HQSF finishing

```
G132 D60 M2 R50 U50. O1;
G102 Z-50.01 R0.31 E3750 I5 J4 L18 P1111 M0 B0 S8 T16 F2 U4 V400;
G113 X0 Y0 Z10.0;
M30;
```

Point

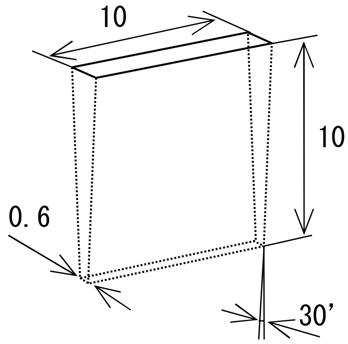
Point

Points

- Use 3-D sphere orbit (machining method 18 or 28 or 8).
- Use satin machining conditions.
- In a large, deep machining, flush from several places in order to ensure proper distribution of µSC during machining.

6.8.5　Rib

Electrode	Copper
Workpiece	STAVAX (St)
Number of elec.	2 pcs.
Elec. reduction	0.1mm/side
MC depth	−10.0mm
μSC density	1g/liter



Machining program

Rough electrode : Roughing

```
G132 Q22 A32 M2 R8 U20.;
G100 Z-9.80 E262 R5 P2222 S12 T3 F10;
G113 X0 Y0 Z10.0;
M30;
```

Finish electrode : Semi-finishing

```
G132 Q2 A32 M2 R8 U20.;
G101 Z-10.0 R0.1 E521 I8 J15 O15 L43 P2222 S12 T3 F10 M313 U15 V15 W15;
G113 X0 Y0 Z10.0;
;
```

HQSF finishing　　Point

```
G132 D60 M2 R8 U20. O1;
G101 Z-10.03 R0.12 E3600 I4 J3 L43 P2222 S12 T3 F10 M304 U15 V15;
G113 X0 Y0 Z10.0;
M30;
```

Point

・In HQSF finishing, use the discharging jump.

7. GLAZED MACHINING AND SATIN MACHINING

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7.1 Glazed machining ··· 7－2

7.2 Satin machining ·· 7－5

7.1 Glazed machining

In the range of surface roughness below 3μmRz, a glazed finished surface can be attained. However, note that the finishing result varies depending on the workpiece material, as listed below. Also, if a polishing is to be done after EDM, do not execute a glazed machining, but execute a usual or satin machining.

Workpiece material	Finishing result
SKD-61 NAK80 STAVAX	Good glazed surface
SK-3 S55C	Rather poor glazed surface
SKD-11 NAK55	Glazed surface not attained

The glazed surface can be attained by using either of the following three glazed machining conditions:

Machining conditions	E2703	E3102	E3100
Surface roughness	1.0μmRz	0.4 μmRz (glazed)	0.2 μmRz (glazed)

A glazed machining can be executed with either of the following three methods:

①Use glazed machining model data 16 – 18 (including three glazed machining conditions).

②Finish the surface to 3μmRz with a certain model data, then use the glazed machining model data 29 that specifies three glazed machining conditions only.

③Use the Glazed machining model data adding function (the operation in②is executed automatically). (A usage method is given on the following page.)

In using either method, the time control must be set for three glazed machining conditions. In this case, set the time according to the discharge area as listed below:

Standard time for time control by area (MC depth 10mm)

Discharge area	Machining conditions		
	E2703 (1.0μmRz)	E3102 (0.4μmRz)	E3100 (0.2μmRz)
□10	60 min	90 min	120 min
□20	100	140	180
□30	140	200	240

The jump setting is automatically changed to proper values under these conditions.

Glazed machining by the “Glazed machining model data adding function”.

・Setting method

FINISH PROCESS No. = ○ ○ ○

Glazed machining condition number

Finish process No.

Setting 1 – 3 to the glazed machining condition number changes automatically the model data to model data 29 after the finish process of current model data is completed.
In this case, set the process number whose surface roughness is less than 3 μ mRz to the finish process No.

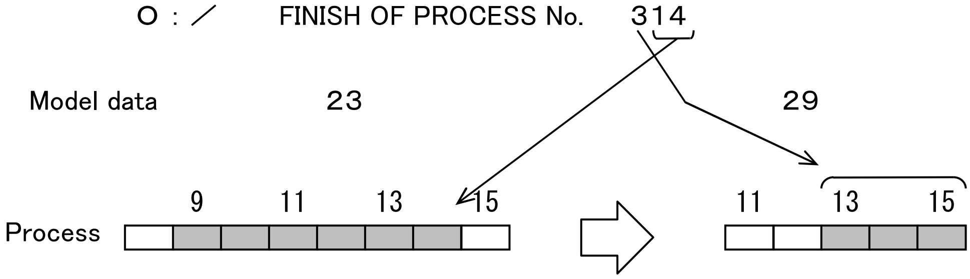
Glazed machining condition number

1・・・・・・・・Machining with E2703 (1.0 μ mRz) (Glazed surface is not attained.)

2・・・・・・・・Machining with E2703 and E3102 (0.4 μ mRz)

3・・・・・・・・Machining with E2703, E3102 and E3100 (0.2 μ mRz)

<Example>	E : ＊	MODEL DATA No.	23	
	I : ／	START OF PROCESS No.	9	
	J : ／	END OF PROCESS No.	(14)	omitable
	O : ／	FINISH OF PROCESS No.	314	



The model data is automatically changed to model data 29, and the machining depth and electrode reduction are added by 10 μ m. Also, the jump setting is automatically changed to proper values.

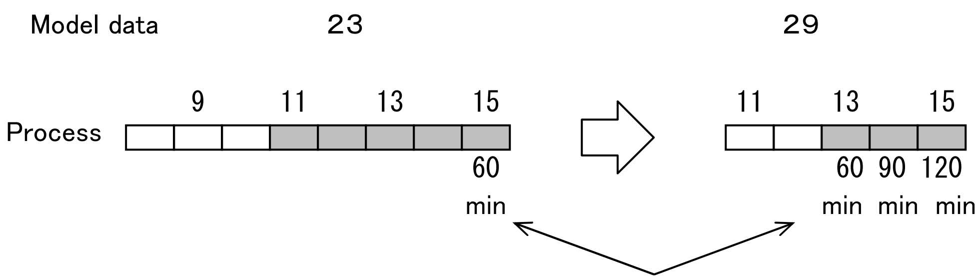
Note : This function cannot be used for the corner machining model (G104) and machining method 7.

・Time control setting

The process before the finish process of the model data set by the item E : MODEL DATA No. can be set as the TIME CONTROL MC START PROC. No.

〈Setting example for □10 (G101)〉

E : ＊ MODEL DATA No.・・・・・・・・・・・・・・・・・・・・・・・・・21
I : ／ START OF PROCESS No.・・・・・・・・・・・・・・・・11
J : ／ END OF PROCESS No.・・・・・・・・・・・・・・・・・・(15) omitable
O : ／ FINISH PROCESS No.・・・・・・・・・・・・・・・・・・・315
:
M : ／ TIME CONTROL MC START PROC.No.・・・・・15
U : ／ 1 PROCESS・・・・・・・・・・・・・・・・・・・・60
V : ／ 2 PROCESS・・・・・・・・・・・・・・・・・・・・90
W : ／ 3 PROCESS・・・・・・・・・・・・・・・・・・・・120



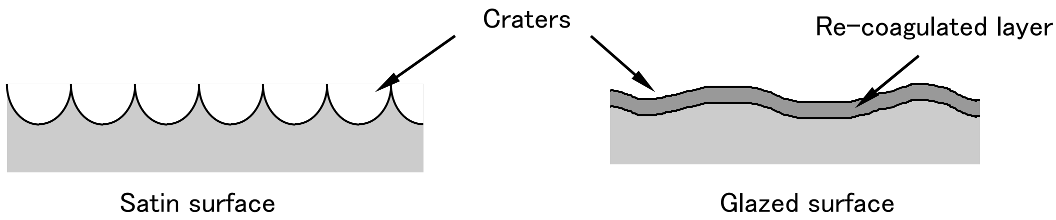
Same time is set before and after model data change.

7.2 Satin machining

The surface roughness below 3 μ mRz provides a satin finish surface.
This finishing method is effective for those workpieces that require high accuracy.
Satin machining is more stable than glazed machining, and is less affected by the workpiece material.
Satin machining circuit must be installed for a satin machining. The Satin machining circuit is standard attached in EDAC1, EDAF2, 3 and EDNC6.

①Use model data 19 – 24 etc.
②Set the time control machining on demand.

Difference between satin surface and glazed surface



Enlarged machining section

(Craters are deeper than its radius. Less re–coagulated layer does not result in glazed surface.)

(Craters are shallow but their radius are large. Thick re–coagulated layer Results in glazed surface.)

The satin surface has a thinner re–coagulated layer than that of glazed surface, thus facilitating polishing workpiece. Also, better discharge gap accuracy and flatness of finished surface are suitable for high accuracy machining.
Use this satin machining because there is no advantage of the glazed machining when the workpiece material is SKD–11 and so on.

8. PIN GATE MACHINING

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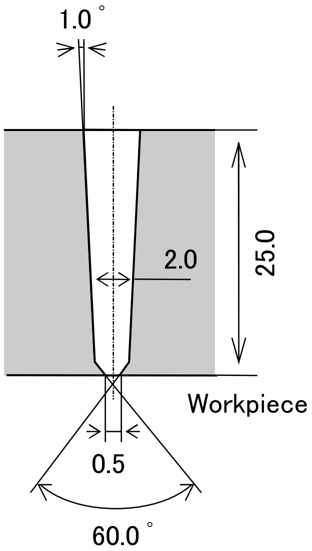
8.1　Pin gate machining··8－2

8.1 Pin gate machining

In EDM pin gate machining, the depth of machining is deep as compared to the electrode diameter. Therefore, machined chips hardly come out, result in difficult machining.
In such a case, the electrode may be rotated or a special pipe electrode may be used in order to shorten the machining time.
The following, however, describes a general machining method.



[Electrode] Quantity : 2 pcs.
Reduction : 0.25

[Setting] No injection

The finished diameter at the leading end of gate varies depending on the dimensional accuracy and centering accuracy of electrode.
The machining depth is deep as compared to the electrode diameter, so take care of the jump setting.

〈Program〉

AUX :MC control setting (G132)

Address	Attri.	Talk items	Set value
D	／	STARTING COND. No.	
H	／	τoff ADJ SETTING	
C	／	HQSF μSC DENSITY [g/l]	
Q	／	EXP P-PULSE	2
A	／	A-JUMP	32
E	／	F-JUMP	
K	／	STEP ANGLE [deg]	
S	／	SUPER SPARK	
M	／	CYCLE JUMP MODE	1
R	／	NO.OF JUMP	10
U	／	JUMP AMOUNT [code,u,t]	15.0
V	／	CYCLE [code,0.001sec]	
W	／	NUMBER OF TIMES	
O	／	DISCHARGING JUMP (1:ON)	
P	／	SERVO JUMP AMOUNT [u,t]	
L	／	JUMP METHOD	
X	／	ARBITRARY JUMP X AXIS [u,t]	
Y	／	Y AXIS [u,t]	
Z	／	Z AXIS [u,t]	
T	／	SETTING FOR FINE MATTE FINISH	
B	／	POLARITY REVERSE CYCLE [min]	

↓

MC : Single MC (G100)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
X	／	MC DEPTH X AXIS [u,t]	
Y	／	Y AXIS [u,t]	
Z	／	Z AXIS [u,t]	-25.25
C	／	C AXIS[/ANGLE]	
W	／	AUTO DEPTH MAX. TRAVEL [u,t]	
L	／	MC LAST STOP (1:ON)	
E	*	MC COND. No.	277
U	／	REMAIN AMOUNT [u,t]	
R	／	PATTERN RADIUS [u,t]	30
P	／	MODE/PATTERN	1111
A	／	ROT. ANGLE [deg]	
B	／	CIRCUIT SPEED [m.i/min]	
S	／	JUMP AMOUNT [code,u,t]	16
T	／	CYCLE [code,0.001sec]	3
F	／	SPEED [code,m,i/min]	10
I	／	CLAMP AMOUNT [u,t]	
H	／	TIME CONTROL TIME [min]	
M	／	START MC COND. No. (DF[%])	
D	／	START J. CYCLE [code,0.001sec]	
V	／	START MC REMAIN AMOUNT [u,t]	

↓

POS : Dispersed (G113) etc.

↓

AUX :MC control setting (G132)

Address	Attri.	Talk items	Set value
D	／	STARTING COND. No.	
H		τoff ADJ SETTING	
C	／	HQSF μSC DENSITY [g/l]	
Q	／	EXP P-PULSE	22
A	／	A-JUMP	32
E	／	F-JUMP	
K	／	STEP ANGLE [deg]	1.0
S		SUPER SPARK	
M	／	CYCLE JUMP MODE	1
R	／	NO.OF JUMP	10
U	／	JUMP AMOUNT [code,u,t]	15.0
V	／	CYCLE [code,0.001sec]	
W	／	NUMBER OF TIMES	
O	／	DISCHARGING JUMP (1:ON)	
P	／	SERVO JUMP AMOUNT [u,t]	
L	／	JUMP METHOD	
X	／	ARBITRARY JUMP X AXIS [u,t]	
Y	／	Y AXIS [u,t]	
Z	／	Z AXIS [u,t]	
T	／	SETTING FOR FINE MATTE FINISH	
B	／	POLARITY REVERSE CYCLE [min]	

↓

MC : Bottom stopped - complex (G102)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
X	／	MC DEPTH X AXIS [u,t]	
Y	／	Y AXIS [u,t]	
Z	／	Z AXIS [u,t]	-25.45
C	／	C AXIS[/ANGLE]	
R	*	ELECTRODE REDUCTION [u,t]	0.25
E	*	MODEL DATA No.	521
I	／	START OF PROCESS No.	4
J	／	END OF PROCESS No.	12
O	／	FINISH PROCESS No.	12
D	／	SIDE REMAIN AMOUNT COMP [%]	120
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	1111
A	／	ROT.ANGLE [deg]	
K	／	SIDE TAPER ANGLE [deg]	
M	／	BOTTOM SHAPE PATTERN	0
B	／	CORNER ANGLE [deg]	60.0
S	／	JUMP AMOUNT [code, u,t]	12
T	／	CYCLE [code,0.001sec]	3
F	／	SPEED [code,m.i/min]	10
U	／	TIME CONTROL MC START PROC.No.	
V	／	PROCESS CONTROL TIME [min]	

↓

POS : Dispersed (G113) etc.

M30 ;

9. THREAD CUTTING METHOD BY ORBITING

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9.2 Preparation before machining ········· 9 — 3

9.3 Pilot hole dimensions ········· 9 — 3

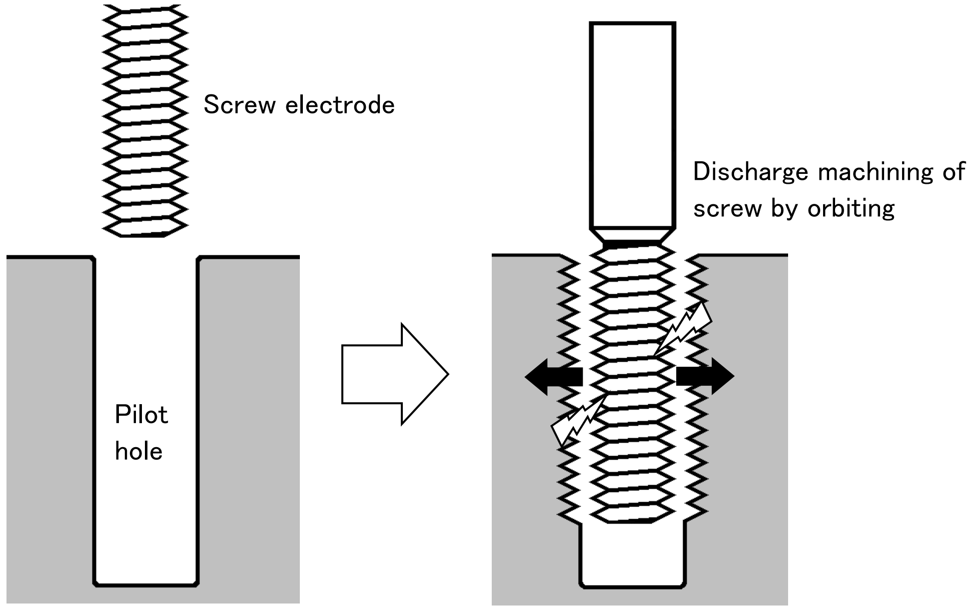
9.4 Pre-machined hole method by discharge ········· 9 — 4

9.5 Discharge thread cutting method by expanded orbit ········· 9 — 8

9.6 Finishing machining method by screw electrode cut out ········· 9 — 1 1

9.1 Overview

By using discharge machining by orbiting, female screw shape can be easily machined even on steel material after hardening or ultra-hard material.



When doing thread machining by discharge, it is necessary to open a pilot hole.
When it is difficult to make a pre-machined hole using cutting tools due to the effect of shape etc., refer to the explanation from next page onwards and open a pilot hole with discharge machining.

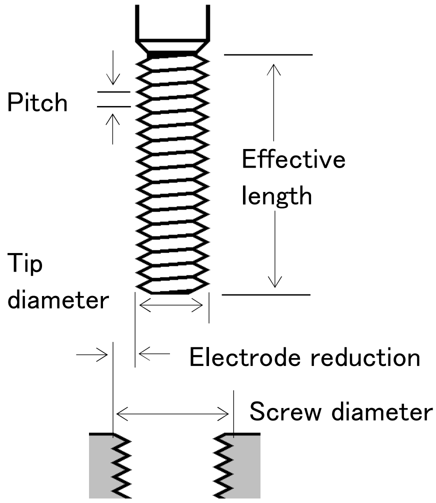
This chapter explains setup and programming method using the following examples.

Example of machining
Model data 6
Female Screw shape
Length 12.0mm
Surface roughness Rz10.0 μm (Ra1.7 μm)
Screw electrode : Tip diameter φ4.6mm
Effective length 12.0mm
Pitch length1.0mm
Pilot hole : Diameter φ5.0mm Depth 15.0mm
Electrode for pilot hole : Diameter φ4.0mm
Material Cu (in the case of iron workpiece)
CuW (in the case of tungsten carbide workpiece)

9.2 Preparation before machining

Purchase commercially available screw electrodes according to screw dimensions and workpiece material.

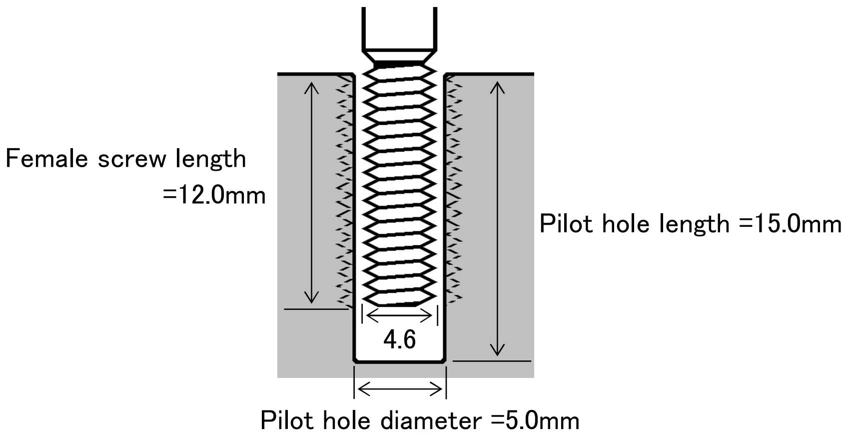
Workpiece material	Electrode material
Steel (including stainless)	Copper(Cu)
Tungsten carbide	Copper tungsten(CuW)



Tip diameter of screw electrode is made smaller than the regular screw diameter. Half of this contraction is referred to as electrode reduction (per-side) etc. It is necessary to enter this value in the program at a later stage. Besides, when machining screw shape in carbide material, pitch dimensions of screw mount may be required. Therefore, note it down in advance.

9.3 Pilot hole dimensions

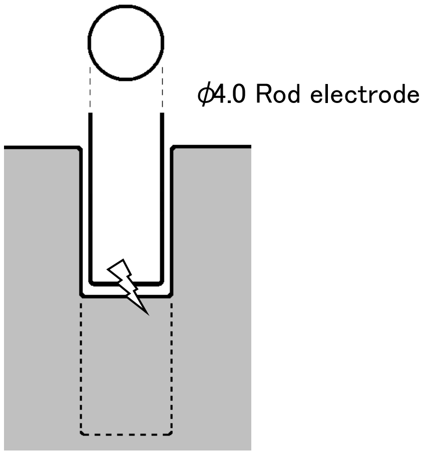
Machine the pilot hole at 3–5 mm depth from the female screw length to be machined.
It is recommended to machine the diameter of pilot hole to electrode tip electrode + 0.4mm or more.
If clearance between pilot hole and screw electrode is too narrow, discharge efficiency of machining debris will worsen, and discharge may become unstable. Furthermore, in order to prevent pilot hole side face and screw mount from discharging before when Z is axis lowered, it is necessary to select appropriate machining conditions of electrode reduction.



9.4 Pre-machined hole method by discharge

(a) Pre-machined hole with rod electrode

Although it takes some amount of machining time, it can be easily machined.



Separately use the machining programs according to the workpiece material.
From the next page onwards, sample programs for iron and carbide material are shown.

・Workpiece material: For Steel

Sample program

G132Q2A32F3M2R20U20. 0;

G103Z−15. 0R0. 5E121I4J10O10L16P1111S10T3F10;

G113X0Y0Z5. 0;

M30;

AUX : MC CONTROL SETTING (G132)

Address	Attri.	Talk items	Set value
D	/	STARTING COND. No.	
H	/	τoff ADJ SETTING	
C	/	HQSF μSC DENSITY [g/l]	
Q	/	EXP P-PULSE	2
A	/	A-JUMP	32
E	/	F-JUMP	
K	/	STEP ANGLE [deg]	
S	/	SUPER SPARK	
M	/	CYCLE JUMP MODE	2
R	/	NO. OF JUMP	20
U	/	JUMP AMOUNT [code, u, t]	20. 0
V	/	CYCLE [code, 0. 001sec]	
W	/	NUMBER OF TIMES	
O	/	DISCHARGING JUMP (1:ON)	
P	/	SERVO JUMP AMOUNT [u, t]	
…	…	…	

Set cycle jump amount that exceeds the top face of workpiece

MC : THROUGH (G103)

Address	Attri.	Talk items	Set value
N	/	ABS/INC (90/91)	
X	/	MC DEPTH X AXIS [u, t]	
Y	/	Y AXIS [u, t]	
Z	/	Z AXIS [u, t]	-15. 0
C	/	C AXIS [ANGLE]	
R	*	ELECTRODE REDUCTION [u, t]	0. 5
E	*	MODEL DATA No.	121
I	/	START OF PROCESS No.	4
J	/	END OF PROCESS No.	10
O	/	FINISH PROCESS No.	10
D	/	SIDE REMAIN AMOUNT COMP [%]	
H	/	BOTTOM REMAIN AMOUNT COMP [%]	
L	/	MC METHOD	16
P	/	PATTERN	1111
A	/	ROT. ANGLE [deg]	
B	/	SIDE TAPER ANGLE [deg]	
S	/	JUMP AMOUNT [code:u, t]	10
T	/	CYCLE [code:0. 001sec]	3
F	/	SPEED [code:m, i/min]	10
M	/	DEPTH CHANGE START PROC. No.	
U	/	ADD MC DEPTH [u, t]	
V	/	TIME CONTROL MC START PROC. No.	
W	/	PROCESS CONTROL TIME [min]	

Finish a premachined hole up to ϕ5.0.
0.5×2+0.4 = 5.0mm

For machine with Z-axis stabilizer, set 15.

Note.

According to electrode diameter and pilot hole diameter, adjust G103 item R: “electrode reduction”.

When discharge becomes unstable, increase G132 item H: “τoff ADJ SETTING”, or increase jump amount, or reduce jump frequency.

・Workpiece material: For Tungsten carbide
(Carbide machining circuit or Ultra-fine machining circuit is required)

Sample program

G132H9A32M2R20U20. 0;

G103Z−15. 0R0. 5E74I4J8O8L16P1111S10T3F10;

G113X0Y0Z5. 0;

M30;

AUX : MC CONTROL SETTING (G132)

Address	Attri.	Talk items	Set value
D	/	STARTING COND. No.	
H	/	τ off ADJ SETTING	9
C	/	HQSF μSC DENSITY [g/l]	
Q	/	EXP P-PULSE	
A	/	A-JUMP	32
E	/	F-JUMP	
K	/	STEP ANGLE [deg]	
S	/	SUPER SPARK	
M	/	CYCLE JUMP MODE	2
R	/	NO.OF JUMP	20
U	/	JUMP AMOUNT [code:u, t]	20.0
V	/	CYCLE [code:0.001sec]	
W	/	NUMBER OF TIMES	
O	/	DISCHARGING JUMP (1:ON)	
P	/	SERVO JUMP AMOUNT [u, t]	
…	…		

Set to the value where discharge stabilizes.

Set cycle jump amount that exceeds the top face of workpiece

MC : THROUGH (G103)

Address	Attri.	Talk items	Set value
N	/	ABS/INC (90/91)	
X	/	MC DEPTH X AXIS [u, t]	
Y	/	Y AXIS [u, t]	
Z	/	Z AXIS [u, t]	-15.0
C	/	C AXIS [ANGLE]	
R	*	ELECTRODE REDUCTION [u, t]	0.5
E	*	MODEL DATA No.	74
I	/	START OF PROCESS No.	4
J	/	END OF PROCESS No.	8
O	/	FINISH PROCESS No.	8
D	/	SIDE REMAIN AMOUNT COMP [%]	
H	/	BOTTOM REMAIN AMOUNT COMP [%]	
L	/	MC METHOD	16
P	/	PATTERN	1111
A	/	ROT. ANGLE [deg]	
B	/	SIDE TAPER ANGLE [deg]	
S	/	JUMP AMOUNT [code:u, t]	10
T	/	CYCLE [code:0.001sec]	3
F	/	SPEED [code:m, i/min]	10
M	/	DEPTH CHANGE START PROC. No.	
U	/	ADD MC DEPTH [u, t]	
V	/	TIME CONTROL MC START PROC. No.	
W	/	PROCESS CONTROL TIME [min]	

Finish a premachined hole up to φ5.0.
0.5×2＋0.4 = 5.0mm

For machine with Z-axis stabilizer, set 15.

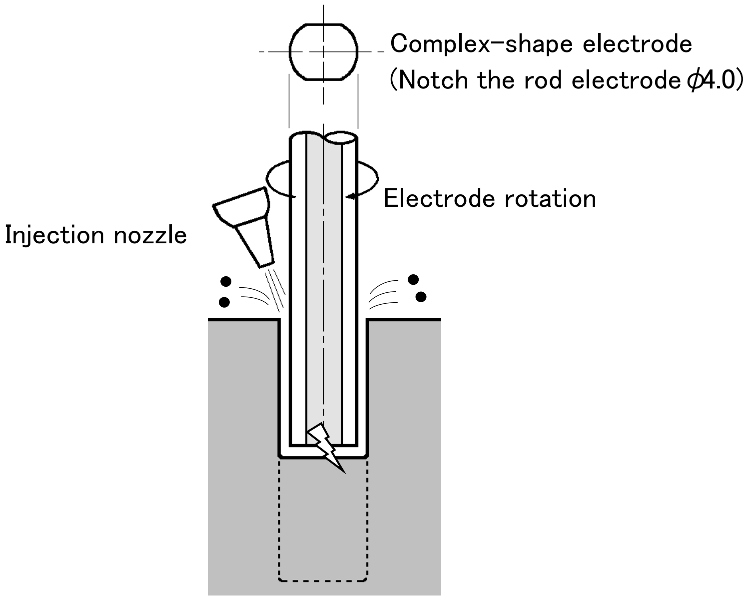
Note.

When discharge becomes unstable, increase G132 item H: " τ off ADJ SETTING", or increase jump amount, or reduce jump frequency.

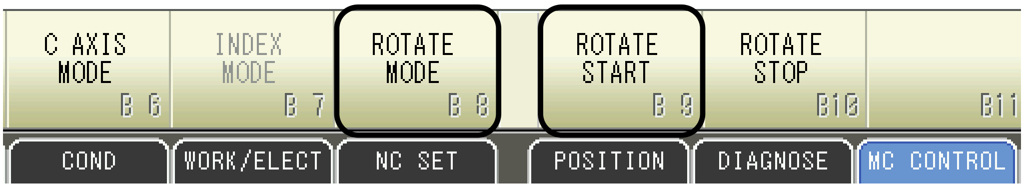
When machining carbide material, use nozzle flushing of dielectric fluid as and when required.

(b) Pre-machined hole with complex-shape electrode

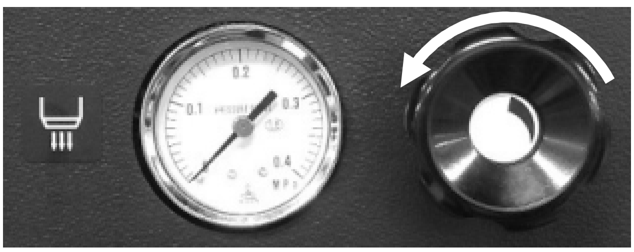
In the machine equipped with MA HEAD (Optional) or electrode rotary unit (Optional), by jointly using complex-shape electrode and injection nozzle, jump frequency T can be set longer than the usual. For details of electrode rotary unit, refer to Chapter 11 “PREMACHINED HOLE MACHINING BY PIPE ELECTRODE”.
Rotating the complex-shape electrode equipped with notch and injecting dielectric fluid in the clearance helps in efficient discharge of machining debris. Machining time changes depending on how dielectric fluid is injected. Therefore, adjust the position and angle of nozzle while observing the discharge state.



Operate MA HEAD with [MC CONTROL (F11)]-ROTARY HEAD (L3)] screen.
After changing to rotation mode with the ROTATE MODE [B8] button, pressing the ROTATE START [B9] button will rotate the spindle. Adjust spindle speed while observing the discharge status of machining debris.

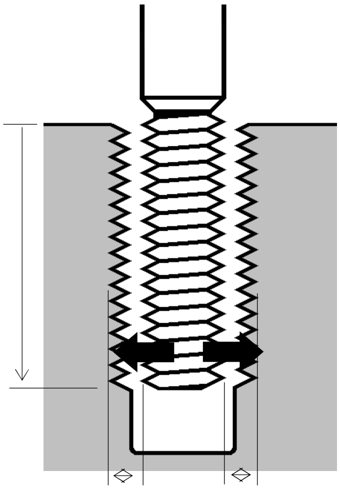


Connecting the injection nozzle to coupler, and opening the nozzle when the fluid circulation button is on will inject the dielectric fluid.



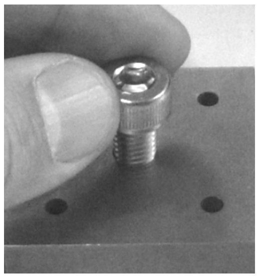
9.5 Discharge thread cutting method by expanded orbit

Refer to the following description, create program and do Setup, and then perform the machining.



Workpiece coordinate on Z axis = −12.0mm

Orbit radius 0.7mm (G103 item R:Electrode reduction)



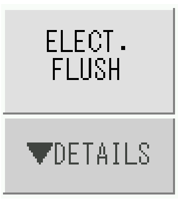
After completing the machining, provisionally tighten the screw without removing electrode and workpiece, and check the finishing dimension. When screws cannot be tighten properly, measure the tip diameter of screw electrode with micro meter. Add half of the worn out dimension to G103 item R:electrode reduction, and run the program once again.

When machining carbide material, electrode wear becomes large, and therefore ensure to check the finishing dimensions. Refer to 9.6 “Finishing machining method by screw electrode cut out” for getting dimensional accuracy in finish machining.

When there is a hole in the center of screw electrode, by injecting dielectric fluid from this hole, you can set longer jump frequency.

In the MA/MR head specifications machine, by pressing the [ELECT. FLUSH] button, you can inject dielectric fluid from the chuck hole of spindle. Therefore, use it as and when required.

※Holder having a through hole in the center will be required.



MC CONTROL[F8]-
MC OPERATE SWITCH[L1]
“ELECT. FLUSH” button

Holder with a through hole

Hole

Colette

・Workpiece material: For Steel

Sample program

```
G132Q2A2M2R20U20. 0;
G103Z－12.R0. 7E121 I105 J10O10D120L16P1111S7T4F6
G113X0Y0Z5. 0;
M30;
```

AUX : MC CONTROL SETTING (G132)

Address	Attri.	Talk items	Set value
D	/	STARTING COND. No.	
H	/	τoff ADJ SETTING	
C	/	HQSF μSC DENSITY [g/l]	
Q	/	EXP P-PULSE	2
A	/	A-JUMP	2
E	/	F-JUMP	
K	/	STEP ANGLE [0.001 deg]	
S	/	SUPER SPARK	
M	/	CYCLE JUMP MODE	2
R	/	NO.OF JUMP	20
U	/	JUMP AMOUNT [code, u, t]	20. 0
V	/	CYCLE [code, 0.001sec]	
W	/	NUMBER OF TIMES	
O	/	DISCHARGING JUMP (1:ON)	
P	/	SERVO JUMP AMOUNT [u, t]	
…	…		

Set cycle jump amount that exceeds the top face of workpiece

MC : THROUGH (G103)

Address	Attri.	Talk items	Set value
N	/	ABS/INC (90/91)	
X	/	MC DEPTH X AXIS [u, t]	
Y	/	Y AXIS [u, t]	
Z	/	Z AXIS [u, t]	-12. 0
C	/	C AXIS [ANGLE]	
R	*	ELECTRODE REDUCTION [u, t]	0. 7
E	*	MODEL DATA No.	121
I	/	START OF PROCESS No.	105
J	/	END OF PROCESS No.	10
O	/	FINISH PROCESS No.	10
D	/	SIDE REMAIN AMOUNT COMP [%]	120
H	/	BOTTOM REMAIN AMOUNT COMP [%]	
L	/	MC METHOD	16
P	/	PATTERN	1111
A	/	ROT. ANGLE [deg]	
B	/	SIDE TAPER ANGLE [deg]	
S	/	JUMP AMOUNT [code:u, t]	7
T	/	CYCLE [code:0.001sec]	4
F	/	SPEED [code:m, i/min]	6
M	/	DEPTH CHANGE START PROC. No.	
U	/	ADD MC DEPTH [u, t]	
V	/	TIME CONTROL MC START PROC. No.	
W	/	PROCESS CONTROL TIME [min]	

Screw dia. ϕ6.0
$0.7 \times 2 + 4.6 = 6.0$mm

Model data 6 is also useful when targeting lower wear

With +100, orbit is turned off when Z axis is lowered.

Increase the numerical value when emphasizing finishing of the side face

When flushing is used, extend jump frequency T

Note.

When discharge becomes unstable, increase G132 item H: “ τ off ADJ SETTING”, or increase jump amount, or reduce jump frequency.

・Workpiece material: For Tungsten carbide

(Carbide machining circuit or Ultra-fine machining circuit is required)

Sample program

```
G132H9A2M2R20U20.0;
G103Z−12.0R0.7E74I105J8O8D120L16P1111S7T4F6;
G113X0Y0Z5.0;
M30;
```

AUX : MC CONTROL SETTING (G132)

Address	Attri.	Talk items	Set value
D	/	STARTING COND. No.	
H	/	τ off ADJ SETTING	9
C	/	HQSF μSC DENSITY [g/l]	
Q	/	EXP P-PULSE	
A	/	A-JUMP	2
E	/	F-JUMP	
K	/	STEP ANGLE [0.001 deg]	
S	/	SUPER SPARK	
M	/	CYCLE JUMP MODE	2
R	/	NO.OF JUMP	20
U	/	JUMP AMOUNT [code, u, t]	20.0
V	/	CYCLE [code, 0.001sec]	
W	/	NUMBER OF TIMES	
O	/	DISCHARGING JUMP (1:ON)	
P	/	SERVO JUMP AMOUNT [u, t]	
…	…		

Set to the value where discharge stabilizes.

Set cycle jump amount that exceeds the top face of workpiece

MC : THROUGH (G103)

Address	Attri.	Talk items	Set value
N	/	ABS/INC (90/91)	
X	/	MC DEPTH X AXIS [u, t]	
Y	/	Y AXIS [u, t]	
Z	/	Z AXIS [u, t]	−12.0
C	/	C AXIS [ANGLE]	
R	*	ELECTRODE REDUCTION [u, t]	0.7
E	*	MODEL DATA No.	74
I	/	START OF PROCESS No.	105
J	/	END OF PROCESS No.	8
O	/	FINISH PROCESS No.	8
D	/	SIDE REMAIN AMOUNT COMP [%]	120
H	/	BOTTOM REMAIN AMOUNT COMP [%]	
L	/	MC METHOD	16
P	/	PATTERN	1111
A	/	ROT. ANGLE [deg]	
B	/	SIDE TAPER ANGLE [deg]	
S	/	JUMP AMOUNT [code:u, t]	7
T	/	CYCLE [code:0.001sec]	4
F	/	SPEED [code:m, i/min]	6
M	/	DEPTH CHANGE START PROC. No.	
U	/	ADD MC DEPTH [u, t]	
V	/	TIME CONTROL MC START PROC. No.	
W	/	PROCESS CONTROL TIME [min]	

Screw dia. ϕ6.0
0.7×2+4.6 = 6.0mm

With +100, orbit is turned off when Z axis is lowered.

Increase the numerical value when emphasizing finishing of the side face

When flushing is used, extend jump frequency T

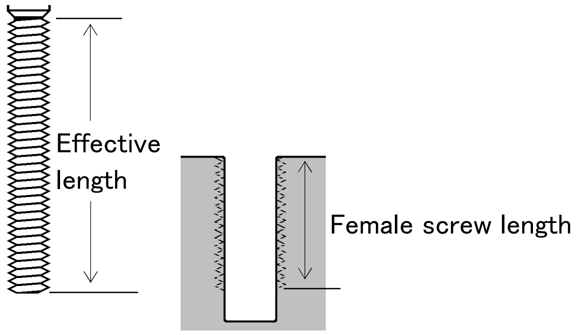
Note.

When discharge becomes unstable, increase G132 item H: " τ off ADJ SETTING", or increase jump amount, or reduce jump frequency.

9.6 Finishing machining method by screw electrode cut out

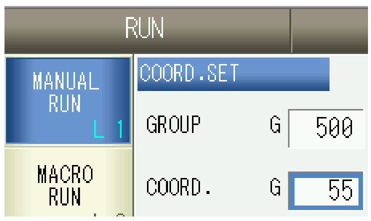
During female screw machining of carbide material, if you cannot get satisfactory accuracy with electrode wear, you may cut out screw electrode and do roughing and finishing machining. As shown below, if the discharged places are separated, phase of screw mount can be machined together. When cutting using wire EDM, do not remove screw electrode from the holder.

①Purchase screw electrode having more than twice of effective length of female screw length.

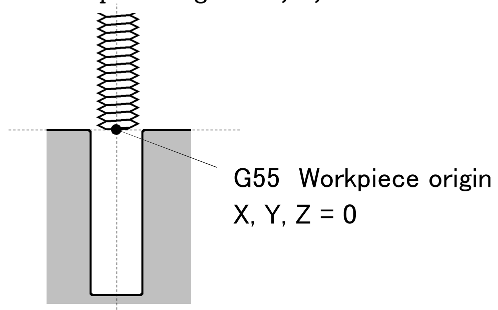


②Install workpiece where pre-machined hole is already made.

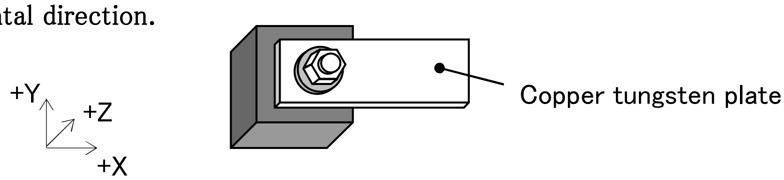
③Change workpiece coordinates (example: G55) for screw machining, and perform centering. After that, set the center position of pilot hole to the workpiece origin of X, Y, Z axis.



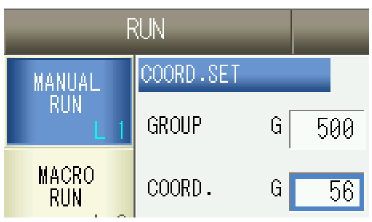
RUN[F2]-COORD. G



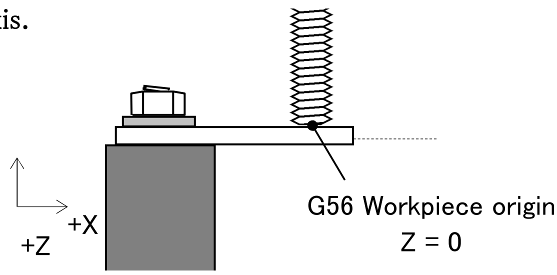
④Install it keeping the copper tungsten plate (edge material is also fine) protruded in the horizontal direction.



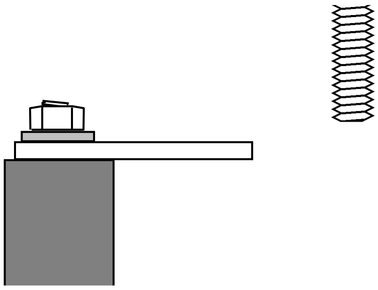
⑤Change to the workpiece coordinate system (example: G56) of cutting out, let the screw electrode subject to touch sensing on the top side of copper tungsten plate, and set this position as workpiece origin of Z axis.



RUN[F2]-COORD. G

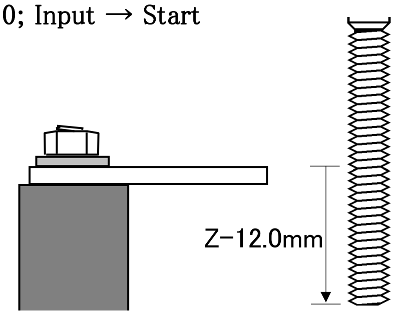


⑥Move the screw electrode to a position that is apart from the copper tungsten plate.

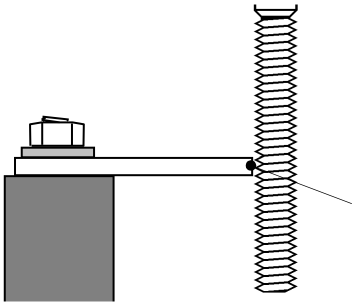


⑦Go to RUN [F2]-MDI RUN [L3] screen (select MDI from the RUN screen), and lower the Z axis by female screw length only.

Example: Z-12.0; Input → Start

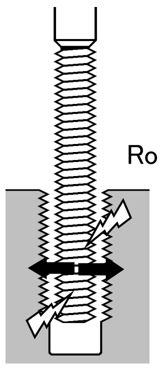


⑧Perform touch sensing on the side face of screw electrode, and set the workpiece origin of X and Y axis.



⑨Change to the workpiece coordinate system (example: G55) for thread cutting, and perform rough machining.

RUN[F2]-COORD. G



Sample program

G132H9A2M2R20U20. 0;

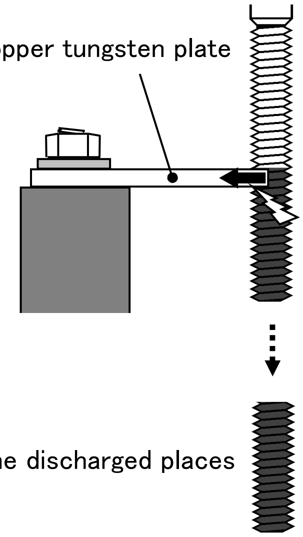
G103Z−12. 0R0. 7E74I105J8O8D120L16P1111S7T4F6;

G113W55X0Y0Z5. 0;

M30;

With the position model, specify workpiece coordinate system G55.

⑩Change to the workpiece coordinate system (example: G56) for cut out, execute the following program, and cut the tip of screw electrode.



Sample program for electrode cut out (Carbide machining circuit or Ultra-fine machining circuit is required)

```
G132H9;
G100X−10.0E7315S3T8F4;
G113W56X2.0Y0Z−12.0;
M30;
```

With the position model, specify workpiece coordinate system G56.

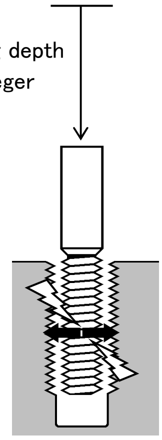
AUX : MC CONTROL SETTING (G132)

Address	Attri.	Talk items	Set value
D	/	STARTING COND. No.	
H	/	τoff ADJ SETTING	9 ← Set to the value where discharge stabilizes.
…	…		

MC : THROUGH (G103)

Address	Attri.	Talk items	Set value
N	/	ABS/INC (90/91)	
X	/	MC DEPTH X AXIS [u, t]	-10.0 ← Machining in -X axis direction
…	/		
E	*	MC CONDITION No.	7315 ← Electrode dressing condition
…	/		
S	/	JUMP AMOUNT [code:u, t]	3
T	/	CYCLE [code:0.001sec]	8 ← Jump setting for lateral discharge
F	/	SPEED [code:m, i/min]	4
…	…		

⑪Perform finish machining with workpiece coordinates (example: G55) for thread cutting. Lower machining depth Z axis in the integer multiple of pitch will align the pitch.



Finishing

Calculation of machining depth Z axis

Female screw length :12.0mm

Screw pitch : 1.0mm

Corrected amount of MC depth :12.0mm = 1.0mm × 12 threads

MC depth for Z axis :

− (female screw depth + corrected amount) = −24.0mm

Sample program

```
G132H9A2M2R20U20.0;
G103Z−24.0R0.7E74I105J8O8D120L16P1111S7T4F6;
G113W55X0Y0Z5.0;
M30;
```

With the position model, specify workpiece coordinate system G55.

MC : THROUGH (G103)

Address	Attri.	Talk items	Set value	
N	/	ABS/INC (90/91)		
X	/	MC DEPTH X AXIS [u,t]		
Y	/	Y AXIS [u,t]		
Z	/	Z AXIS [u,t]	-24.0	= −12.0−12.0
C	/	C AXIS [ANGLE]		
R	*	ELECTRODE REDUCTION [u,t]	0.7	
E	*	MODEL DATA No.	74	
I	/	START OF PROCESS No.	105	
J	/	END OF PROCESS No.	8	
O	/	FINISH PROCESS No.	8	
D	/	SIDE REMAIN AMOUNT COMP [%]	120	
H	/	BOTTOM REMAIN AMOUNT COMP [%]		
L	/	MC METHOD	16	
P	/	PATTERN	1111	
A	/	ROT. ANGLE [deg]		
B	/	SIDE TAPER ANGLE [deg]		
S	/	JUMP AMOUNT [code:u,t]	7	
T	/	CYCLE [code:0.001sec]	4	
F	/	SPEED [code:m,i/min]	6	
M	/	DEPTH CHANGE START PROC. No.		
U	/	ADD MC DEPTH [u,t]		
V	/	TIME CONTROL MC START PROC. No.		
W	/	PROCESS CONTROL TIME [min]		

10. CONTOURING

A programming of contour must completely be understood in executing contour machining. This manual, however, does not cover it. Use the automatic programming training course.

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10.3 Program examples ······ 10 − 8

10.4 Setting finish process (machining conditions and offset) ······ 10 − 10

10.1 General description

In contouring, a contour is generated by rotating the electrode under the control of a program.
The use of an electrode that is run-out or has poor accuracy cannot ensure good machining. Therefore, the electrode must be dressed to eliminate run-out. For the electrode dressing, see section 10.2.
A special profile electrode that has taper at the side is dressed by a primary electrode having the same sectional profile, made by a wire electric discharge machine (Figures 1 and 2). In addition, an electrode having a sphere at the leading end can be dressed by a bar as primary electrode (figure 3).
The optimum material for the primary electrode is copper tungsten.

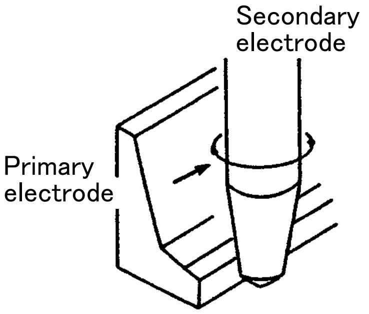


Figure 1

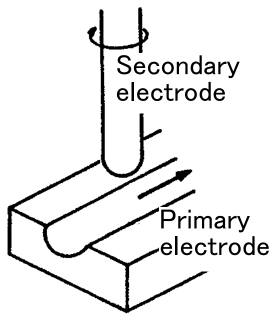


Figure 2

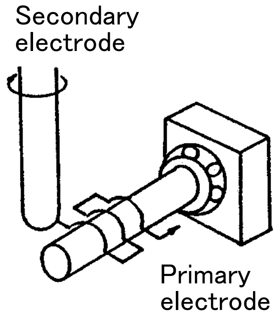


Figure 3

Generally, in a contouring, side machining is fast and bottom machining is difficult. This is because the rotation speed in the electrode center is “0” and machining does not progress if chip is caught in the electrode center. It is recommended that, in machining a workpiece that has a wide bottom, the workpiece is at first cut by a machine and then it is hardened, or an electrode is formed by a wire electrical discharge machine (Figure 4).

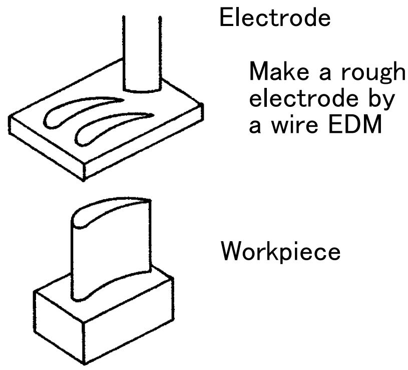
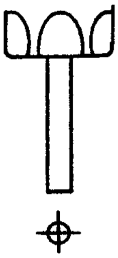
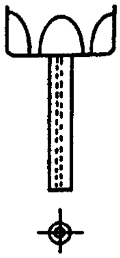
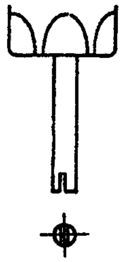
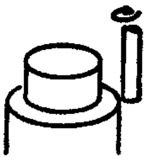
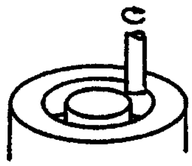
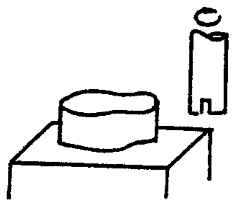
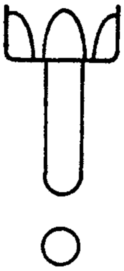
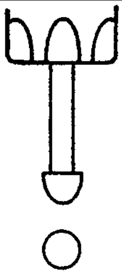
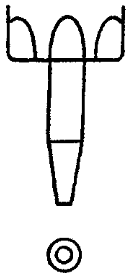
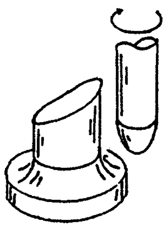
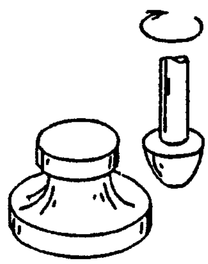
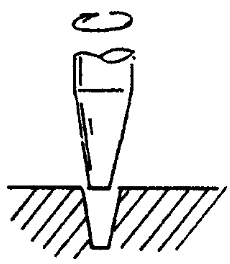


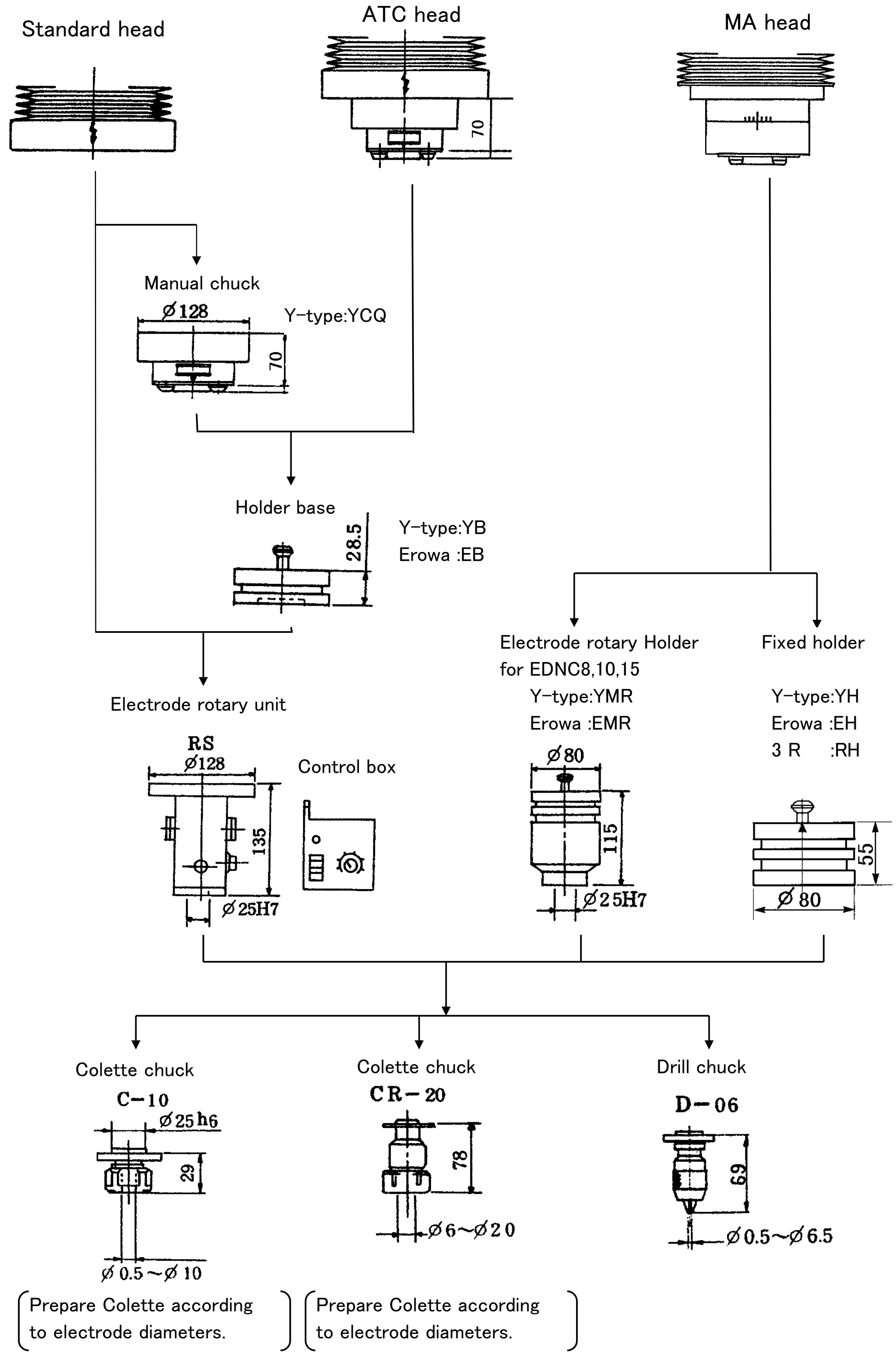
Figure 4

If contouring is unavoidable, the use of a pipe electrode or an electrode having slits can reduce chip jamming .

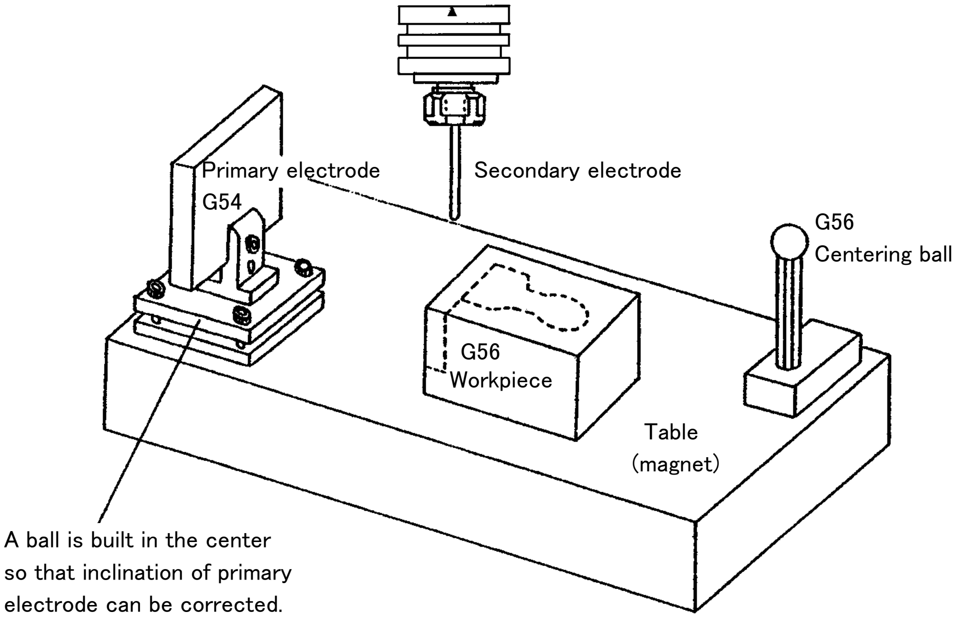
Typical electrode used for contouring

	Solid bar electrode	Pipe electrode	Slit electrode
Profile			
Application	General contouring 	Fluid processing is possible from electrode side. Suitable for groove or bottom machining. Thin pipe wall is much Consumed. 	Suitable for bottom machining that does not require fluid processing. 
	R electrode	Stepped electrode	Taper electrode
Profile			
Application	Suitable for a fillet Or chamfer portion of Punch. 	Suitable for a recess Of punch. 	Suitable for taper Groove or rib. 

Tooling plan for contouring ※Additionally, there are a lot of tools.
Refer to each catalog for details.

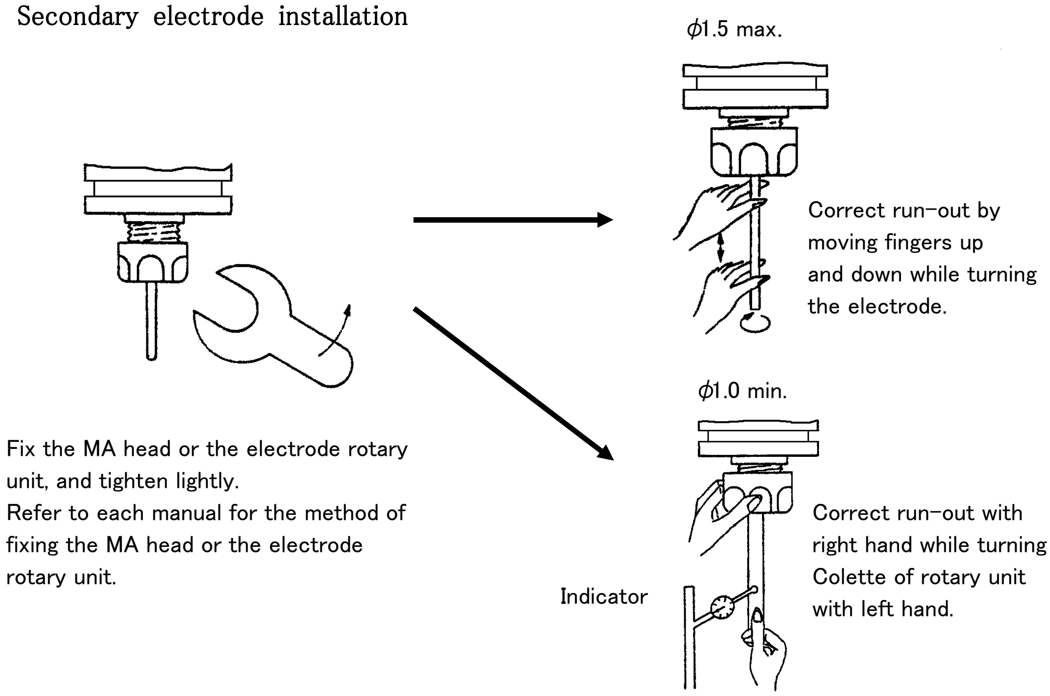


Setup example



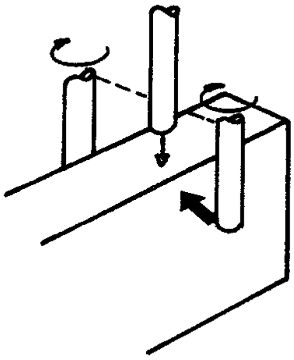
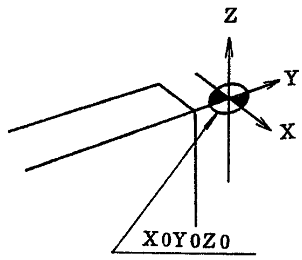
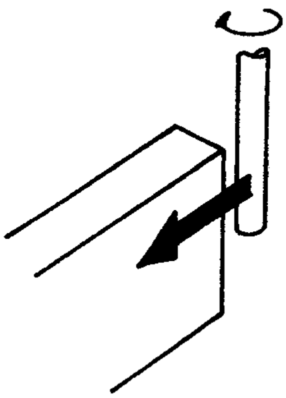
a. Install the primary electrode and adjust parallelism and verticality.
b. Adjust parallelism of workpiece.
c. Install a centering ball in the traverse range.
d. Use the coordinate setting for electrode dressing.

Secondary electrode installation



10.2 Electrode dressing

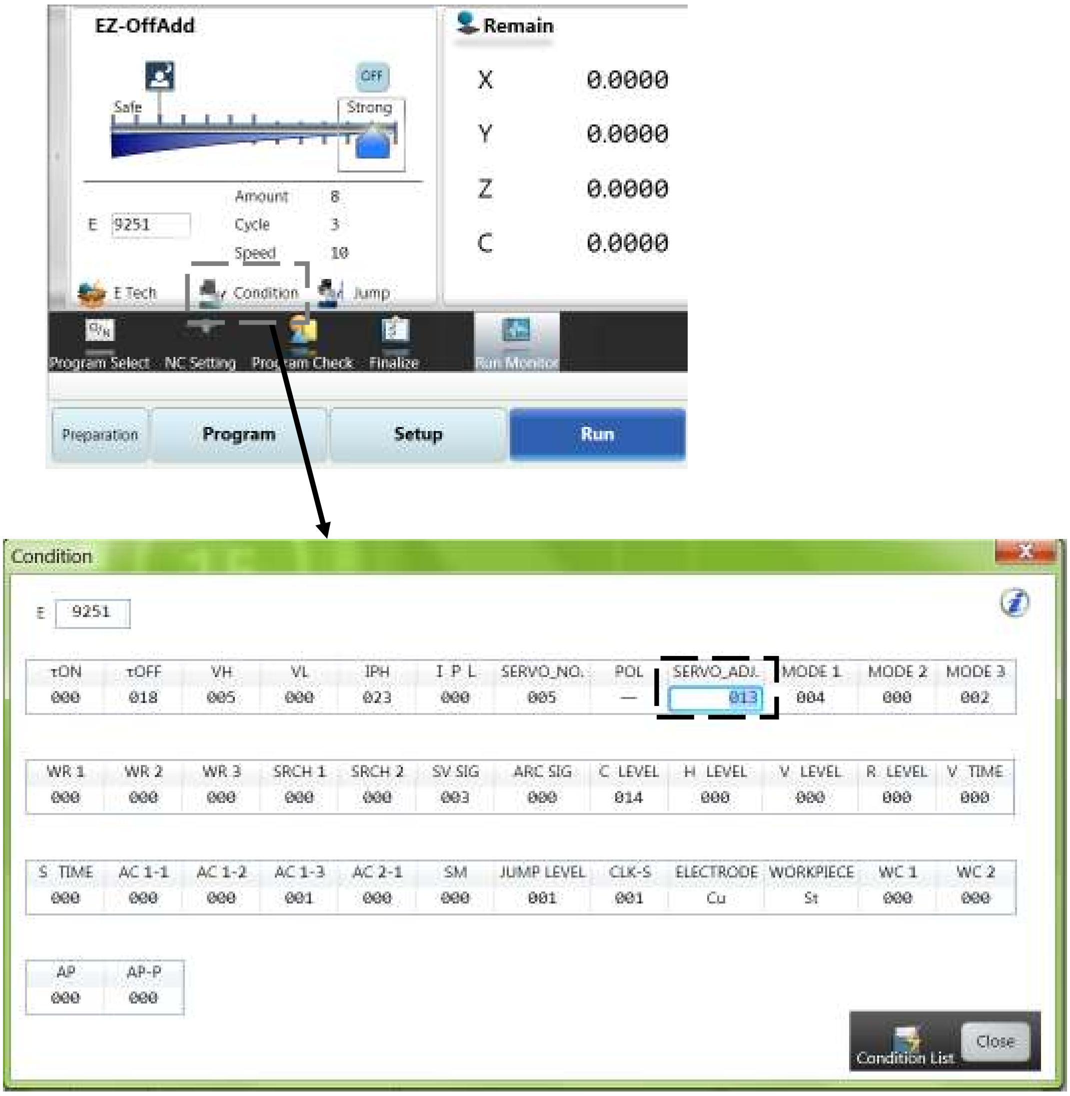
The electrode will run out immediately after it is installed on the Colette chuck. Dressing eliminates this and also makes electrode Diameter smaller. There are many methods for dressing. In any case, the electrode is rotated during dressing. Here described is a method that uses horizontal servo. At first, measure the thickness “T” of primary electrode with micrometer etc.

		Program	
Setting coordinate system	（G５４）  Primary electrode thickness: T	G54 G84 Z−20.0 G86 X(T + Electrode dia. + 10.) Z−10.0 G92 X(−T/2) Z1. M30 The point where electrode comes in contact with end face is “0” in Y axis.	Setting G54 coordinate System. 
Electrode dressing		G54 G90G00 X+(Note1) Y0 Z−(length) M26 G01 E3308 Y−10.0 M19 G00 Y0 X+(Note2) G01 E3307 Y−11.0 M19 G00 Y0 Z30.0 M30	Revolution: approx 200 rpm Note1: Desired secondary electrode dia./2 + gap + finish allowance (20 μm) (Gap=0.03mm) Note2: Desired secondary electrode dia./2 + gap (Gap=0.03mm) *Set τ off ADJ to “3”. (creen)

Eliminate run-out by dressing by 0.05 mm since a little run-out remains even after manual run-out correction.

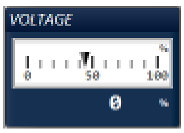
Reduced SERVO ADJ. setting with electrode run-out does not generate a true circle of electrode. Adjust the SERVO ADJ. setting in the following manner.

(Note1) SERVO ADJ.: Condition at Run mode.



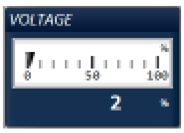
Make decision by observing voltage during machining.

○ Good



Good if machining voltage exceed 30.

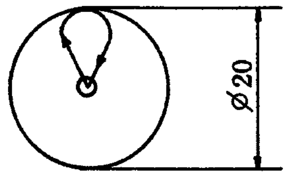
× No good



Use a larger SERVO ADJ. setting if machining voltage is below 25.

10.3 Program examples

Assume that an inner diameter machining is executed as shown to the right.



[Program sample for one operation]

```
O20;                          Program No.
G959;                         Contouring mode on
G90G00X0Y0;                   Positioning
Z-30;                         Z axis positioning
M26E3209;                     Machining ON
G01G42D1X-2949Y4615;          Offset RH direction
G02X0Y10000I2949J1885;        CW direction
J-10000;
X2949Y4615J-3500;
G01G40X0Y0;                   Offset cancel
G958;                         Contouring mode cancel
M30;                          End
```

[Program example for four operations]

(Main program)

```
O100;
G959;
G90G00X0Y0;
Z-30;
M98O20E3213D1;
M98O20E3212D2;
M98O20E3210D3;
M98O20E3209D4;
G958;
M30;
```

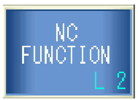
(Subprogram)

```
O20;
M26;
G90G01G42X-2949Y4615;
G02X0Y10000I2949J1885;
J-10000;
X2949Y4615J-3500;
G01G40X0Y0;
M99;
```

[Precautions on operating program]

1. Check or set a plane (G17,G18,G19) when using the offset.
   (Usually, G17 (XY Plane) has been set.)
2. Offset cannot be active by the G83. Use the G01.
3. Machining starts by the M26. So insert it before G01.
4. When offset is used, positioning (G00) is not executed if offset is not cancelled.
5. Although both linear and circular interpolations can be specified in either absolute or incremental mode, the center point I, J, K must be specified in incremental value as viewed from the start point of circular arc.
6. Simultaneous 3-axis can be specified.
7. Up to 99 offsets, D1 to D99, can be used.
8. Take care of electrode movement, though offset value may be changed during machining.

[Dry run feed]

Activation of DRY RUN mode with 

mode can stop machining and increase traverse speed even if the feed rate (G01 to G 03) is set.
The traverse speed during dry run is that selected on the portable operation panel (RAPID, HIGH, MIDDLE, or LOW).

Note 1: The dry run is used to check a program.
Note 2: The rapid feed (G00) command is always active regardless of dry run ON/OFF, or machining ON/OFF (M26, M27).
Note 3: Keep electrode away from the workpiece properly when the dry run is used.
Note 4: Deactivate the dry run mode immediately after use. The electrode will be damaged if machining starts with dry run mode active.

10.4 Setting finish process (machining condition and offset)

Contouring has not been registered in the model data. Accordingly, the machining condition and offset values must be calculated.

[How to see finish process sheet]

Finish process	40 μ mRz → 10 μ mRz				
Roughness	40 μ	24 μ	18 μ	13 μ	10 μ
M/C cond. E	3215	3213	3212	3210	3209
Offset value	D/2 + 74 μ m	d_1/2 + 54 μ m	d_2/2 + 34 μ m	d_3/2 + 21 μ m	d_4/2 + 15 μ m
Feed rate	·	10	10	10	10

Final gap

Varies with the machining rate.
(See page 10-17)

Feed rate per minute. Estimated machining time can be obtained from the given circumferential length to be machined (Unit: mm/min)。
This rate slows remarkably when the bottom is machined.

D: Initial electrode dia.
(measured by micrometer or centering ball)
d: Electrode dia. at the end of previous process.
(Varies with the circumferential length to be machined)

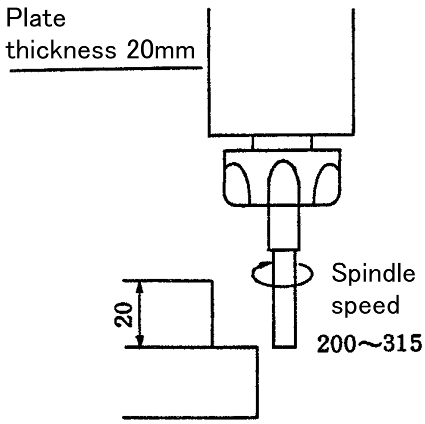
Machining condition E: Use E3205 to E3217 in contouring.

Roughness: Side face roughness in μ mRz.

Finish process: Process table with machining start condition E3215 and end condition E3209.

[Finish process example 1]

Initial machining condition : E3216 (46 μ mRz)
Electrode diameter used : φ 2 or more



Finish process	46 μ mRz→18 μ mRz		
Roughness	46	32	18
M/C cond. E	3216	3214	3212
Offset value	D/2 + 121	d_1/2 + 61	d_2/2 + 26
Feed rate		10	10

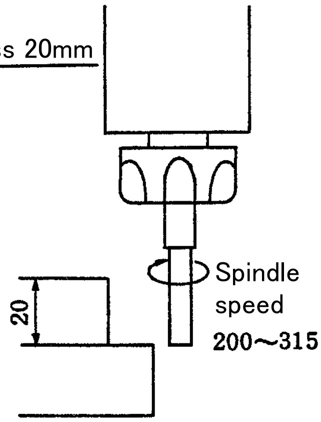
Finish process	46 μ mRz → 10 μmRz				
Roughness	46	32	18	13	10
M/C cond. E	3216	3214	3212	3210	3209
Offset value	D/2 + 129	d_1/2 + 69	d_2/2 + 34	d_3/2 + 21	d_4/2 + 15
Feed rate		10	10	10	10

Finish process	46 μ mRz → 5 μ mRz							
Roughness	46	32	18	13	9	6	5	5
M/C cond. E	3216	3214	3212	3210	3208	3206	3205	3205
Offset value	D/2 + 155	d1/2 + 95	d2/2 + 60	d3/2 + 40	d4/2 + 27	d5/2 + 19	d6/2 + 14	d7/2 + 12
Feed rate		10	10	10	10	10	10	10

[Finish process example 2]

Initial machining condition : E3215 (40 μ mRz)
Electrode diameter used : φ 2 or more

Finish process	40 μ mRz→18 μ mRz		
Roughness	40	24	18
M/C cond. E	3215	3213	3212
Offset value	D/2 + 106	d_1/2 + 46	d_2/2 + 26
Feed rate		10	10

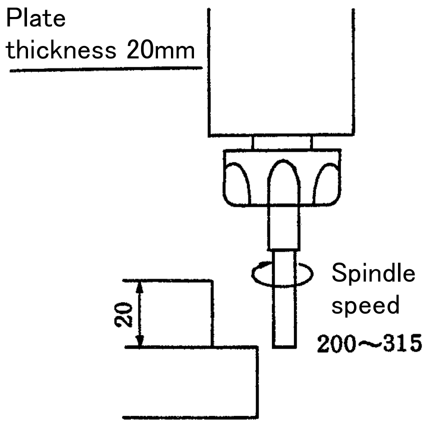


Finish process	40 μ mRz → 10 μ mRz				
Roughness	40	24	18	13	10
M/C cond. E	3215	3213	3212	3210	3209
Offset value	D/2 + 94	d_1/2 + 54	d_2/2 + 34	d_3/2 + 21	d_4/2 + 15
Feed rate		10	10	10	10

Finish process	40 μ mRz → 5 μ mRz							
Roughness	40	24	18	13	9	6	5	5
M/C cond. E	3215	3213	3212	3210	3209	3206	3205	3205
Offset value	D/2 + 140	d_1/2 + 100	d_2/2 + 60	d_3/2 + 40	d_4/2 + 27	d_5/2 + 19	d_6/2 + 14	d_7/2 + 12
Feed rate		10	10	10	10	10	10	10

[Finish process example 3]

Initial machining condition : E3214 (32 μ mRz)
Electrode diameter used : ϕ 2 or more



Finish process	32 μ mRz→18 μ mRz		
Roughness	32	24	18
M/C cond. E	3214	3213	3212
Offset value	D/2 + 76	d_1/2 + 46	d_2/2 + 26
Feed rate		10	10

Finish process	32 μ mRz → 10 μ mRz				
Roughness	32	24	18	13	10
M/C cond. E	3214	3213	3212	3210	3209
Offset value	D/2 + 84	d_1/2 + 54	d_2/2 + 34	d_3/2 + 21	d_4/2 + 15
Feed rate		10	10	10	10

Finish process	32 μ mRz → 5 μ mRz							
Roughness	32	24	18	13	9	6	5	5
M/C cond. E	3214	3213	3212	3210	3209	3206	3205	3205
Offset value	D/2 + 130	d_1/2 + 100	d_2/2 + 60	d_3/2 + 40	d_4/2 + 27	d_5/2 + 19	d_6/2 + 14	d_7/2 + 12
Feed rate		10	10	10	10	10	10	10

[Preparation of machining process sheet]

The following factors should be determined:

a. Initial machining condition
b. Finish allowance remained
c. Finish roughness
d. Circumferential length to be machined

– Machining example –

The finish allowance remained after pre-mill is 0.3mm per side.
Finish roughness is 15μRz.
Circumferential length is approx 100mm.

– Machining process example –

A: Machining condition – from GAP table (See page 10-15)

Machining condition E	Roughness	GAP	Additional M/C amount①
3216	46		40
3215	40		35
3214	32		30
3213	24		20
3212	18		15
3211	15	20	

Final gap

As the finish roughness is 15μmRz, the process sheet should be prepared so that machining ends under machining condition E3211.

Additional M/C amount

a) E3211 d/2 + Final GAP + 15 → A

b) E3212 d/2 + (A) + 20 → B

c) E3213 d/2 + (B) + 30 → C

d) E3214 d/2 + (C) + 35 → D

e) E3215 d/2 + (D) + 40 → E

f) E3216 d/2 + (E) + Roughness → F

The process sheet should be prepared setting from smaller condition.

46μmRz → 15μmRz					
46	40	32	24	18	15
3216	3215	3214	3213	3212	3211
D/2	d/2	d/2	d/2	d/2	d/2
+	+	+	+	+	+
205	160	120	85	55	35
F	E	D	C	B	A

Rougher machining conditions may be omitted (additional M/C amount ②,③).

Machining condition – GAP table

Machining condition E	roughness μmRz	Final GAP μm	Additional M/C amount ① μm	Additional M/C amount ② μm	Additional M/C amount ③ μm
3216	46	50	40	Initial condition ↓	
3215	40	40	35	60	Initial Condition ↓
3214	32	35	30	↓	40
3213	24	30	20	35	20
3212	18	26	15	↓	↓
3211	15	20	10	13	13
3210	13	18	6	6	↓
3209	10	15	4	4	8
3208	9	14	3	3	↓
3207	7	13	3	3	5
3206	6	12	3	3	3
3205	5	12			

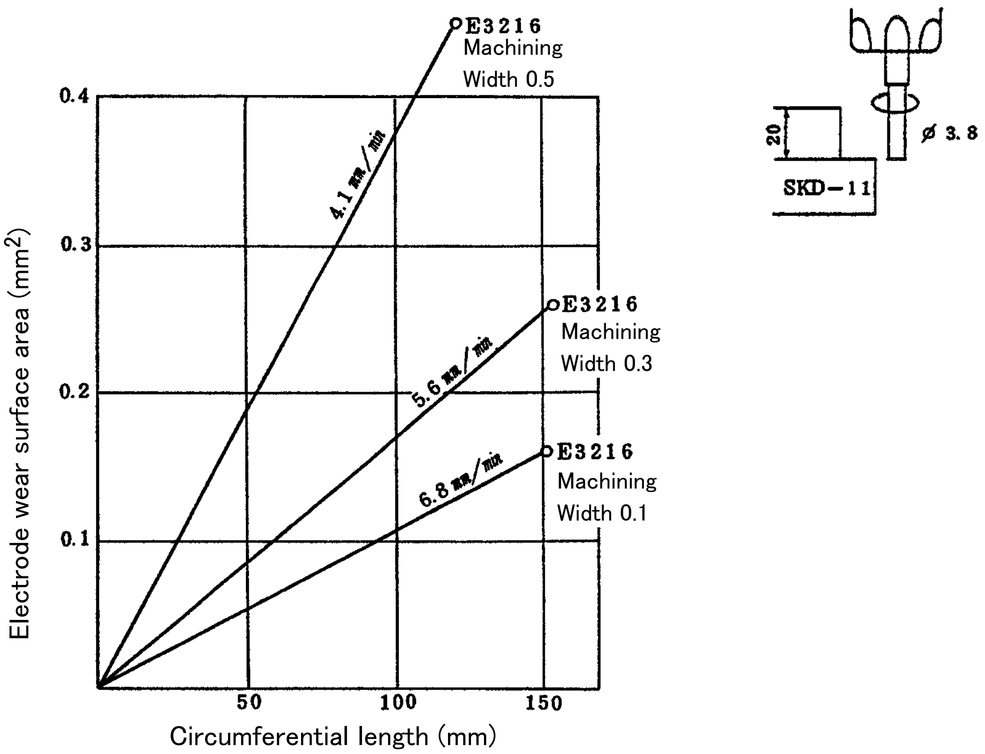
Electrode wear to circumferential length

Example : circumferential length 150 mm
Electrode diameter ϕ3.8
Depth of machining 20 mm

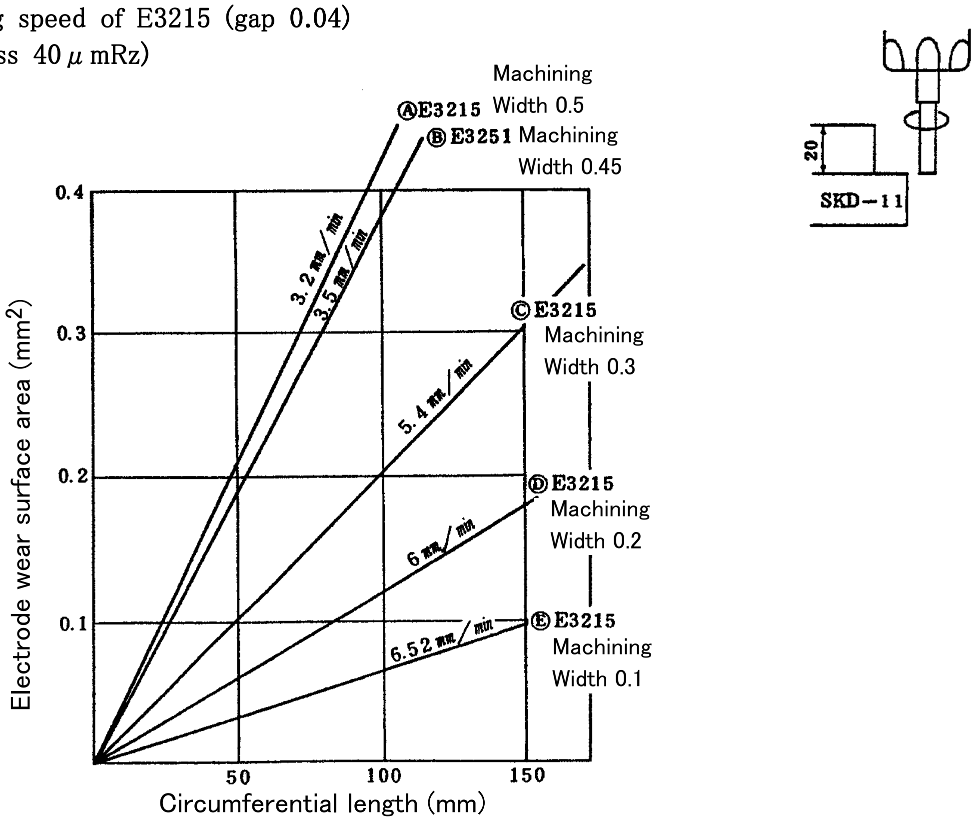
ADD. M/C amount mm	M/C cond. / Roughness μmRz	3210	3211	3212	3213	3214	3215	3216	3217
		13	15	18	24	32	40	46	55
0.5	Electrode wear mm								
	Feed rate mm/min								
0.4	Electrode wear mm								
	Feed rate mm/min								
0.3	Electrode wear mm						0.038	0.035	
	Feed rate mm/min								
0.2	Electrode wear mm						0.02	0.02	
	Feed rate mm/min						6	6	
0.1	Electrode wear mm					0.006	0.008	0.008	
	Feed rate mm/min					7	7	7	
0.05	Electrode wear mm				0.002	0.002			
	Feed rate mm/min				10	10			
0.03	Electrode wear mm			0.002	0.0015	0.0015			
	Feed rate mm/min			10	10	10			
0.02	Electrode wear mm		0.0015	0.0015					
	Feed rate mm/min		10	10					

Note: Small electrode diameter results in large wear.

Machining speed of E3216 (gap 0.05)
(Roughness 46 μ mRz)



Machining speed of E3215 (gap 0.04)
(Roughness 40 μ mRz)



11. PREMACHINED HOLE MACHINING BY PIPE ELECTRODE
(Use of electrode rotary unit)

There are many machining methods that use a pipe electrode according to machining speed, accuracy and number of holes to be machined.
This section covers a method of which stress is put on the machining speed rather than machining accuracy, such as machining of prepared holes for wire electrical discharge machining.

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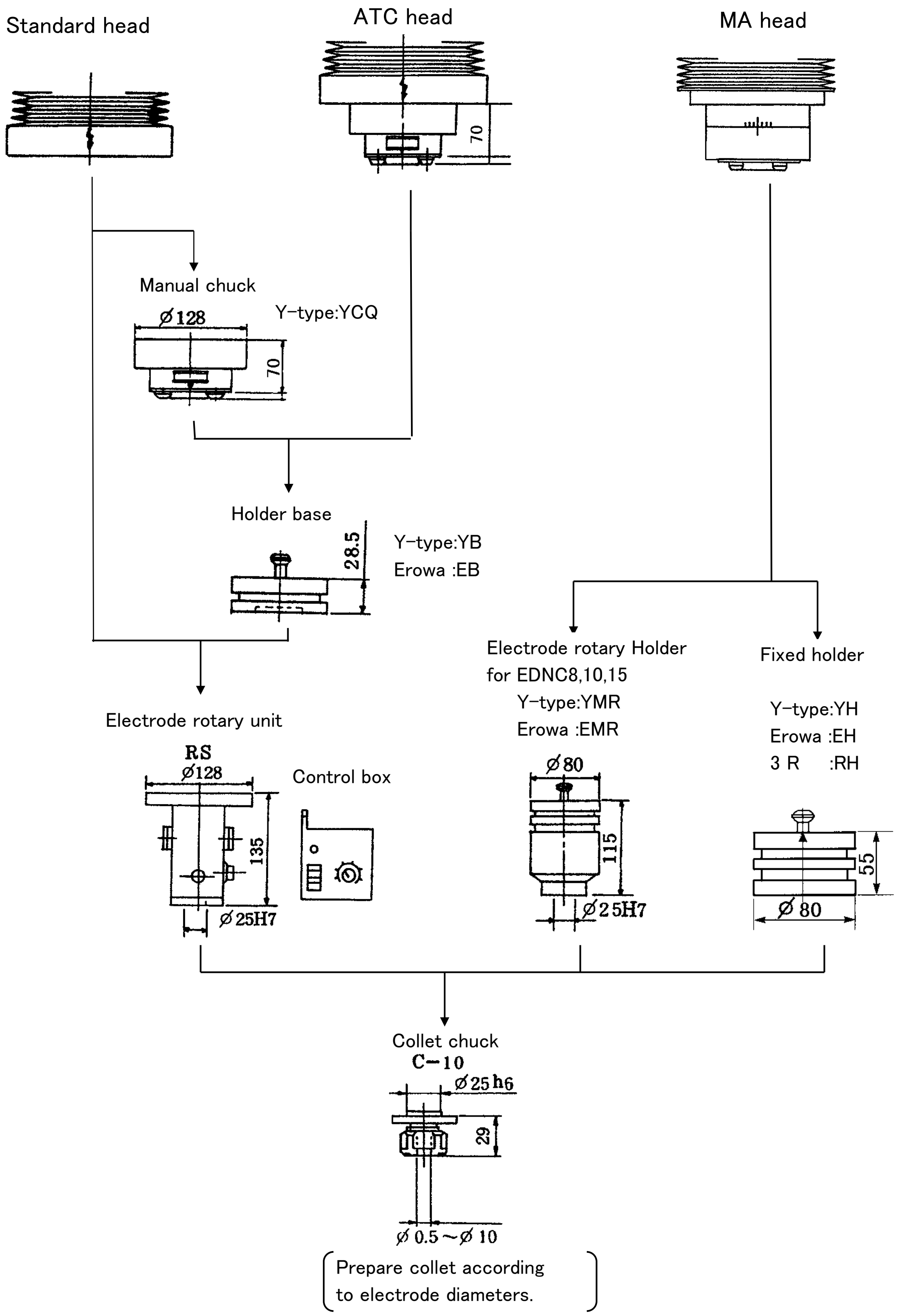
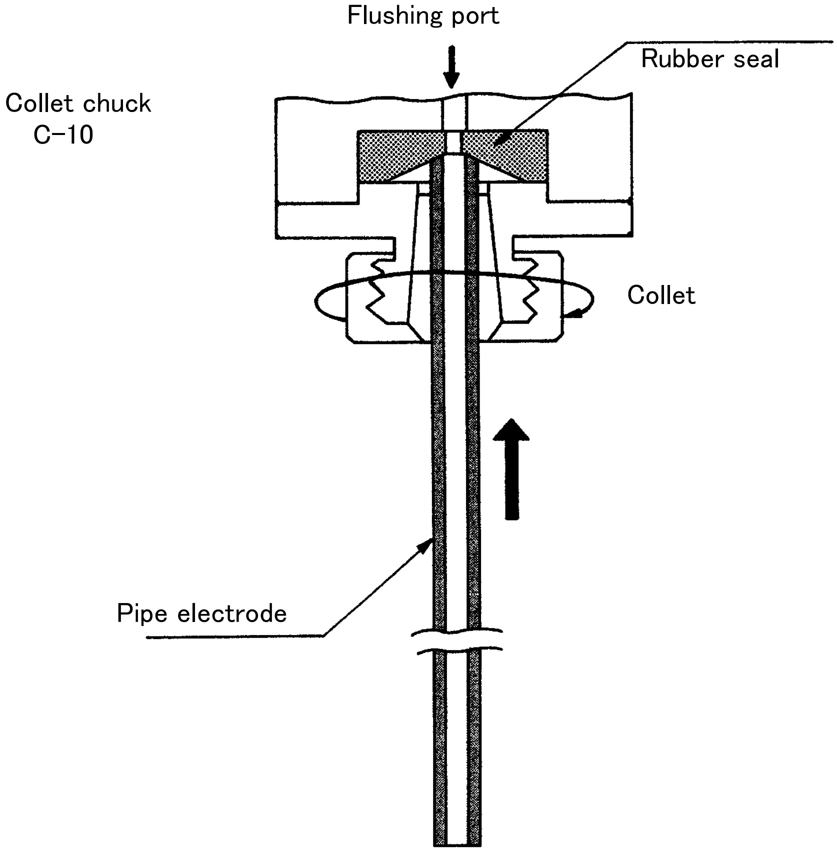
11.1 Tooling plan for machining by pipe electrode

※Additionally, there are a lot of tools.
refer to each catalog for details.

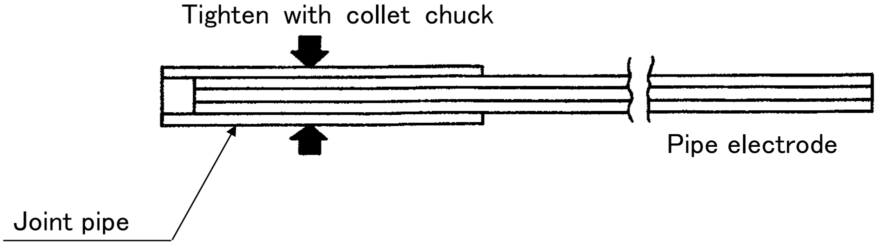


12.2 Installing pipe electrode

Tighten the collet with pipe electrode pushed against the rubber seal.



When pipe electrode diameter is below 1.8mm, it is smaller than the flushing port of rubber seal. In this case, use a joint pipe or a collet chuck having smaller diameter as shown below.

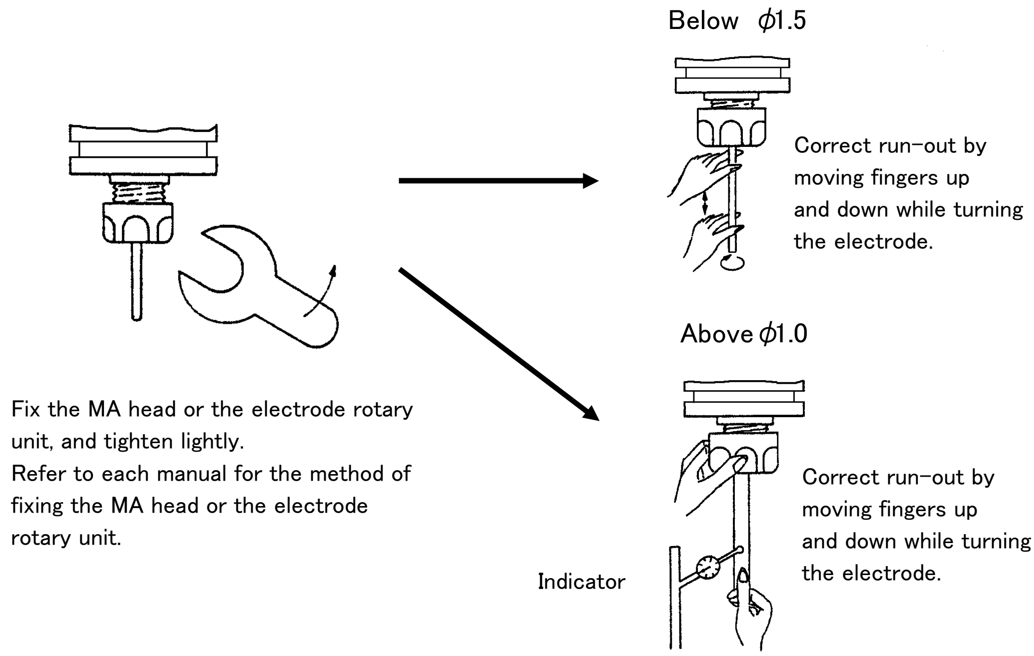


Small diameter
Electrode holder

EROWA compact spec.

3R junior spec.

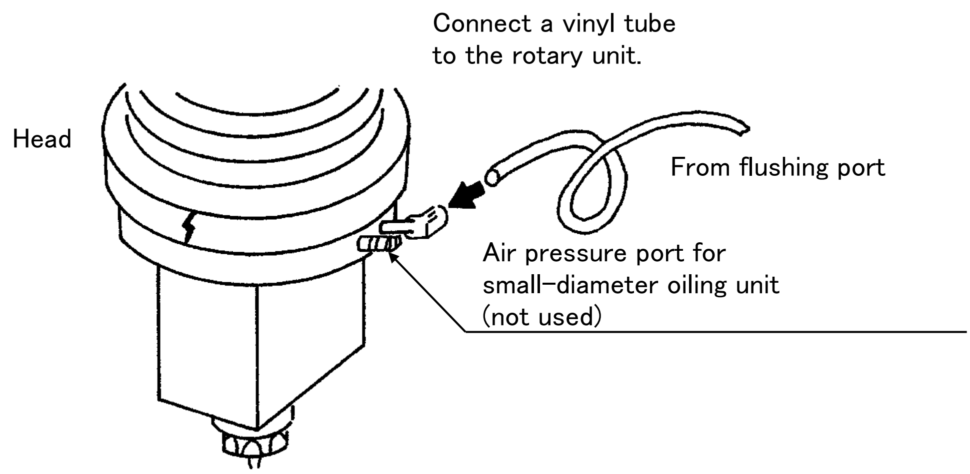
11.3 correcting run-out of electrode



The presence of large run-out of electrode affects machining performance including machining speed, accuracy and electrode wear. So correct it as small as possible.

11.4 Setup for supplying fluid to pipe electrode

[when using electrode rotary unit]



11.5 Machining setting

[Spindle speed]

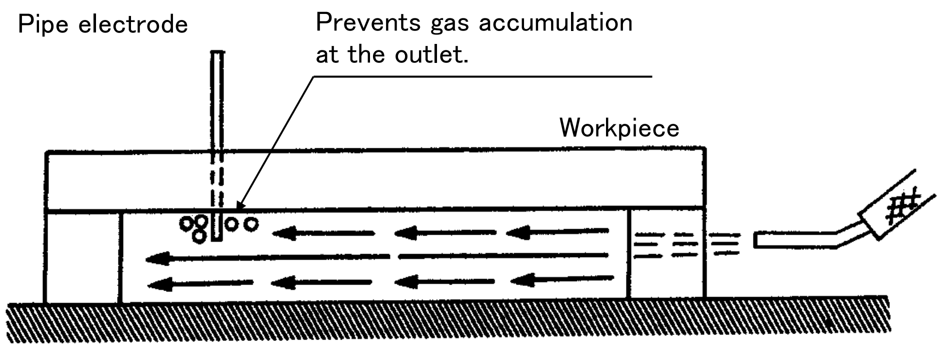
Set approx 500 rpm. Precise setting is not required.

[Flushing pressure]

Set 0.02 to 0.05 MPa.
Higher flushing pressure, in general, increases machining speed, but promotes electrode wear.

[Others]

Convection of fluid at the bottom of workpiece as shown below makes machining stable when electrode retracts.



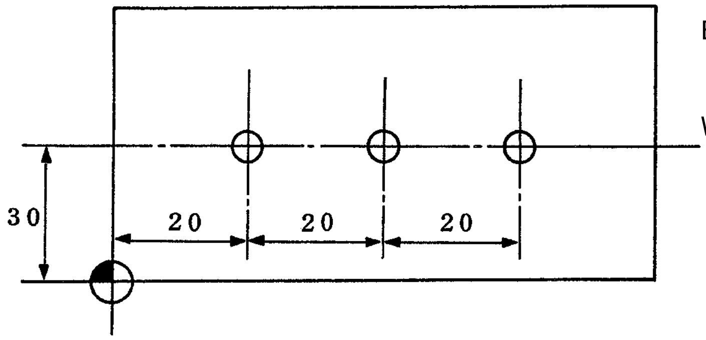
Chips are well discharged through pipe electrode by flushing, thus eliminating necessity of jumping. The use of jump wastes time and decreases machining speed.

11.6 Machining condition

- Copper pipe – Steel E3400 to E3421
- Copper pipe – Tungsten carbide E3500 to E3521

Refer to instruction manual “Machining Condition”.

11.7 Machining example



Electrode: Cu pipe
Diameter 2.0mm

Workpiece: SKD-11
Thickness 20mm

MC : SINGLE MC (G100)

Address	Attri.	Talk items	Set value
N	/	ABS/INC (90/91)	
X	/	MC DEPTH X AXIS [u,t]	
Y	/	Y AXIS [u,t]	
Z	/	Z AXIS [u,t]	-35.0 ← Thickness + (thickness × wear ratio + 5.0
C	/	C AXIS [rot./ANGLE]	
W	/	AUTO DEPTH MAX. TRAVEL [u,t]	
L	/	MC LAST STOP (1:ON)	-70.0 ← Obtain from possible electrode length.
E	*	MC COND No.	3407
U	/	REMAIN AMOUNT [u,t]	
R	/	PATTERN RADIUS [u,t]	
P	/	MODE/PATTERN	
A	/	ROT.ANGLE [deg]	
B	/	CIRCUIT SPEED [m,i/min]	
S	/	JUMP AMOUNT [code:u,t]	0 ← Select jump OFF.
T	/	CYCLE [code:0.001sec]	
F	/	SPEED [code:m,i/min]	
I	/	CLAMP AMOUNT [u,t]	
H	/	TIME CONTROL TIME [min]	
M	/	START MC COND. No. (DF[%])	
D	/	START J. CYCLE [code:0.001sec]	
V	/	START MC REMAIN AMOUNT [u,t]	

POS. : DISPERSED (G113)

Address	Attri.	Talk items	Set value
H	/	PLANE (1:X-Y,2:Z-X,3:Y-Z)	
W	/	WORK CORD. SYSTEM	
X	*	START CORD. X AXIS [u,t]	20.0
Y	*	(ABS) Y AXIS [u,t]	30.0
Z	*	Z AXIS [u,t]	5.0
U	/	No.2 HOLE (ABS) I AXIS [u,t]	40.0
V	/	II AXIS [u,t]	30.0
I	/	No.3 HOLE (ABS) I AXIS [u,t]	60.0
J	/	II AXIS [u,t]	30.0
K	/	No.4 HOLE (ABS) I AXIS [u,t]	
B	/	II AXIS [u,t]	
C	/	No.5 HOLE (ABS) I AXIS [u,t]	
P	/	II AXIS [u,t]	
Q	/	No.6 HOLE (ABS) I AXIS [u,t]	
R	/	II AXIS [u,t]	
L	/	ANGLE INDEX (C AXIS,INDEX,DH)	
A	/	INDEX ANGLE [deg]	
D	/	ELECT. ROT. OFFSET (1:ON)	
S	/	C AXIS SYNC PATTERN (1:ON)	
T	/	OPPOSITE (1:ON)	

12. FINE-HOLE MACHINING METHOD BY USING ELECTRODE DRESSING

The "Electrode dressing macro program" and the rotary head are required to utilize the fine hole machining method by the electrode dressing described in this section. The "Electrode dressing macro program" and rotary head are optional, and therefore it is not supplied as standard.

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12.1 Electrode

Fine hole machining by electrode dressing requires a stick electrode for the fine hole machining and a plate electrode for dressing.

- For the electrodes used for fine hole machining, where toughness and less wear are required, use silver tungsten or copper tungsten.
  - Silver tungsten rod
  - Tungsten rod
  - Copper tungsten rod

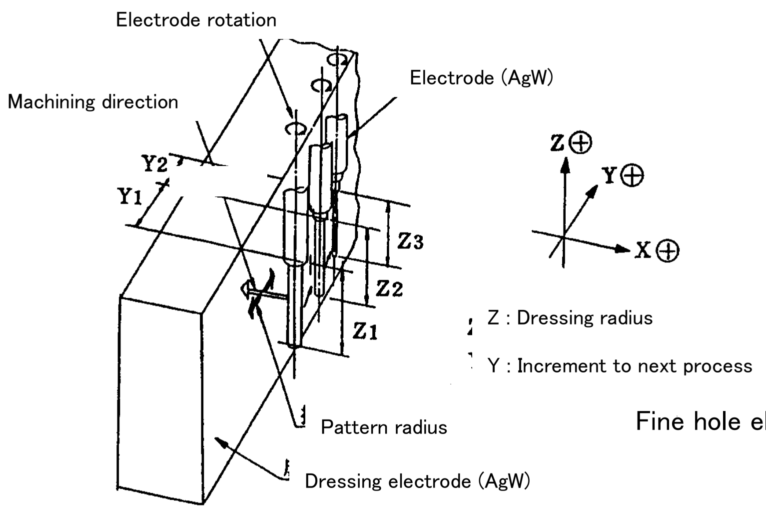
- For the electrodes used for dressing, use silver tungsten or copper tungsten with a flat surface.
  - Silver tungsten plate
  - Copper tungsten plate

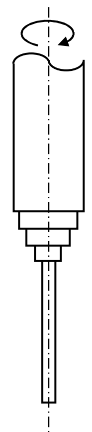
ø1 silver tungsten stick electrode

Copper tungsten plate electrode for dressing

12.2 Electrode Dressing Method

The ″Electrode dressing macro program ″(O9020) for the electrode dressing is used.
A program can be easily created through talk input. The bar electrode is dressed to have steps as shown in the following figure to ensure rigidity.

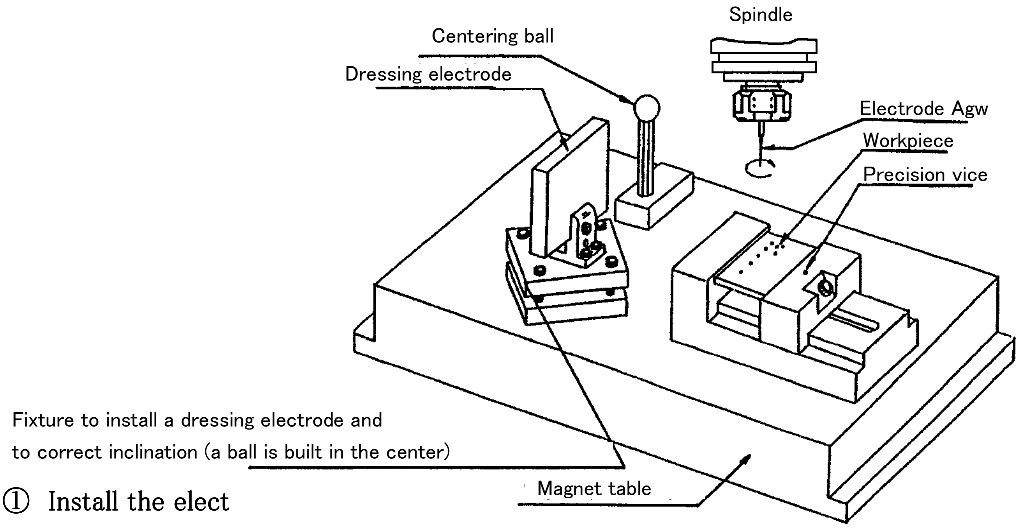




Fine hole electrode after dressing

12.3 Setup

Perform the setup work by referring to the following figure and the procedure ① to ⑥



① Install the elect

② Clamp the workpiece with a vise, etc

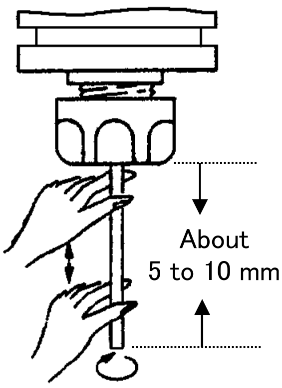
③ Attach the fine hole machining electrode to the spindle through a collet, etc. Large run-out of electrode will affect adversely the machining time or dressing accuracy. Attach the electrode so that its run-out is as less as possible by referring to the procedures.

＜Run-out eliminating procedure＞

④ Rotate the rotary head at the maximum speed.

[MC F11] ⇨ [MA/MR L 3] ⇨ [ROTATE MODE B 8]

⇨ [ROTATE START B 9] ⇨ [HIGH →]



⑤ Pinch the electrode with your hand as shown in the right figure, and slide your hand vertically by adding a force so as to allow the electrode to bow a little.

⑥ Slowly get your hand off the electrode, and check visually the run-out. In case of a large run-out, repeat the steps ⑤ and ⑥.

The electrode overhang length should be constant, usually about 5 to 10 mm. Varying overhang length causes a dispersion of electrode finish diameter.

12.4 Input of Electrode Dressing Macro Program (O9020)

Call “G105 (PACKAGE)” from the Machining Menu, and perform talk input.

RUN [F 2] ⇒ [MDI RUN L 3] OR EDIT [F 5] ⇒ 「G105O9020;」 ⇒ [MODEL PLAN B1]

Address	Attri.	Take items	Description	Input range
O	*	CALL PROGRAM NO.	9020	
N	／	P.MODEL COMBINATION (1:NO USE)	Enter “1” when position model is not used	1
X	*	START POINT X AXIS [mm]	Program start point X AXIS	
Y	*	Y AXIS [mm]	Program start point Y AXIS	
Z	／	TARGET DRESSING LENGTH [mm]	Target dressing length	R×50times or less
R	／	TARGET FINISH DIAMETER [mm]	Target finish diameter	0.06-1.0
I	／	START OF PROCESS NO.	Start of process No.	1-10
J	／	END OF PROCESS NO.	End of process No.	1-10
T	／	REPETATIONS IN 10TH PROCESS	Repetitions in 10th process	1-100
L	／	DRESSING DIRECTION	Specify the approach direction to the dressing electrode.	1-4
A	／	SHIFT OF ELECTRODE CENTER [mm]	Shift amount of electrode center position	
B	／	SHIFT OF DRESSING LENGTH [mm]	Shift amount of electrode dressing length	
M	／	SPINDLE ROTATION [CODE]	Specify the spindle rotation speed during the dressing	1-15

12.5 Electrode Dressing Macro (O9020) Model Talk Items

O:* CALL PORGRAM NO.

Enter O number of macro stored. Enter the [9020].

N:/ P.MODEL COMBINATION (1:NO USE)

Enter “1” if the position model is not used and only O9020 is used for the machining. When position model is used, set to empty.

Z, R:/ TARGET DRESSING LENGTH, TARGET FINISH DIAMETER

Use these items for automatic setting of electrode dressing data. If Z and R are entered, the machining data is automatically written to the offset No.31 – 99. (See Section 12.6) As default, no data is written. It will be convenient that the model data is written once and then corrected later, even if the data is set manually. Entry of a value less than 0.06 for the finish diameter, or a value exceeding 50 times of R for the dressing length will cause an alarm.

L:/ DRESSING DIRECTION

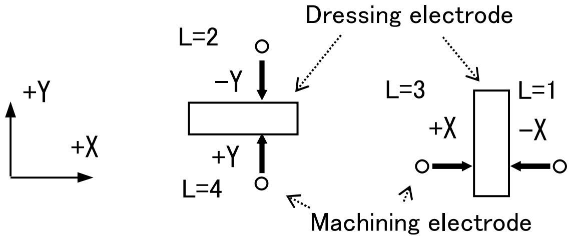
Specify the approach direction to the dressing electrode.

L = 1 : −X direction

L = 2 : −Y direction

L = 3 : +X direction

L = 4 : +Y direction



As default, the approach is made in −X direction (L = 1).

T:/ REPETITIONS IN 10TH PROCESS

The same command can be repeated for the 10th process only. By specifying this item, the dispersion of the electrode diameter due to the wear of the dressing electrode can be reduced. Use this with machining conditions such as E9590, in which the electrode wear is high.

I, J:/ START OF PROCESS NO., END OF PROCESS NO.

Use this when starting or ending the electrode dressing at mid process. Even if the electrode dressing is started from mid process, the dressing position will be the same as when it is started from the first process.

A, B:/ SHIFT OF ELECTRODE CENTER, SHIFT OF DRESSING LENGTH

The electrode center position and dressing length of the electrode dressing data (see Section 12.6) can be corrected.

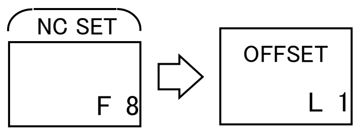
Use this to adjust the electrode diameter or the dressing length.

M:/ SPINDLE ROTATION

Using a code, specify the spindle rotating speed during the dressing. Normally, specify “15”.

12.6 Machining Data during Dressing and Its Change Method

If the “TARGET DRESSING LENGTH Z” and “TARGET FINISH DIAMETER R” are entered, the machining data for electrode dressing are automatically created, and it is set on the “NC SET” or “OFFSET” screen. By correcting this data manually on screen, the machining can be adjusted finely. If this data was corrected, execute the dressing with the “TARGET DRESSING LENGTH Z” and “TARGET FINISH DIAMETER R” items left blank. Otherwise, if items not set empty and run dressing, the data is changed and the correction becomes ineffective.



＜Input example in the case of finish diameter 0.06＞

Process	M/C condition	Electrode Center position	Dressing length	Servo speed	Pattern radius	Pattern speed	Increment to next process
1	(31)7339	(41)0.150	(51)6.5	(61)2.2	(71)400	(81)20.0	(91)1.2
2	(32)7338	(42)0.140	(52)6.0	(62)2.2	(72)200	(82)10.0	(92)0.7
3	(33)7337	(43)0.120	(53)5.5	(63)3.3	(73)150	(83)7.0	(93)0.4
4	(34)7335	(44)0.085	(54)5.0	(64)5.5	(74)50	(84)1.0	(94)0.3
5	(35)7333	(45)0.070	(55)4.5	(65)5.5	(75)50	(85)1.0	(95)0.3
6	(36)7332	(46)0.060	(56)3.8	(66)5.5	(76)40	(86)0.5	(96)0.3
7	(37)7331	(47)0.047	(57)3.3	(67)5.5	(77)30	(87)0.5	(97)0.3
8	(38)7330	(48)0.035	(58)3.0	(68)5.5	(78)20	(88)0.5	(98)0.3
9	(39)	(49)	(59)	(69)	(79)	(89)	(99)
10	(40)	(50)	(60)	(70)	(80)	(90)	(100)Note1

Note 1 : There is no offset number (100). It is assumed same as data (99).

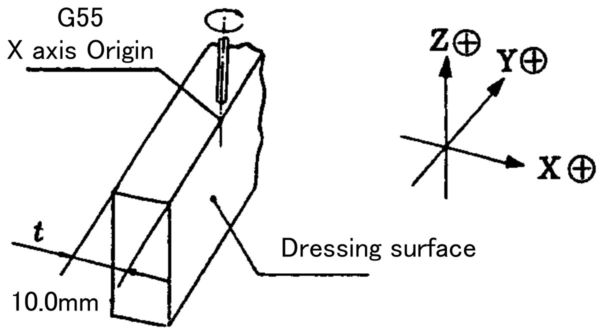
Note 2 : Input of “0” in the machining condition field, executes positioning, but machining is omitted.

12.7 Applications of Electrode Dressing

Example: If the electrode diameter is dressed in to ø 0.1

First, dress preliminarily the ø 1 electrode blank into ø 0.5 electrode, and correct the dressing dimension and perform the centering of the workpiece.

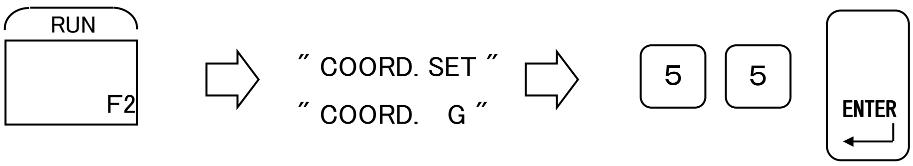
(1) Measure the thickness (“t” in the following figure) of the dressing electrode with a micrometer. In this example, the plate thickness t = 10.0 mm. Then, install the dressing electrode in parallel direction with the Y axis.



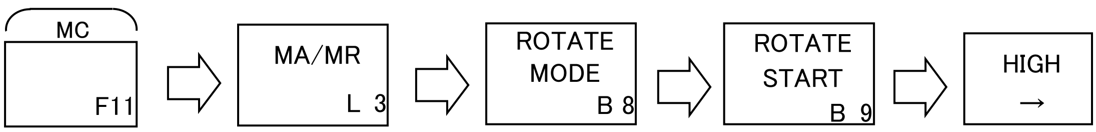
Dressing electrode AgW

(2) Attach the ø1.0 electrode blank to the spindle, overhanging 5 to 10 mm from the spindle nose.

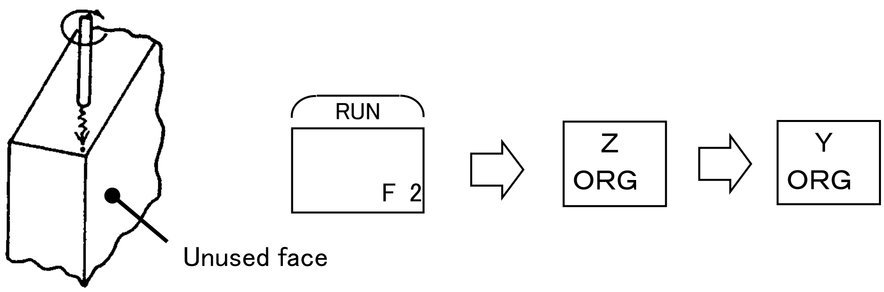
(3) Change the coordinate system to “G55”.



(4) Rotate the spindle at the maximum speed.

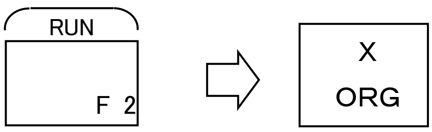


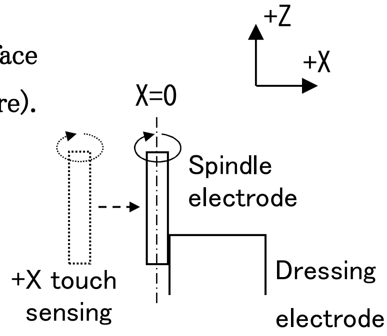
(5) Make the spindle electrode touch-sensed on the top face of the unused surface of the dressing electrode to set the workpiece origin in the Y and Z axis.



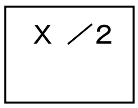
Then, perform the centering of the spindle electrode and dressing electrode by using the Measuring Menu “G122 (PLATE/COLUMN)” or the method given below.

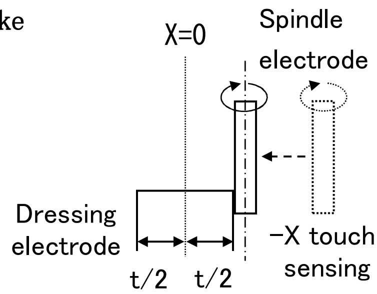
(6) Make the spindle electrode touch-sensed to the unused surface of the dressing electrode in +X direction (see the right figure). Set the work coordinate of X axis at the touch-sensed position.





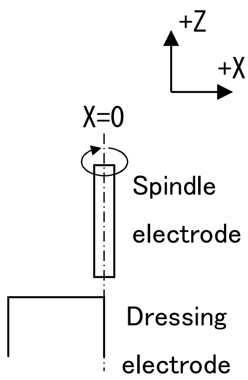
(7) Move the spindle electrode above the dressing electrode. Make the spindle electrode touch-sensed in −X direction (see the right figure). Set the work coordinate of X/2 at the touch-sensed position.

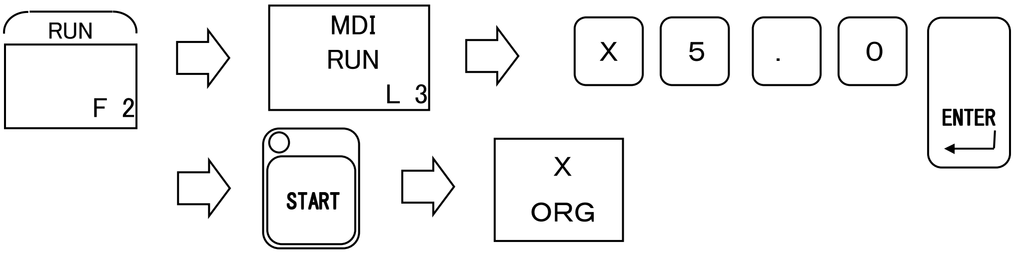




At this time, the electrode rotation center coincides with the end face of dressing electrode. This position remains unchanged even if the electrode was replaced; therefore it will be convenient to save this coordinates when continuing electrode forming.

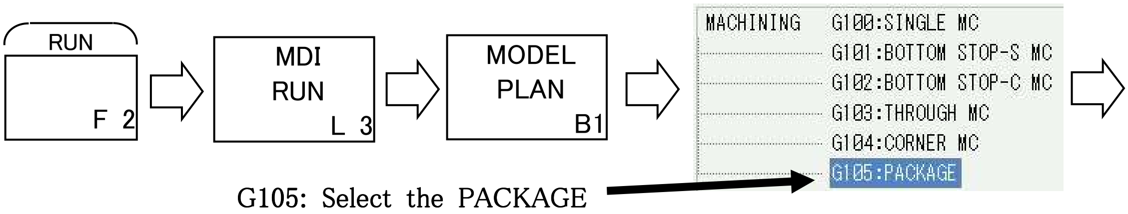
(8) In the MDI RUN mode, move the spindle electrode to the X (t/2) position (X5.0 coordinate if thickness t = 10.0mm), and set the workpiece origin in the X axis. By this operation, the electrode rotation center coincides with the end surface of the dressing electrode.
This position remains unchanged even if the electrode was replaced, and therefore this coordinates can be used as they are for the dressing of the next electrode. It will be convenient to save this coordinates during the fine hole machining with the dressed electrode.

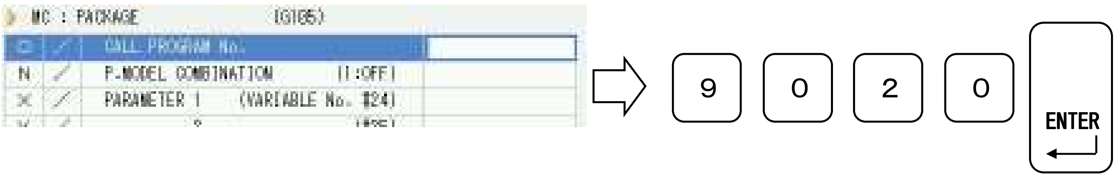




(9) Keep the spindle electrode off the dressing electrode, and fill the work tank with circulating dielectric fluid.

(10) From the G105: PACKAGE, call the talk screen and create the machining blocks



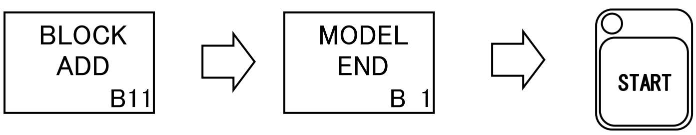


With the called model talk menu, enter the items as shown below.

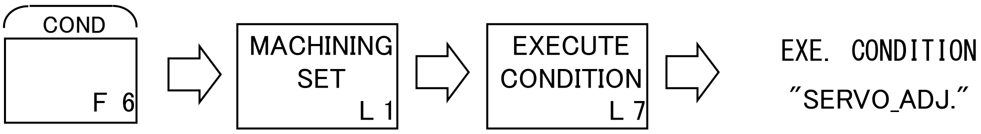
MACHINING – G105 : PACKAGE

Address	Attri.	Talk Items	Set Value
O	*	CALL PROGRAM NO.	9020
N	/	P.MODEL COMBINATION (1:NO USE)	1
X	*	STRAT POSITION X AXIS [mm]	0
Y	*	Y AXIS [mm]	0
Z	/	TARGET DRESSING LENGTH [mm]	5.0
R	/	TARGET FINISH DIAMETER [mm]	0.5
I	/	START OF PROCESS NO.	
J	/	END OF PROCESS NO.	
T	/	REPETITIONS IN 10TH PROCESS	
L	/	DRESSING DIRECTION	
A	/	SHIFT OF ELECTRODE CENTER [mm]	
B	/	SHIFT OF DRESSING LENGTH [mm]	
M	/	SPINDLE ROTATION [CODE]	15

Add blocks and press the START button.



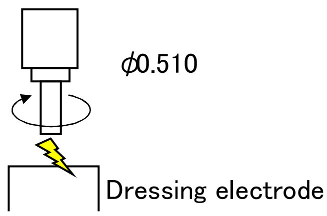
(11) A discharge with the undressed electrode may be unstable due to the eccentricity or large deflection of the electrode. In such a case, open the machining condition screen and set the EXE. CONDITION "SERVO ADJ." to larger than standard value, and then observe the discharge for a while. When the entire electrode can discharge evenly, return gradually the set value to the original value to finish the electrode. (For the details of servo adjustment, see Section 12.12)



(12) After the dressing is finished, take out the electrode holder, and measure the electrode diameter with a projector or a microscope, etc. If it is not finished to the required electrode diameter, re-dress the electrode through the following procedures.

Example: If the electrode is dressed to ϕ0.510 against the target dia. 0.5

(A) Replace the electrode with a new one or remove the tip of the electrode with ϕ0.510.The tip portion can be easily removed without replacing the steps and discharging on upper surface of the dressing electrode by using dressing conditions (Section 12.14).



(B) Enter −0.005, which is obtained by converting the symbol at half of electrode radius error, in item A: SHIFT OF ELECTRODE CENTER in the Electrode Dressing Macro Program. Use unused forming surface by shifting the item A: Program start point Y AXIS.

MACHINING − G105 : PACKAGE

Address	Attrib.	Talk Items	Set Value
O	*	CALL PROGRAM NO.	9020
N	/	P.MODEL COMBINATION (1:NO USE)	1
X	*	STRAT POSITION X AXIS [mm]	0
Y	*	Y AXIS [mm]	3.5
Z	/	TARGET DRESSING LENGTH [mm]	5.0
R	/	TARGET FINISH DIAMETER [mm]	0.5
I	/	START OF PROCESS NO.	
J	/	END OF PROCESS NO.	
T	/	REPETITIONS IN 10TH PROCESS	
L	/	DRESSING DIRECTION	
A	/	SHIFT OF ELECTRODE CENTER [mm]	-0.005
B	/	SHIFT OF DRESSING LENGTH [mm]	
M	/	SPINDLE ROTATION [CODE]	15

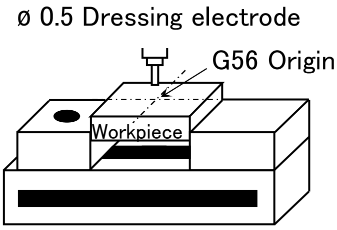
Move to unused dressing surface

Offset

(C) Circulate dielectric fluid to repeat dressing.

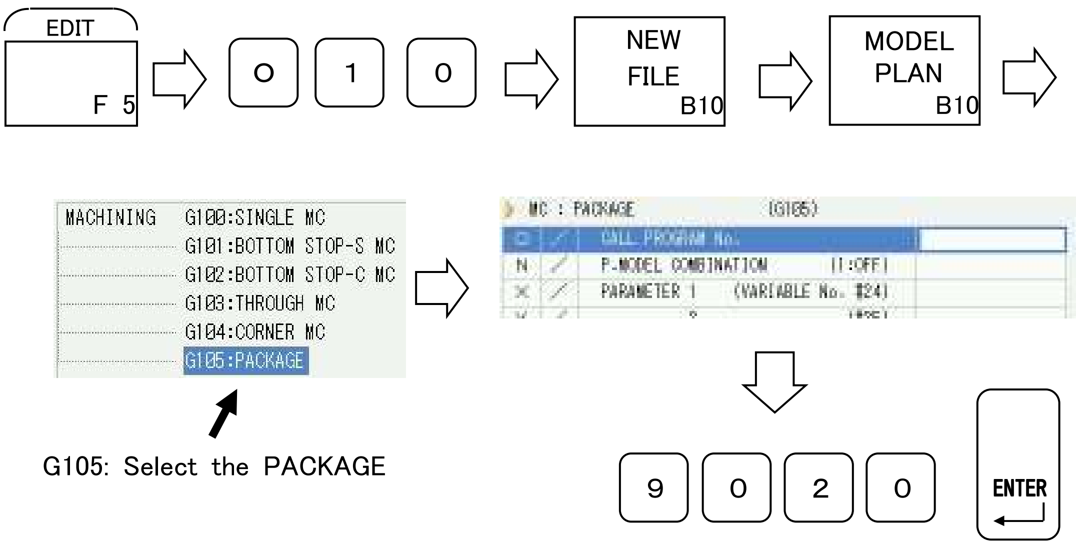
Also, dimensions of the electrode can be adjusted by changing the machining data "Electrode Center Position" (section 12.6) on the "Offset" screen, note that the changes made so far are overwritten unless the program is started with the talk items Z and R left blank.

(13) Perform the centering of the preliminarily dressed ø 0.5 electrode to the workpiece. The reason of why the preliminarily dressed electrode is used for centering is that the target ø 0.1 electrode is deficient in rigidity and the centering is difficult. Select another coordinate system such as G56 and set the work coordinate.



Next, dress electrode to ø0.1. In this example, dressing is executed with the preliminarily dressed ø0.5 to get ø0.1. If the electrode is faulty, replace the new bar electrode.

(14) Create the program for dressing. In this example, new program O10 was created.



(15) With the model talk menu called, enter the items. Add the blocks, end off by typing the M30 command and close the file.

MACHINING – G105 : PACKAGE

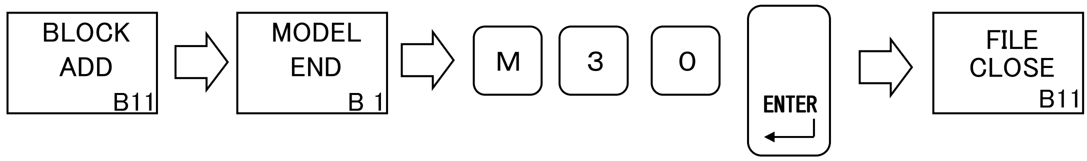
Address	Attrib.	Talk Items	Set Value
O	*	CALL PROGRAM NO.	9020
N	/	P.MODEL COMBINATION (1:NO USE)	1
X	*	STRAT POSITION X AXIS [mm]	0
Y	*	Y AXIS [mm]	7.0
Z	/	TARGET DRESSING LENGTH [mm]	4.0
R	/	TARGET FINISH DIAMETER [mm]	0.1
I	/	START OF PROCESS NO.	
J	/	END OF PROCESS NO.	
T	/	REPETITIONS IN 10TH PROCESS	
L	/	DRESSING DIRECTION	
A	/	SHIFT OF ELECTRODE CENTER [mm]	
B	/	SHIFT OF DRESSING LENGTH [mm]	
M	/	SPINDLE ROTATION [CODE]	15

Move to unused dressing surface

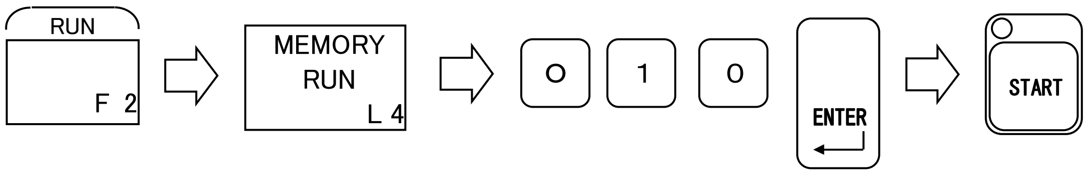
Shortening the dressing length for 1mm

Dressing electrode diameter ϕ0.1mm

(16) Write "M30" command after adding a block and close the file.



(17) Run the created program to dress the electrode to ø 0.1.

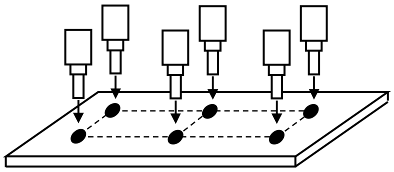


(18) After the dressing is finished, take out the electrode holder and measure the electrode diameter with a projector or a microscope, etc. If it is acceptable, the electrode dressing is complete.

12.8 Fine Hole Machining Method by Dressed Electrode

Use the fine shape machining macro program (O9010). The program can be created through talk input, where the machining model and the position model are combined, same as usual machining programs. For the machining conditions, use exclusive conditions mentioned in Section 12.15

G105O9010Z-3.0E7343B5.5S0; ··· Fine shape machining macro (machining model)
G111X0Y0Z1.0P10.0Q5.0U1V3I1J2; ··· Line/Grid (position model)
M30;



12.9 Input of Fine Shape Machining Macro Program (O9010)

The fine shape machining macro program is entered through talk input by calling the “Machining Menu” -> “G105 (PACKAGE)”.

EDIT F 5 ⇨ 「G10509010;」 ⇨ MODEL PLAN B10

Address	Attrib.	Talk Items	Description
O	＊	CALL PROGRAM NO.	9010
N	／	P.MODEL COMBINATION (1:NO USE)	“1” if a combination with position model is not be invalid
X	／	MC DEPTH X AXIS [mm]	X axis value
Y	／	Y AXIS [mm]	Y axis value
Z	／	Z AXIS [mm]	Z axis value
C	／	C AXIS [rot/deg]	C axis value
E	／	MC COND. NO.	Machining condition number
B	／	SERVO SPEED (FOWARD.BACK)	Servo axis forward/backward feed rate
R	／	PATTERN RADIUS [mm]	Pattern radius (pattern radius in taper machining)
P	／	MODE/PATTERN	Pattern mode, pattern
A	／	ROT. ANGLE [0.001deg]	Pattern angle
F	／	CIRCUIT SPEED [mm/min]	Pattern speed
S	／	JUMP AMOUNT [code,mm]	Jump amount (OFF for “0”)
T	／	CYCLE [code,0.001sec]	Jump cycle
U	／	SPEED [code,mm/min]	Jump speed
I	／	SERVO JUMP AMOUNT [mm]	Servo jump amount
L	／	MACHINING PARAMETER	For details, see Section 12.10
J	／	TAPER ANGLE [0.001deg]	Taper machining (taper angle)
K	／	FEED STEP [mm]	Taper machining (taper step)
D	／	PROGRAM NO. INSERTED	Program No. inserted
H	／	TIME CONTROL [min]	Specify Upper limit time of MC process
M	／	SPINDLE ROTATION [code]	Specify the spindle rotation speed at machining

12.10 Fine Sharp Machining Macro　Model Talk Item (O9010)

O:＊　CALL PROGRAM NO.

Enter O number of macro stored. Enter the [9010]

N:/　P.MODEL COMBINATION (1:NO USE)

Enter "1" if multi-workpiece operation by position model is not required and machining is executed only with the machining model. When use position model, set empty.

L:/　MACHINING PARAMETER

＊＊1 … Machining stop at end point

Machining stops at the command value.　(however, MDI mode only)

＊＊2 … Continuous machining command

The bottom is machined up to the specified value with pattern OFF and enlarge pattern machining is executed only if the enlarge pattern (P2****) is specified in the pattern mode.

＊1＊ … Incremental command

Use incremental command.

□＊＊ … Pattern offset data number

Function is same as in the machining model "BOTTOM STOP – SIMPLE".

B:/　SERVO SPEED (FOWARD.BACK)

The discharge servo forward/backward speed can be set to a slow speed. Use this when the discharge with a micro electrode is unstable. (See 12.15 Machining Condition Table, bottom row)

＊.＊:　(Forward speed).(Backward speed)

Input value	1	2	3	4	5	6	7
Speed ratio	1/1	1/2	1/4	1/8	1/16	1/32	1/64

Example: E7345 ø 0.3 dressed electrode fine hole machining condition

Item B Servo Speed ＝ 4.4

Forward speed 1/8　Backward speed 1/8

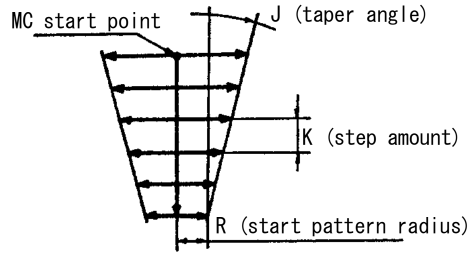
I:/　SERVO JUMP AMOUNT

The discharge restarts at the point advanced by the amount of set length when the jump returns. Usually, use this item in a range of 5 to 30 mm.

J, K:/ TAPER ANGLE, TAPER FEED STEP

R:/ START PATTERN RADIUS (meaning varies only for taper machining)

These items are used for the taper machining (phased large pattern machining). Enter suitable values to all items J, K, and R. Also,enter"2**** (enlarged pattern machining)in item P:Pattern mode,pattern.

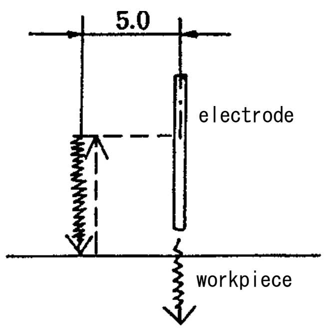


D:/ PROGRAM NO. INSERTED

Before machining, the program of O number entered in this item can be executed. In the example shown below, to eliminate variations in the machining depth due to the electrode wear, the touch sensing is done in the Z direction by the G84 command to set the origin, and then the machining is executed.

Example: The following program is registered to O10 with item D = 10

```
O10
G91;          … Select INC mode
G00X-5.0      … Move to X-5.0 position
G84Z-20.0;    … Measure in -Z direction, and return
G92Z1.0;      … Set work coordinate of Z axis
G00X5.0;      … Return to original X position
M99
```



M:/　SPINDLE ROTATION

Set the below code or rotation speed when the machining is executed by rotating the spindle.

Normally spindle speed is 1000 rpm. Please adjust rotation speed as the below when the machining is unstable.

・When electrode diameter is thick : Reduce rotation speed

・When electrode diameter is thin : Increase rotation speed

Code : Input range 0 ～ 15 (TAP)

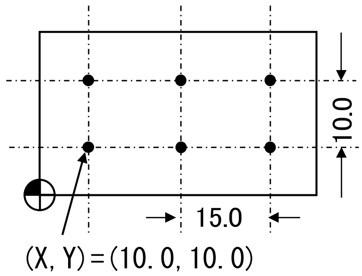
Code	Speed[rpm]	Code	Speed[rpm]	Code	Speed[rpm]
0	10	6	125	12	500
1	40	7	160	13	630
2	50	8	200	14	800
3	63	9	250	15	1000
4	80	10	315		
5	100	11	400		

Direct value : Input range 100 ～ 2000 [rpm]

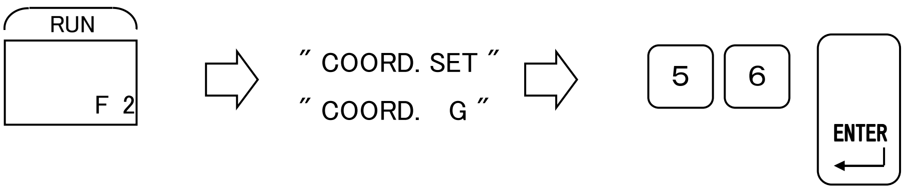
12.11 Applications of Fine Hole Machining by Dressed Electrode

This section describes an applicable example of fine hole machining with the dressed electrode. As the diameter of the machined holes varies depending on the workpiece thickness or the electrode condition after dressing, it is recommended to perform a test machining before actual machining.

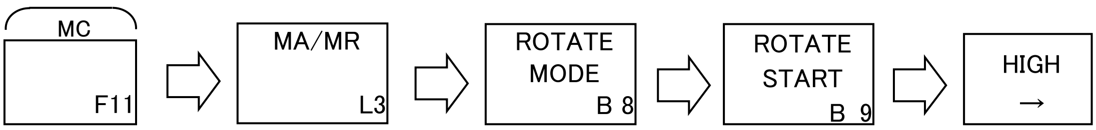
Electrodeø 0.1 silver tungsten (AgW)
Workpiece   Steel, thickness 0.5mm
Machining points   6 places (see right figure)



(1) Change the coordinate system to “G56”.

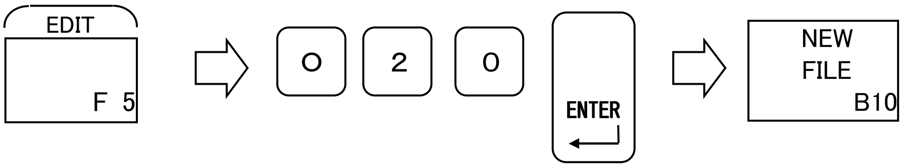


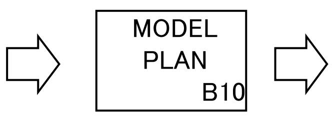
(2) Rotate the spindle at the maximum speed.



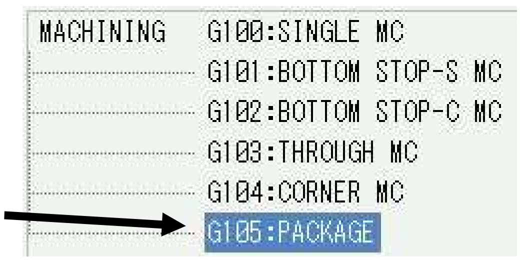
(3) Make the dressing electrode touch-sensed to the workpiece, and set the workpiece origin. Even if the electrode is replaced, the center of the dressed electrode remains unchanged because the electrode is rotating. Too thin electrode will bend when it touches the workpiece.

(4) Create a machining program. In this example, O20 is newly created.

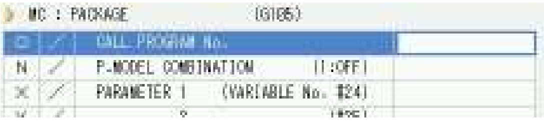


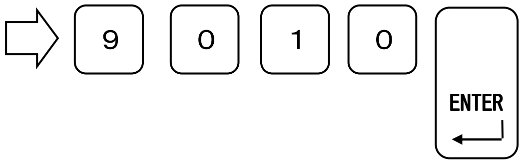


G105: Select the PACKAGE



(5) Item O: Enter O number in the “CALL PROGRAM NO.”. Enter the set value in the called talk menu, and add the blocks.





MACHINING – G105: PACKAGE

Address	Attrib.	Talk items		Set Value
O	*	CALL PROGRAM NO.		9010
N	/	P.MODEL COMBINATION	(1:NO USE)	
X	/	MC DEPTH X AXIS	[mm]	
Y	/	Y AXIS	[mm]	
Z	/	Z AXIS	[mm]	-3.0
C	/	C AXIS	[rot/deg]	
E	/	MC COND. NO.		7343
B	/	SERVO SPEED	(FOWARD.BACK)	5.5
R	/	PATTERN RADIUS	[mm]	
P	/	MODE/PATTERN		
A	/	ROT. ANGLE	[0.001deg]	
F	/	CIRCUIT SPEED	[mm/min]	
S	/	JUMP AMOUNT	[code, mm]	3
T	/	CYCLE	[code, 0.001sec]	3
U	/	SPEED	[code, mm/min]	6
I	/	SERVO JUMP AMOUNT	[mm]	
L	/	MACHINING PARAMETER		
J	/	TAPER ANGLE	[0.001deg]	
K	/	FEED STEP	[mm]	
D	/	PROGRAM NO. INSERTED		
H	/	TIME CONTROL	[min]	
M	/	SPINDLE ROTATION	[code]	15

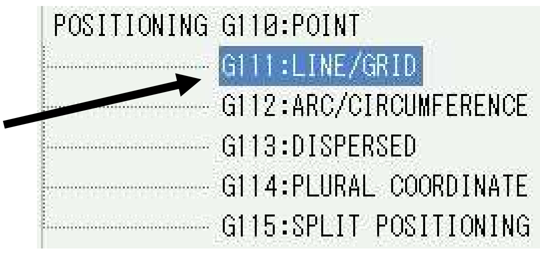
⇨ BLOCK ADD B11

The following machining model is outputted in the file.

G105O8010Z-3.0E7343B5.5S0M15;

(6) Select G111 (LINE/GRID) of the POSITION menu on the left side of the screen.

G111: Select the LINE/GRID



(7) Enter the set value in the called talk menu, and add the blocks.

POSITIONING – G111:LINE/GRID

Address	Attrib.	Talk items	Set Value
H	/	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	/	WORK COORD. SYSTEM	
X	*	START COORD X AXIS [u, t]	10.0
Y	*	(ABS) Y AXIS [u, t]	10.0
Z	*	Z AXIS [u, t]	1.0
P	*	PITCH WIDTH I AXIS [u, t]	15.0
Q	*	II AXIS [u, t]	10.0
U	/	MC EXTENT I AXIS START (n-th)	1
V	/	PROCESSION END (n-th)	3
I	/	II AXIS START (n-th)	1
J	/	END (n-th)	2
M	/	HOLE START (n-th)	
N	/	END (n-th)	
B	/	ROTATE ANGLE [0.001deg]	
K	/	SQUARE (1:ON)	
L	/	ANGLE INDEX (C AXIS, INDEX, DH)	
A	/	INDEX ANGLE [0.001deg]	
D	/	ELECT. ROT. OFFSET (1:ON)	
S	/	C AXIS SYNC PATTERN (1:ON)	
T	/	OPPOSITE (1:ON)	

⇨ BLOCK ADD B11

The following position model is outputted in the file.

G111X10.0Y10.0Z1.0P15.0Q10.0U1V3I1J2;

(8) Write "M30" command at the end of file and close the file.

MODEL END B 1 ⇨ ⬇ ⇨ M 3 0 ENTER ⇨ FILE CLOSE B11

(9) Start the machining program to execute the fine hole machining.

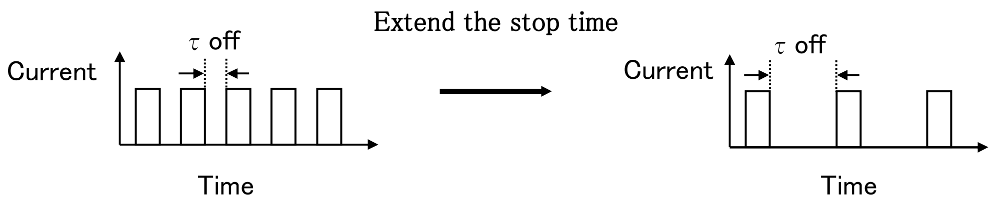
RUN F 2 ⇨ MEMORY RUN L 4 ⇨ O 2 0 ENTER ⇨ START

12.12 In Case of Faulty Machining

In fine hole machining by electrode dressing, a discharge may be unstable and the machining does not progress normally. In such a case, the machining conditions must be changed by measures. This section describes the points of machining condition change.

τoff : Discharge stop time

Setting a larger value can reduce the frequency of the discharge. Use this item when the discharge becomes unstable due to excessively strong machining power.

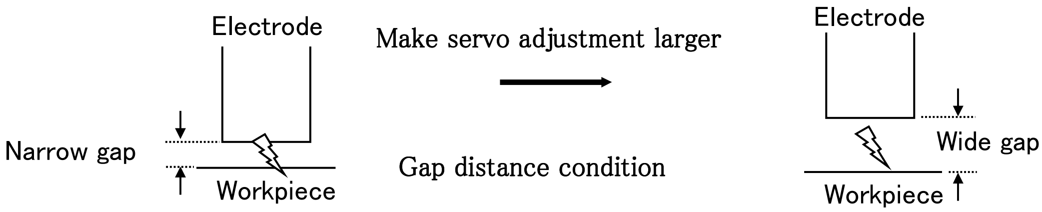


Discharge pulse generating condition

By solely making adjustment to the τOFF (discharge stop time) may not improve the discharge stability due to frequent short-circuits. The reason to this will be mentioned later. In such a case, include changes to the servo adjustment (SERVO_ADJ) as described below.

SERVO_ADJ (servo adjustment): Adjustment of gap distance

Setting a larger value can widen the distance of the gap (between electrode and workpiece). This item will be effective when the short-circuit occurs frequently during the discharge.



τOFF (discharge stop time).

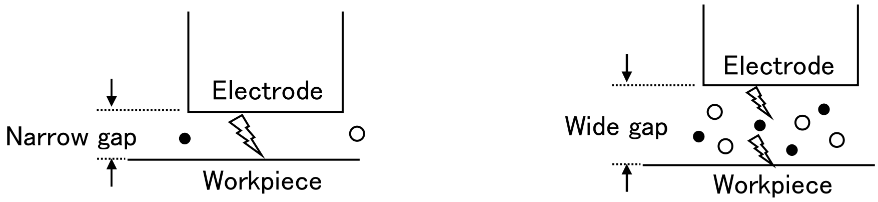
Similar to the effect of setting a larger servo adjustment value, a large discharge stop time value reduces the frequency of the discharge, Set an appropriate value by referring to the servo lamp and discharge sound.

CLK-S: Adjustment range of servo adjust

Sets an adjustment range for the servo adjustment (SERVO_ADJ).For CLK-S, four different values of 1, 2, 4, and 8 can be set. Setting a large value widens the servo adjustment range. Use this item when a wide discharge gap is to be set.

The reason why the adjustment of τoff and SERVO_ADJ (servo adjustment) are used together.

Setting a larger τ OFF (discharge stop time) will reduce the generation of machining debris and then narrow the discharge gap, because the discharge gap is determined by the intensity of sparks and the quantity of machining debris in the gap.



In case of less machining debris, the discharge fails unless the gap is narrow.

In case of much machining debris, the discharge is successful even if the gap is wide.

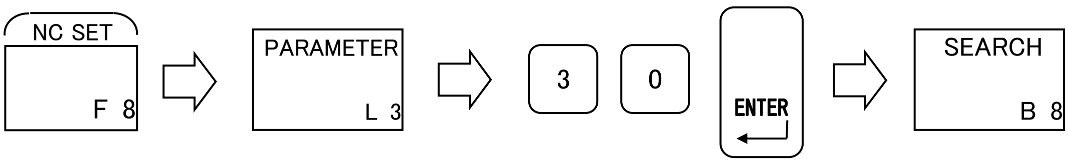
Narrow discharge gap causes frequent short-circuits (touch) between electrode and workpiece, resulting in unstable machining. Thus, the increase in servo adjustment must accompany the increase in discharge stop time to effectively widen discharge gap.

12.13 Macro Programs

The fine hole machining by the dressed electrode requires the following macro programs.

Program name	Registered O numbers
UMAC.108	O9010, O9020

Note: Normally, the programs after O8000 are write-protected. Perform the following operation, if the relevant O numbers are not found on the EDIT screen.



SET "0" to NO.30, 31 parameter

If the relevant O numbers have not been registered, please contact us.

12.14 Electrode Dressing Conditions

Dressing conditions of the electrode wear ratio 15 – 25%

＊ Machining conditions using Satin machining circuit

E number	7330	7331	7332	7333	7334	7335	7336	7337	7338	7339
Application range By elec. dia.[mm]	0.05 or more	0.07 or more	0.1 or more	0.12 or more	0.15 or more	0.17 or more	0.18 or more	0.2 or more	0.3 or more	0.5 or more
τON	1	1	1	1	1	1	1	1	1	1
τOFF	30	20	20	20	20	18	15	12	10	5
VH	0	0	1	2	3	4	5	5	5	5
VL	0	0	0	0	0	0	20	20	20	20
IPH	11	12	1	3	4	5	7	7	7	7
IPL	0	0	0	0	0	0	74	74	80	82
SERVO_NO.	5	5	5	5	5	5	5	5	5	5
POL	+	+	+	+	+	+	+	+	+	+
SERVO_ADJ.	13	13	13	14	14	15	15	15	15	15
CLK-S	1	1	1	1	1	1	1	1	1	1
WC 1	11	12	13	14	15	16	17	18	19	20
SERVO SPEED FORWORD.BACK	5.5~7.7	5.5	5.5	5.5	5.5	5.5	4.4	3.3	2.2	2.2

＊ The servo speed is automatically set during the dressing machining.

12.15 Fine Hole Machining Conditions for Dressed Electrodes

Fine hole rough machining conditions

Electrode AgW, CuW, W

Workpiece St, WC

＊ Machining conditions using Satin machining circuit

E number	7340	7341	7342	7343	7344	7345	7346	7347	7348	7349
Application range By elec. dia.[mm]	0.1 or more	0.1 or more	0.1 or more	0.1 or more	0.1 or more	0.15 or more	0.3 or more	0.4 or more	0.5 or more	0.6 or more
τON	1	1	1	1	1	1	1	1	1	1
τOFF	40	40	40	40	40	40	40	40	50	50
VH	0	1	2	3	4	5	6	7	7	7
VL	0	0	0	0	0	0	0	0	0	0
IPH	13	14	1	2	3	4	4	4	4	4
IPL	0	0	0	0	0	0	0	0	0	0
SERVO_NO.	5	5	5	5	5	5	5	5	5	5
POL	–	–	–	–	–	–	–	–	–	–
SERVO_ADJ.	15	16	16	17	20	20	20	20	20	20
CLK-S	4	4	4	4	4	4	4	4	4	4
WC 1	11	12	13	14	15	16	17	18	19	20
SERVO SPEED FORWORD.BACK	5.5~7.7	5.5~7.7	5.5~7.7	5.5~7.7	5.5	4.4	no need	no need	no need	no need

＊ Specify the O9010 item U: SERVO SPEED according to the machining conditions.

13. PUNCH MACHINING BY POLARITY REVERSE

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13.3 Machining program ･･･ 13－3

13.3.1 Guideline for machining program ･･･ 13－3

13.3.2 Polarity reverse ･･･ 13－4

13.3.3 Using of jump and dielectric processing together ･･･ 13－4

13.3.4 Machining model ･･･ 13－5

13.3.5 Notes in finish machining ･･･ 13－5

13.4 Machining example ･･･ 13－6

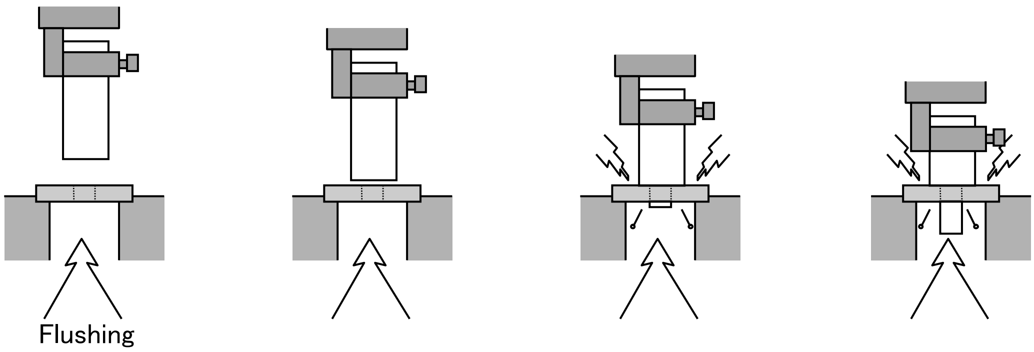
13.1 General description

In sinker EDM, machining is usually executed between workpiece (steel etc.) on the table and electrode (copper etc.) on the spindle. However, it is more effective installing the workpiece onto the spindle and the electrode on the table according to the machining shape.

This section describes polarity reverse machining as an example of punch machining.

The electrode is fixed to a fixture with a hole such that dielectric fluid processing is possible. And the workpiece is fixed to a holder onto the spindle.

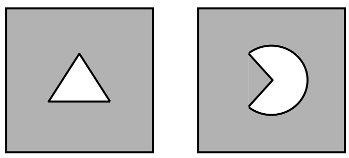
The characteristic of this machining is to finish up by taper machining with dielectric processing (flushing or suction).



13.2 Setup

①Electrode

Pulling out shape is made in a board electrode by wire EDM etc.

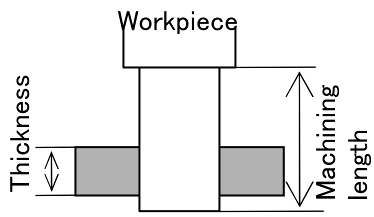


Set a large electrode reduction for rough machining.

Electrode	Reduction [mm]
Rough	0.3～0.5
Finish	0.1

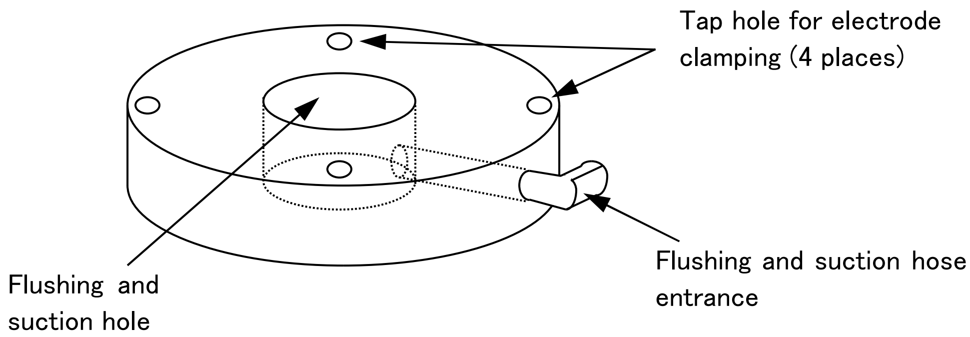
Select board electrode thickness according to the machining length.

Machining length	Thickness
Less than 20mm	5mm
20mm or more	10mm



②Dielectric processing

Dielectric processing is useful for shortening the machining time in rough machining.
The fixture is used to process dielectric on the table.



Prepare the fixture such that it does not leak dielectric so much with the workpiece clamping state in order to improve the effect of flushing and suction. Decide the hole size and thickness of the fixture according to the electrode shape and the machining length.

In flushing, set about 0.03MPa pressure under the machining.
In suction, adjust suction pressure by observing the machining state. The machining stability may worsen if suction is too strong.

13.3 Machining program

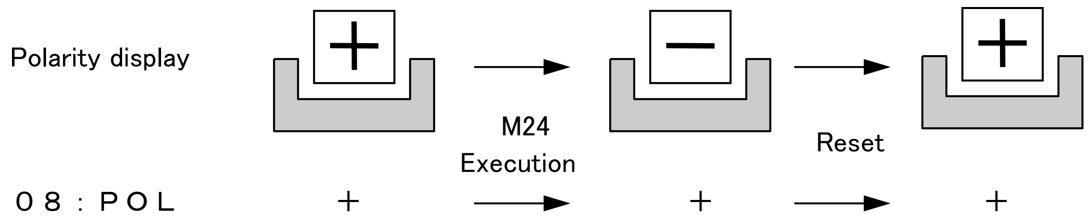
13.3.1 Guideline for machining program

The machining program is composed as follows.

		Main codes
①Polarity reverse		M24
②Roughing	Special setting	G132
	Machining model (Through)	G103
	Positioning model	G113 etc.
③Finishing	Special setting	G132
	Machining model (Through)	G103
	Positioning model	G113 etc.
④End		M30

13.3.2 Polarity reverse

In polarity reverse machining, it is necessary to reverse the polarity because standard model data are set for installing electrode to the spindle and workpiece on the table.
Add “M24;” at the beginning of the program in order to execute polarity reverse machining.
The polarity display on COND – EXECUTE screen reverses when “M24;” is executed. At this time, a machining condition element “08:POL” does not reverse.
Moreover, “M24” is released when resetting.



13.3.3 Using jump and dielectric processing together

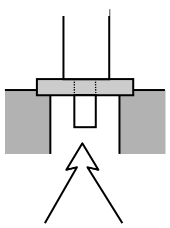
In case dielectric is not processed, set jump elements as follows.

Jump amount(S)	5～7 (1.0～1.4 mm)
Cycle(T)	7～10 (0.7～1.0 s)
Speed(F)	6～8 (300～400 mm/min)

The irregularity on the side can be reduced by using special setting (G132) together.

The jump cycle can be set long by dielectric processing and the machining time can be shortened. The examples of setting the jump according to dielectric processing method are shown as follows.

①For flushing from the fixture

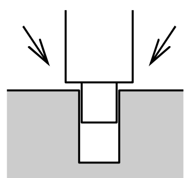


Rough　Jump OFF or jump cycle 2–3 seconds
(S0)　(S5 T3000 F8)

Finish　Special jump and jump cycle is longer
(S5 T12 F8)

Special jump : A-jump, cycle jump, servo jump,
(G132)　and discharging jump

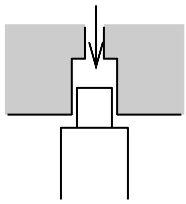
②For flushing from the side



Rough　jump cycle is longer
(S5 T12 F8)

Finish　Jump cycle is longer
(S5 T12 F8)

③For flushing from the electrode



Rough　Jump cycle 2-3 seconds
(S5 T3000 F8)

Finish　Special jump and jump cycle is longer
(S5 T12 F8)

Special jump : A-jump, cycle jump, servo jump,
(G132)　and discharging jump

Example of special setting

Ｇ１３２　Ｍ２Ｒ５０Ｕ５０．　Ｏ１　Ｐ１５；

Cycle jump　Discharging jump　Servo jump

13.3.4 Machining model

Usually, the through machining model (G103) is used with setting to item B "Side taper angle". This is because the upper diameter of the machining part grows a little compared to the under diameter of the punch machining.

Electrode	Machining length	Side taper angle
Rough	Any	-0.01
Finish	Less than 15mm	-0.01
	Less than 25mm	-0.015
	25mm or more	-0.02

Moreover, enter "1" to item L "Machining method".

Example of machining model

Ｇ１０３　Ｚ・・・・・　Ｌ１　Ｐ・・　Ｂ－０．０１　Ｓ・・・；

Machining method　Side taper angle

13.3.5 Notes in finish machining

①Select the model data suited by actual discharge area.

②Prevent the irregularity on the surface.

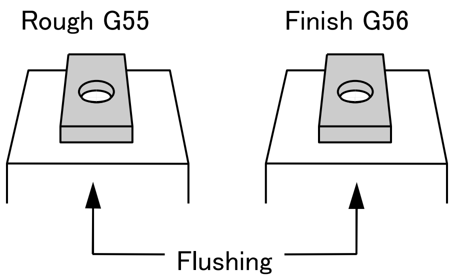
- Extend τ off by adjusting "τ OFF ADJ" on COND - MC SET screen and adjust duty factor (D.F.) 30% or less.
- Shorten jump cycle a little during uninhabited, continuous run.

③If there is presence of irregularity on the surface

- Repeat only the end process of the program. At this time, confirm ②.
- The stability of the machining is valued. And adjust flushing and suction pressure.

13.4 Machining example

Electrode	Cu (Thickness : 5mm)
Coord. system	Rough : G55
	Finish : G56
Electrode reduction	Rough : 0.3mm
	Finish : 0.1mm
Machining depth	−20.0mm
Flushing pressure	0.03MPa



Machining program

```
M24;
G132 A2;
G103 Z-20.0 R0.3 E423 I3 J7 O11 L1 P1111 B-0.01 S5 T12 F8;
G113 W55 X0 Y0 Z5.0;
G132 A2 M2 R50 U50.0 O1 P15;
G103 Z-20.0 R0.1 E123 I7 J11 O11 L1 P1111 B-0.015 S5 T12 F8;
G113 W56 X0 Y0 Z5.0;
M30;
```

14. HOW TO USE A CENTERING BALL

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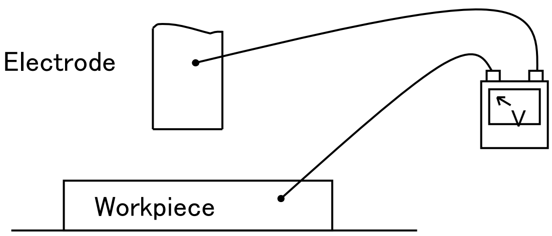
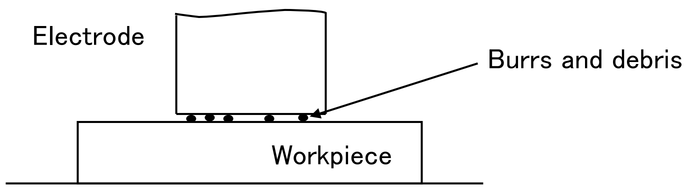
14.1 Merits of centering by using a centering ball and a measuring ball

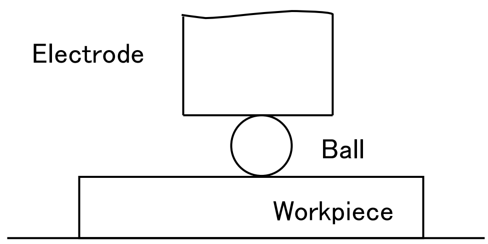
The NC EDM is equipped with the touch sensing function as standard.
This function provides various automatic measurements.
The principle of the touch sensing function is:



It detects insulation status between electrode and workpiece.
If electrode and workpiece are in continuity status, it stops the machine immediately.
On the other hand, the demerit of touch sensing function is that accuracy is lowered by the burrs or debris attached to the workpiece or electrode.



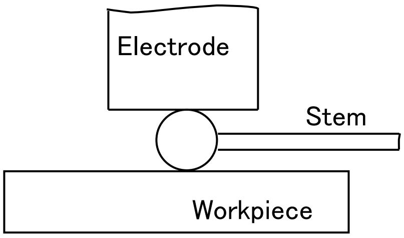
However, various functions cannot be utilized unless the touch sensing function is used.
Under these circumstances, a ball is introduced.

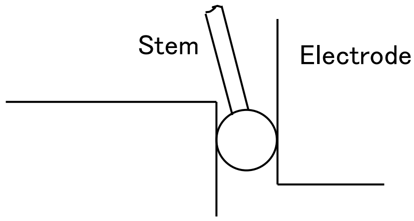


Use of the sphere reduces an error to 0.003 or less, which otherwise is 0.01 to 0.07.
In the NC EDM, it may be said that the coexistence of automation and machining accuracy depends on the usage of the ball.
Therefore, utilize the ball in various applications.

14.2 Utilization of ball 1

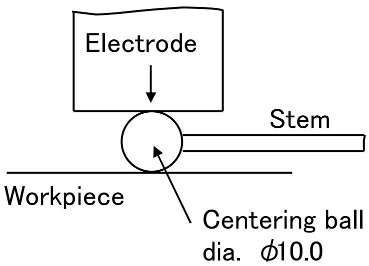
Attach a ball to the stem so that it can easily be inserted into the touch point, as shown below.





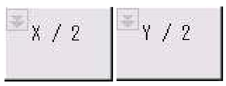
In the above centering, the following provides effective functions.

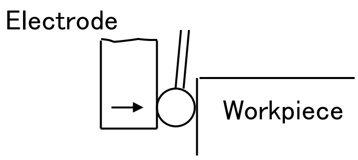
a) WORK SET B11 function



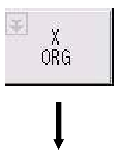
Under this condition, the following operation can be rewritten to the work coordinate.

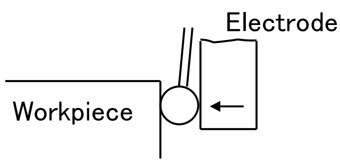
Z 10.0 

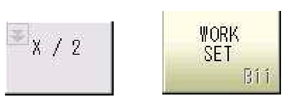
b) Use  function for halving



Execute touch sensing at the left edge of workpiece, and set the X axis origin.



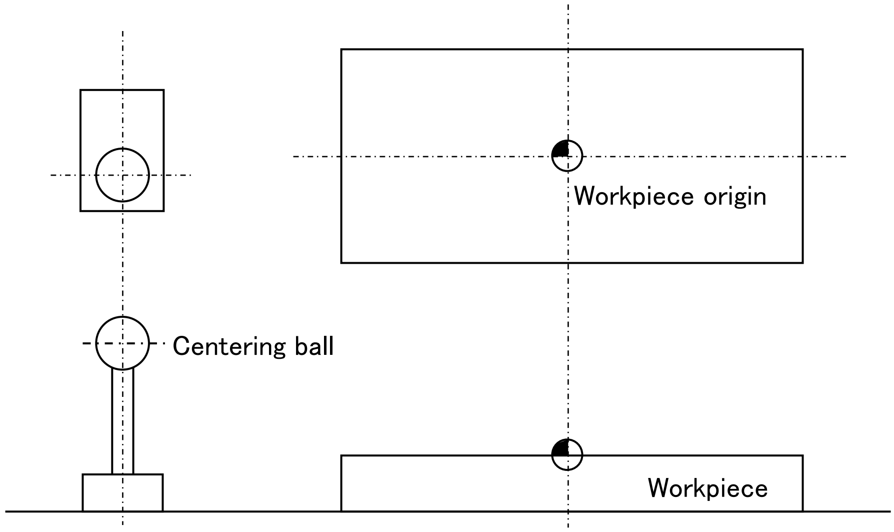




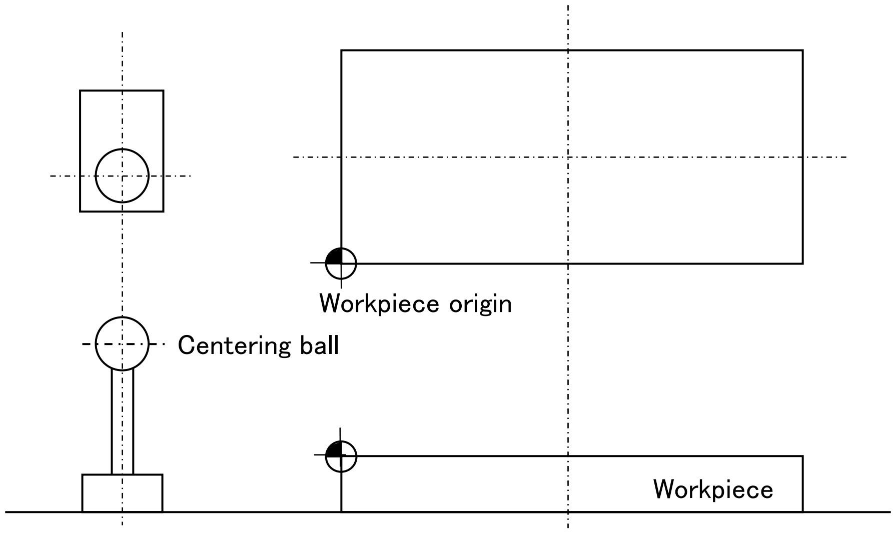
When the next operation is done after touch sensing at the right edge of workpiece, the work coordinate is halved and the X axis origin is set in the center of workpiece.

14.3 Utilization of ball 2

As shown below, the workpiece origin is replaced with a ball, and the electrode is positioned against the ball; The electrode does not touch the workpiece directly.



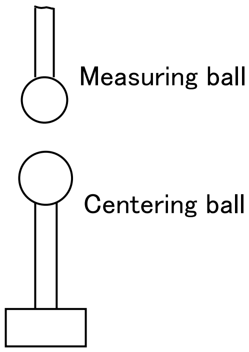
The ball to substitute for workpiece origin is called “centering ball”.
The workpiece origin is set in the center in the above figure, however, it may be at the corner.



(a) Replace the workpiece origin with a centering ball.

Position the center of centering ball at the origin of work coordinate system G54, a nd position the workpiece origin at the origin of work coordinate system G55.

(Setting G54)

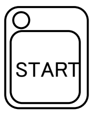


Prepare a measuring ball as shown to the left.
(It should be made in the method described later.)
Attach the measuring ball on the spindle, perform centering against the centering ball, and <u>set the origin of work coordinate system G54</u>.

MEASURE : MEASURE SPHERE (G125)

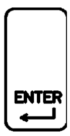
Address	Attri.	Talk items		Set value
R	*	SPINDLE BALL DIA.	[u, t]	10.0 ← Measuring ball dia. ϕ10.0
P	*	TABLE BALL DIA.	[u, t]	10.0 ← Centering ball dia. ϕ10.0
F	/	MEASURE RATE	[m, i/min]	
Q	/	ROT. ANGLE	[deg]	
K	/	RETRACT VALUE	[u, t]	
W	/	SET G54	(1:YES)	1
B	/	ROTATE AXIS CENTER COMP	(1:ON)	

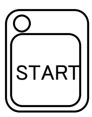
(when using a standard centering ball attached)



Thus, the point at which a measuring ball and a centering ball meet is the origin of work coordinate system G54.
Next, the work coordinate system G55 is set.

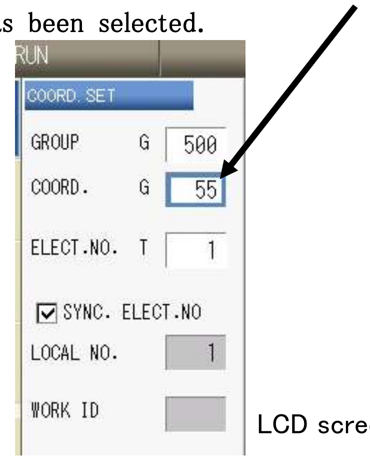
G55;





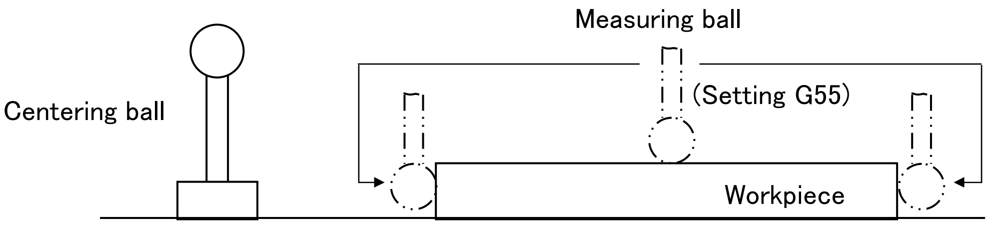
If the MODAL field on the 

screen display "55", the work coordinate system G55 has been selected.

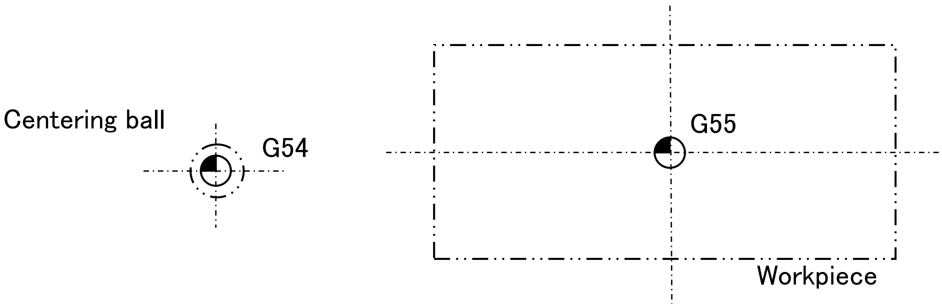


LCD screen

After a measuring ball is positioned against the workpiece, set the origin (work coordinate system G55) in the same manner as in usual work using an electrode.



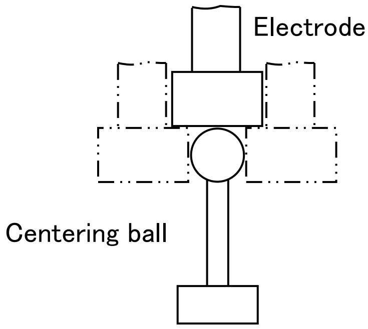
Upon completing the above procedures, the center of centering ball is positioned at both the origin of work coordinate system G54, and the workpiece reference origin of work coordinate system G55.



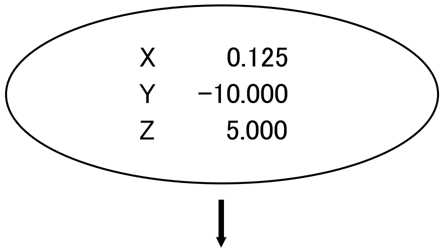
Thus, the workpiece origin has been replaced with the center of centering ball.

(b) Positioning of electrode

The electrode need not be positioned against the workpiece. That is, an error generated when the electrode is positioned against the centering ball means that it is the relative position between the center of measuring ball and the center of the electrode.

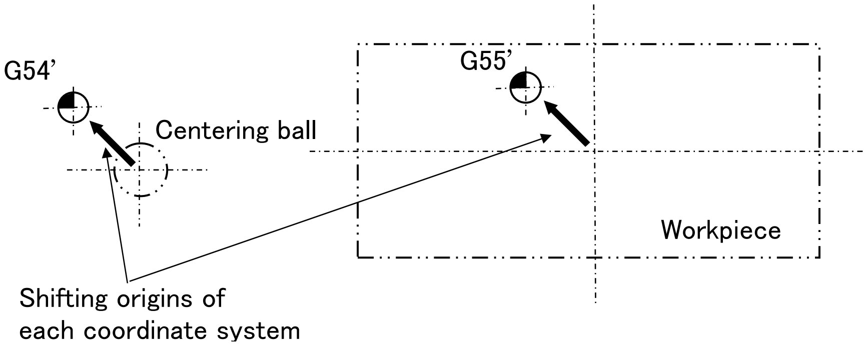


[Display example of work coordinates after centering]



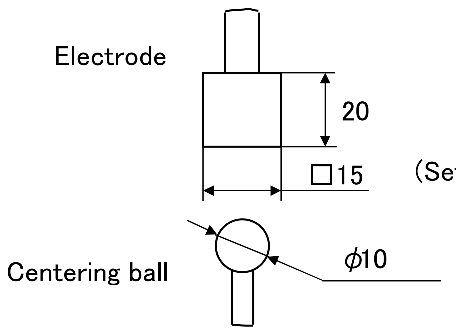
Means relative position between the measuring ball center and the electrode center.

There is a function that shifts temporarily the origins of all coordinate systems on the basis of this relative position.
This function is called "local offset function", and the temporary Shifted coordinate system is called "local coordinate system".



If the electrode is positioned at the origin of work coordinate system G55 with local coordinate system set, the reference point of workpiece coincides with the electrode center.
The above processing is automatically executed by the MEASURING menu described later.

(c) Example of electrode centering program



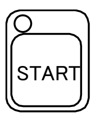
(Setting local coordinate system)

MEASURE : ELERCTRODE SPHERE (G126)

Address	Attri.	Talk items	Set value
P	/	TABLE BALL DIA. [u,t]	10.0
U	/	ELECT. MEA-PART MEA. X AXIS[u,t]	15.0
V	/	Y AXIS[u,t]	15.0
C	/	Z AXIS[u,t]	10.0
I	/	X CENTERING OFFSET X AXIS[u,t]	
J	/	(INC) Y AXIS[u,t]	
A	/	Y CENTERING OFFSET X AXIS[u,t]	
B	/	(INC) Y AXIS[u,t]	
Q	/	Z CENTERING OFFSET X AXIS[u,t]	
W	/	(INC) Y AXIS[u,t]	
F	/	MEASURE RATE [m,i/min]	
K	/	RETRACT VALUE [u,t]	
D	/	LOCAL CORD.SYSTEM SET (1:XYZ,2:Z)	1
N	/	ELECTRODE OFFSET	

Height from electrode bottom to touch point with centering ball

Local coordinate system is set to X,Y,Z axes.



Thus, the electrode has been positioned.

(d) Preparation of a machining program

An important thing in preparing a machining program is to set points in the work coordinate system G55.
The following provides a machining example where the depth of machining is 5 mm.

MC : BOTTOM STOPPED-SIMPLE(G101)

Address	Attri.	Talk items	Set value
N	/	ABS/INC (90/91)	
Q	/	MC AXIS (1:X, 2:Y, 3:Z)	
Z	*	MC DEPTH [u, t]	-5.0
R	*	ELECTRODE REDUCTION [u, t]	0.2
E	*	MODEL DATA No.	123
I	/	START OF PROCESS No.	5
J	/	END OF PROCESS No.	13
O	/	FINISH PROCESS No.	13
D	/	SIDE REMAIN AMOUNT COMP [%]	
H	/	BOTTOM REMAIN AMOUNT COMP [%]	
L	/	MC METHOD	13
P	/	PATTERN	2222
A	/	ROT. ANGLE [deg]	

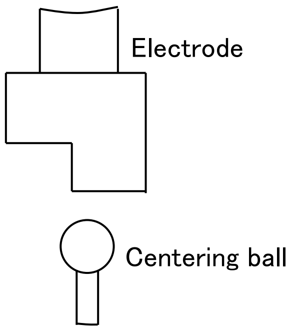
↓

POS. : DISPERSED (G113)

Address	Attri.	Talk items	Set value
H	/	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	/	WORK CORD. SYSTEM	55 ← Enter work coordinate system G55 set to the workpiece.
X	*	START CORD. X AXIS [u, t]	0
Y	*	(ABS) Y AXIS [u, t]	0
Z	*	Z AXIS [u, t]	5.0
U	/	No. 2 HOLE (ABS) I AXIS [u, t]	
V	/	II AXIS [u, t]	
I	/	No. 3 HOLE (ABS) I AXIS [u, t]	
J	/	II AXIS [u, t]	

14.4 Notes on utilizing centering ball

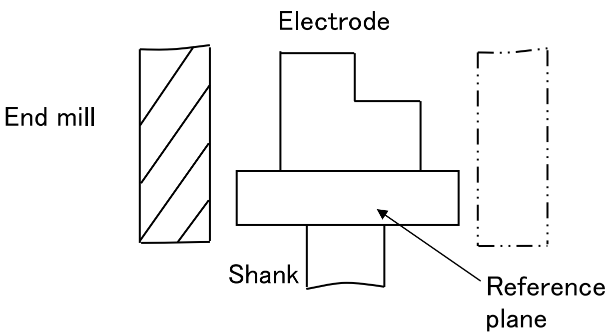
The previous section described how to use a centering ball. However, a question frequently asked:



As shown on the left figure, can a complex electrode be automatically positioned against the centering ball?

It is definitely possible. There are two methods to overcome this problem, as shown below.

(a) Assign the reference plane to the electrode. Also, standardize the shank diameter to one or two kinds.



As shown to the left, provide a reference plane when making the electrode.
Also, standardize the shank diameter to $\phi 10$ or $\phi 20$.

Assignment of a reference plane would be the most important thing in utilizing the ATC unit, etc. (At present, however, the reference plane as shown above cannot be provided when making the electrode by the wire EDM, but design various kinds of reference planes.)

(b) Utilization of ELECTRODE SPHERE menu

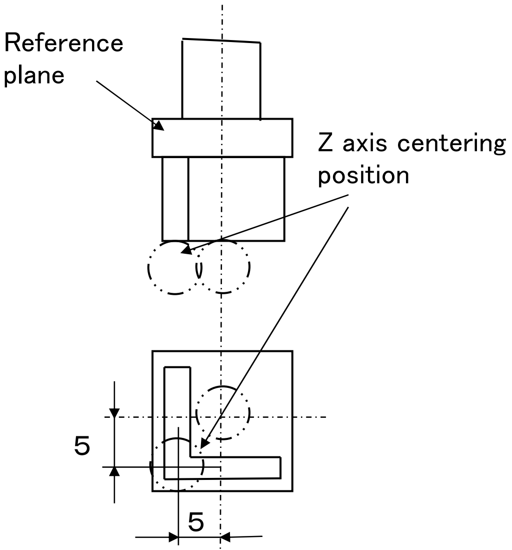
Utilize the CENTERING OFFSET in the ELECTRODE SPHERE menu.

MEASURE : ELERCTRODE SPHERE (G126)

Address	Attri.	Talk items	Set value
P	/	TABLE BALL DIA. [u, t]	
U	/	ELECT. MEA-PART MEA. X AXIS[u, t]	
V	/	Y AXIS[u, t]	
C	/	Z AXIS[u, t]	
I	/	X CENTERING OFFSET X AXIS[u, t]	
J	/	(INC) Y AXIS[u, t]	
A	/	Y CENTERING OFFSET X AXIS[u, t]	← Centering offset
B	/	(INC) Y AXIS[u, t]	
Q	/	Z CENTERING OFFSET X AXIS[u, t]	
W	/	(INC) Y AXIS[u, t]	
F	/	MEASURE RATE [m, i/min]	
K	/	RETRACT VALUE [u, t]	
D	/	LOCAL CORD. SYSTEM SET (1:XYZ, 2:Z)	
N	/	ELECTRODE OFFSET	

[Input example]

Z centering offset



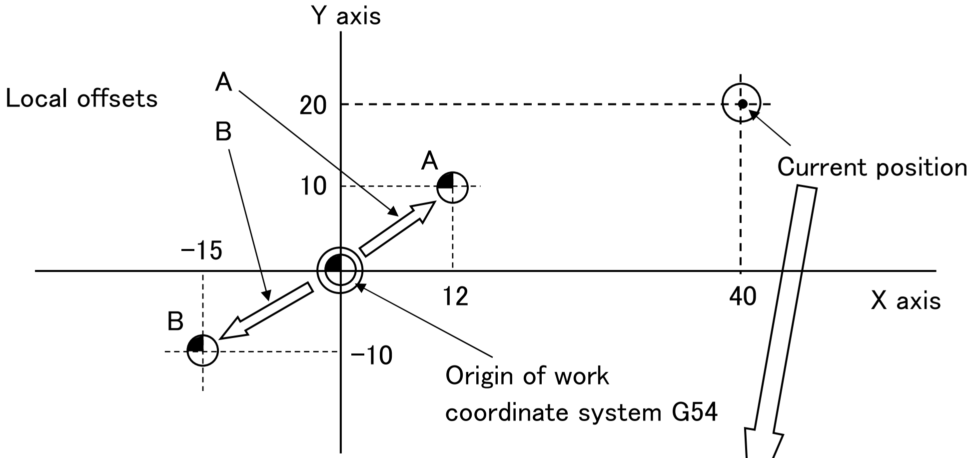
As shown on the left, if Z axis centering position is not in the center of reference plane, the X and Y axes can be shifted temporarily during Z axis centering.

MEASURE : ELERCTRODE SPHERE (G126)

C	/	Z AXIS[u, t]	
I	/	X CENTERING OFFSET X AXIS[u, t]	
J	/	(INC) Y AXIS[u, t]	
A	/	Y CENTERING OFFSET X AXIS[u, t]	
B	/	(INC) Y AXIS[u, t]	
Q	/	Z CENTERING OFFSET X AXIS[u, t]	5.0
W	/	(INC) Y AXIS[u, t]	-5.0
F	/	MEASURE RATE [m, i/min]	

14.5 Local coordinate system

The local coordinate system refers to the one in which the origin of the work coordinate system is temporarily offset.



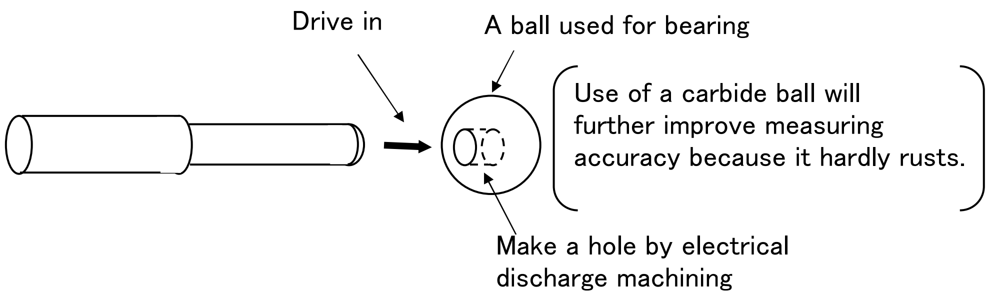
[Display when local offsets A and B are set]

Example of local coord. system	X axis	Y axis
Work coordinate system G54 (Local coord. system cancel)	40.000	20.000
Local coordinate system G54 Work cord. system G54 + Local offset A	28.000	10.000
Local coordinate syatem G54 Work cord. system G54 + Local offset B	55.000	30.000

Thus, the origin of work coordinate system can be shifted to any point without erasing it. This method is commonly used to compensate center error of an electrode. (Local offset values are all set to the work coordinate system G54 ～ G61 (G500 ～ G509) in the same manner.)

14.6 Preparation of a centering ball and a measuring ball

Normally, a centering ball and a measuring ball is supplied. However, several kinds of ball diameters will be necessary according to the workpiece and electrode used. Prepare the ball as shown in the method provided below.



As for a measuring ball, the diameter $\phi 3$, $\phi 5$, and $\phi 10$ will be suitable.

15. INDEX MACHINING

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15.2 Index machining 2

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15.3 Index machining 3

(use of C axis synchronous index function)················· 15－10

15.4 Index machining 4

(use of C axis synchronous index function)················· 15－12

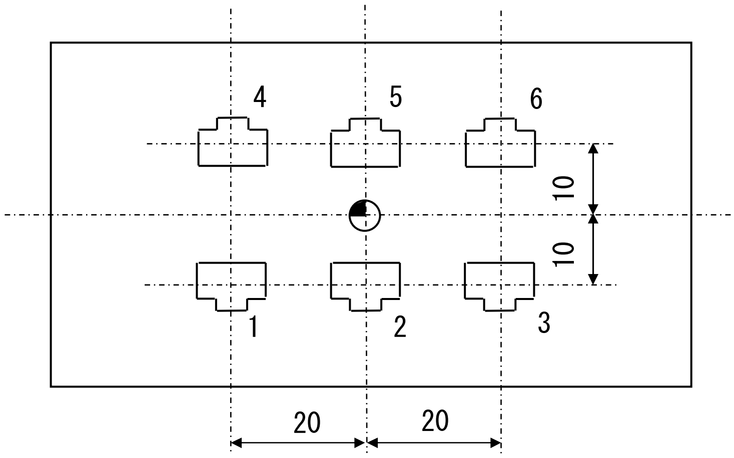
15.5 Index machining 5

(use of C axis synchronous index function)················· 15－15

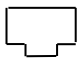
15. 1 Index machining 1 (use of C axis unit)

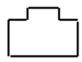
This method sets the coordinate system individually at each index position.

[Machining example]



＜Process＞

① With electrode in  position, specify the work coordinate system G54, perform centering on the basis of workpiece, and set the origin of all axes including C axis.

② Index the electrode 180° using the C axis so that it is in  position, then specify the work coordinate system G55, perform centering on the basis of workpiece, and set the origin of all axes including C axis.

③ Model plan input example

MC : Single MC (G100)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
X	／	MC DEPTH X AXIS [u, t]	
Y	／	Y AXIS [u, t]	
Z	／	Z AXIS [u, t]	-12. 0
C	／	C AXIS[rot. /ANGLE]	
W	／	AUTO DEPTH MAX. TRAVEL [u, t]	
L	／	MC LAST STOP (1:ON)	
E	*	MC COND. No.	1307
U	／	REMAIN AMOUNT [u, t]	
R	／	PATTERN RADIUS [u, t]	100
P	／	MODE/PATTERN	2222
A	／	ROT. ANGLE [0. 001deg]	
B	／	CIRCUIT SPEED [m. i/min]	
S	／	JUMP AMOUNT [code, u, t]	7
T	／	CYCLE [code, 0. 001sec]	3
F	／	SPEED [code, m. i/min]	8
I	／	CLAMP AMOUNT [u, t]	
H	／	TIME CONTROL TIME [min]	
M	／	START MC COND. No. (DF[%])	
D	／	START J. CYCLE [code, 0. 001sec]	
V	／	START MC REMAIN AMOUNT [u, t]	

↓

POS : Line/Grid (G111)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	54
X	*	START CORD. X AXIS [u, t]	-20.0
Y	*	(ABS) Y AXIS [u, t]	-10.0
Z	*	Z AXIS [u, t]	5.0
P	*	PITCH WIDTH I AXIS [u, t]	20.0
Q	*	II AXIS [u, t]	0
U	／	MC EXTENT I AXIS START (n-th)	1
V	／	PROCESSION END (n-th)	3
I	／	II AXIS START (n-th)	
J	／	END (n-th)	
M	／	HOLE START (n-th)	
N	／	END (n-th)	
B	／	ROTATE ANGLE [deg]	
K	／	SQUARE (1:ON)	
L	／	INDEX DEVICE (1:C AXIS, 2:IDX, 3:DH)	1
A	／	INDEX ANGLE [deg]	0
D	／	ELECT. ROT. OFFSET (1:ON)	1
S	／	C AXIS SYNC PATTERN (1:ON)	
T	／	OPPOSITE (1:ON)	

Specify an index unit (optional.). (C axis unit)

↓

POS : Line/Grid (G111)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55
X	*	START CORD. X AXIS [u, t]	-20.0
Y	*	(ABS) Y AXIS [u, t]	10.0
Z	*	Z AXIS [u, t]	5.0
P	*	PITCH WIDTH I AXIS [u, t]	20.0
Q	*	II AXIS [u, t]	0
U	／	MC EXTENT I AXIS START (n-th)	1
V	／	PROCESSION END (n-th)	3
I	／	II AXIS START (n-th)	
J	／	END (n-th)	
M	／	HOLE START (n-th)	
N	／	END (n-th)	
B	／	ROTATE ANGLE [deg]	
K	／	SQUARE (1:ON)	
L	／	INDEX DEVICE (1:C AXIS, 2:IDX, 3:DH)	1
A	／	INDEX ANGLE [deg]	0
D	／	ELECT. ROT. OFFSET (1:ON)	1
S	／	C AXIS SYNC PATTERN (1:ON)	
T	／	OPPOSITE (1:ON)	

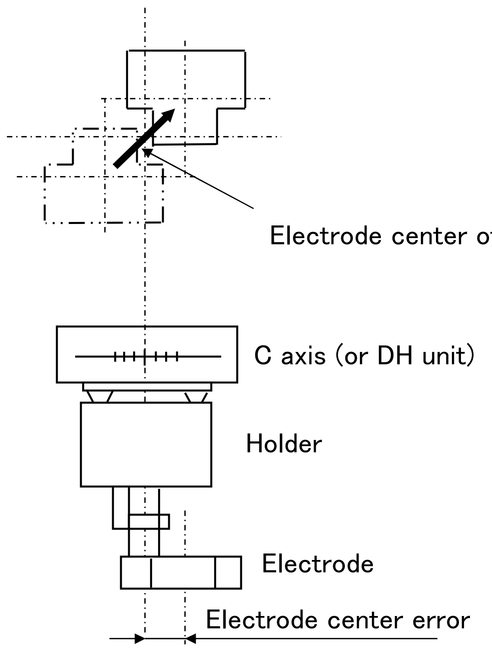
The index angle varies with a setting method of origin.

15.2 Index machining 2 (use of electrode rotation compensate function)

As the number of electrode increase, the origin setting by the index machining 1 and 2 will increase setting operation. In this case, the electrode rotation compensate (D) function is useful.

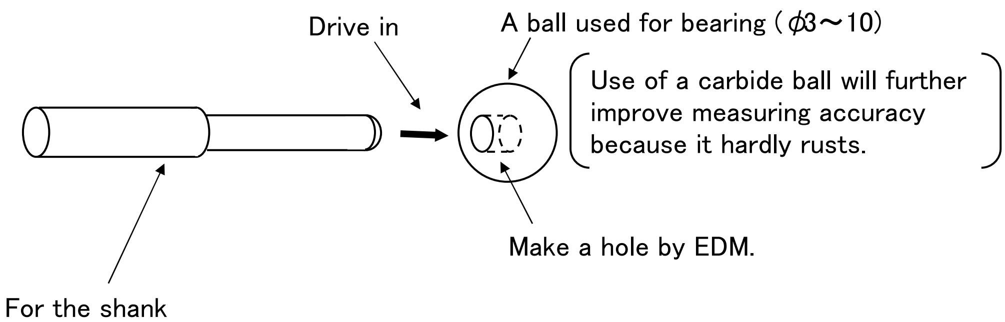
The electrode rotation compensate (D) function compensate the change in electrode center position that will occur when the electrode is indexed if the electrode is not positioned in the center of index unit.

[Electrode compensation at 180° index CCW]

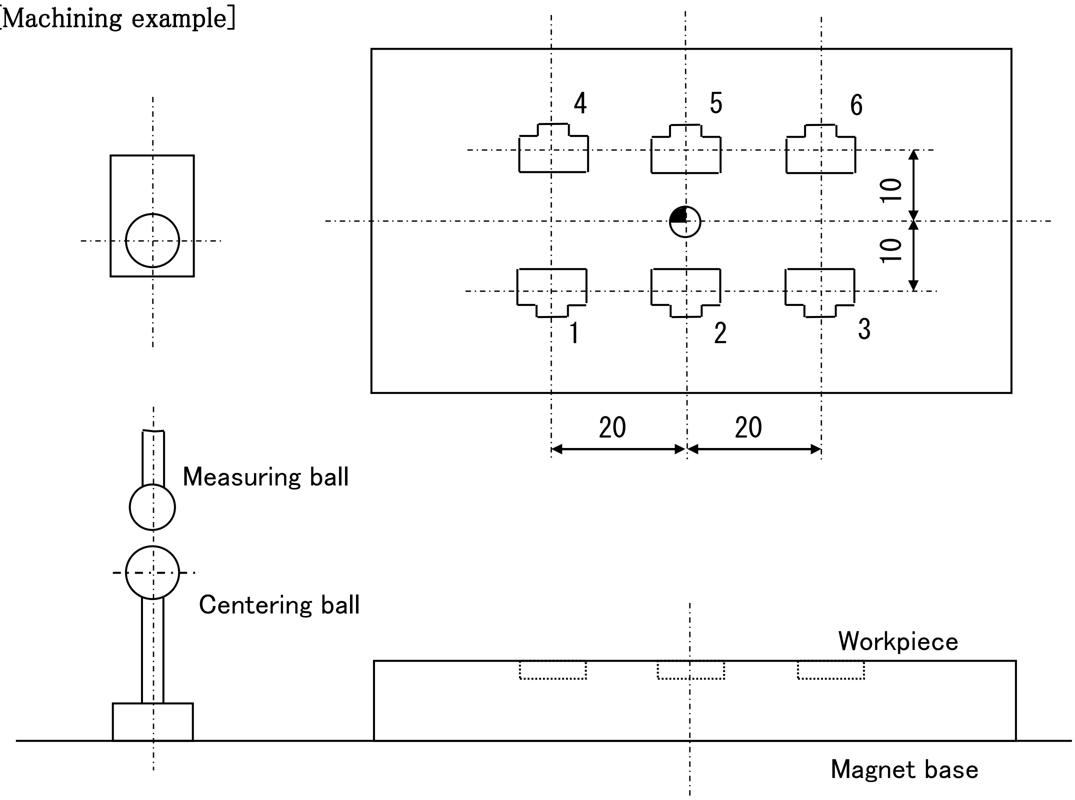


Before using the electrode rotation compensate (D) function, the electrode center error must be read. For this purpose, a centering ball and a measuring ball are required. Prepare the balls in advance.

Normally, a centering ball and a measuring ball is supplied. However, several kinds of ball diameters will be necessary according to the workpiece and electrode used. So, prepare the ball as necessary in the method provided below.



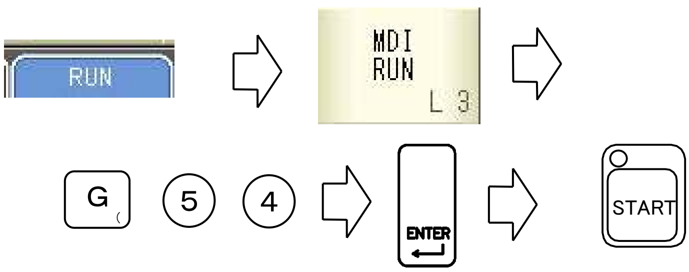
[Machining example]



[Procedure]

① Setting of origin and preparation of electrode rotation compensate function

(a)Set the work coordinate system G54 in MDI RUN mode.



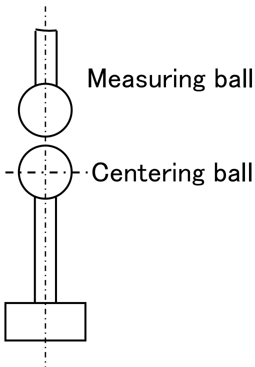
(b)Return the C axis to the origin (0°).

The index unit must be in origin since the electrode rotation compensate function provides compensation on the basis of origin (0°).

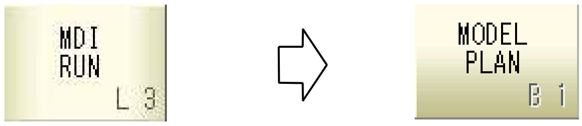
(c)Attach a measuring ball to the spindle.

At this time, the center of measuring ball must be within 3mm of rotation center.

And, move the measuring ball to over of the centering ball.



(d) The point at which the measuring ball is centered against the centering ball is assigned origin of work coordinate system G54. Then, register the dimension from this point to C axis rotation center to the parameter No.392 and 393.



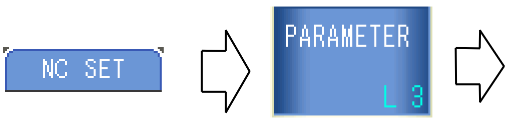
MEA ： Measure/Sphere (G125)

Address	Attri.	Talk items	Set value
R	＊	SPINDLE BALL DIA. [u, t]	10. 0
P	＊	TABLE BALL DIA. [u, t]	10. 0
F	／	MEASURE RATE [m, i/min]	
Q	／	ROT. ANGLE [deg]	
K	／	RETRACT VALUE [u, t]	
W	／	SET G54 (1:YES)	1
B	／	ROTATE AXIS CENTER COMP (1:ON)	
A	／	INDEX DEVICE(1:C AXIS, 2:IDX, 3:DH)	1
M	／	SAVE MEASURED BALL DIA. TO NO.	
E	／	MEA. ERROR LMT. (CENT. DIA.) [u, t]	1

Specify for setting rotating center position

Specify an index unit (optional.).

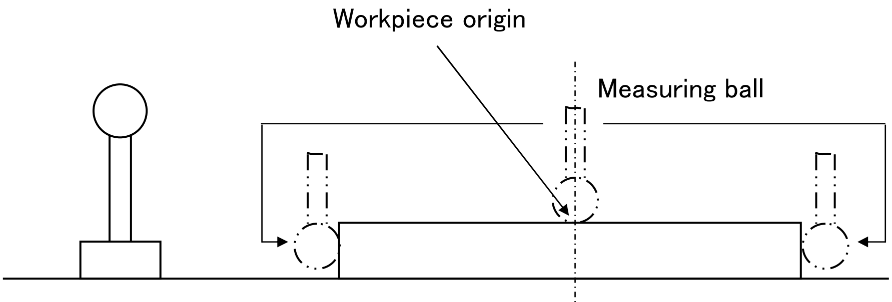
※ Confirm the offset data of parameter No.392 and 393.



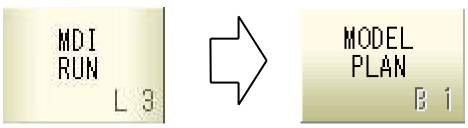
Parameter No.392 and 393.

0392	0.000	X AMOUNT FROM ROTATION CENTER TO MEASURE BALL CENTER
0393	0.000	Y AMOUNT FROM ROTATION CENTER TO MEASURE BALL CENTER

(e) Move the measuring ball on the workpiece, set the work coordinate system G55, and position the measuring ball against the workpiece to set the origin.



(f) Attach an electrode to the spindle. Center the electrode against the centering ball.

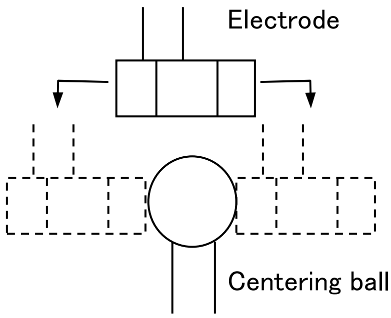


MEA : Electrode/Sphere (G126)

Address	Attri.	Talk items	Set value
P	／	TABLE BALL DIA. [u, t]	10.0
U	／	ELECT. MEA-PART MEA. X AXIS [u, t]	20.0
V	／	Y AXIS [u, t]	20.0
C	／	Z AXIS [u, t]	10.0
I	／	X CENTERING OFFSET X AXIS [u, t]	
J	／	(INC) Y AXIS [u, t]	
A	／	Y CENTERING OFFSET X AXIS [u, t]	
B	／	(INC) Y AXIS [u, t]	
Q	／	Z CENTERING OFFSET X AXIS [u, t]	
W	／	(INC) Y AXIS [u, t]	
F	／	MEASURE RATE [m, i/min]	
K	／	RETRACT VALUE [u, t]	
D	／	LOCAL CORD. SYSTEM SET (1:XYZ, 2:Z)	1
N	／	ELECTRODE OFFSET	
S	／	ELECTRODE OFFSET 2	
H	／	PARALLEL ADJ. (4:+X, 5:-X, 6:+Y, 7:-Y)	
T	／	MEASURE PITCH [m, t]	
M	／	MEASURE COUNT	
X	／	MEASURE ERROR LIMIT [m, t]	
O	／	SAVE MEASURED ELECT. DIA. TO NO [m, t]	
E	／	MEA. ERROR LMT (ELECT. DIA.) [u, t]	

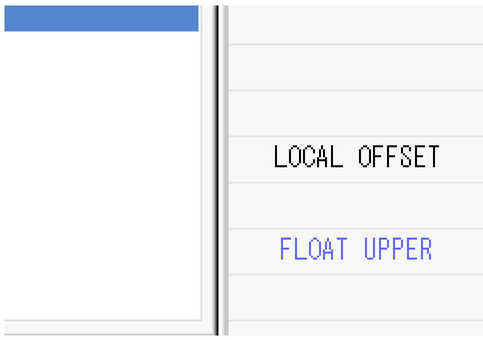
Enter each dimension.

A local coordinates system is set.



Measure offset amount between electrode and measuring ball. And local coordinate system is set. The offset value of local coordinate system is displayed on SET – LOCAL OFFSET screen.

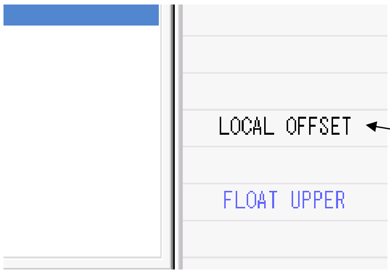
※ “LOCAL OFFSET” is displayed in the status display area on the screen when the local coordinate system is used.



Thus, the centering work is over.

(g) The following covers a complex electrode that cannot be centered automatically by the model plan in step (f).

i) Make sure that the local coordinate system has not been set.



"LOCAL OFFSET" is displayed when the local coordinate system is used.

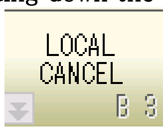
Execute following model plan in MDI RUN in order to cancel local coordinate system.

AUX : Coordinate system set (G130)

Address	Attri.	Talk items	Set value
W	／	WORK CORD. SYSTEM	
X	／	SET CORD. X AXIS [u, t]	
Y	／	Y AXIS [u, t]	
Z	／	Z AXIS [u, t]	
C	／	C AXIS [deg]	
L	／	LOCAL CORD. SYSTEM SET (1:ON)	1
I	／	SET CORD. X AXIS [u, t]	0
J	／	Y AXIS [u, t]	0
K	／	Z AXIS [u, t]	0
B	／	C AXIS [deg]	0
O	／	ELECT. OFFSET No. (LOCAL SET)	
T	／	WORK ROTATION (0:OFF, 1:ON)	

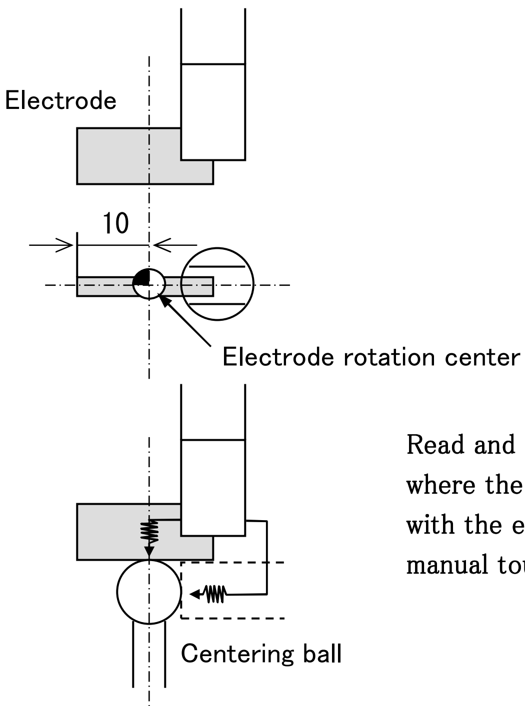
Local offset cancel

Another method is holding down the "LOCAL CANCEL" button.



ii) Set the work coordinate system G54 in MDI RUN mode.

iii) Make the electrode touch the centering ball manually, and read the coordinate value of electrode rotation center.



Read and record the coordinate value where the centering ball center coincides with the electrode rotation center through manual touch sensing.

②Model plan input example

MC : Bottom stopped – simple (G101) etc.

↓

POS : Line/Grid (G111)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55
X	＊	START CORD. X AXIS [u, t]	-20.0
Y	＊	(ABS) Y AXIS [u, t]	-10.0
Z	＊	Z AXIS [u, t]	5.0
P	＊	PITCH WIDTH I AXIS [u, t]	20.0
Q	＊	II AXIS [u, t]	0
U	／	MC EXTENT I AXIS START (n-th)	1
V	／	PROCESSION END (n-th)	3
I	／	II AXIS START (n-th)	
J	／	END (n-th)	
M	／	HOLE START (n-th)	
N	／	END (n-th)	
B	／	ROTATE ANGLE [0.001deg]	
K	／	SQUARE (1:ON)	
L	／	INDEX DEVICE (1:C AXIS, 2:IDX, 3:DH)	1
A	／	INDEX ANGLE [deg]	0
D	／	ELECT. ROT. OFFSET (1:ON)	1
S	／	C AXIS SYNC PATTERN (1:ON)	
T	／	OPPOSITE (1:ON)	

Specify an index unit (optional).

↓

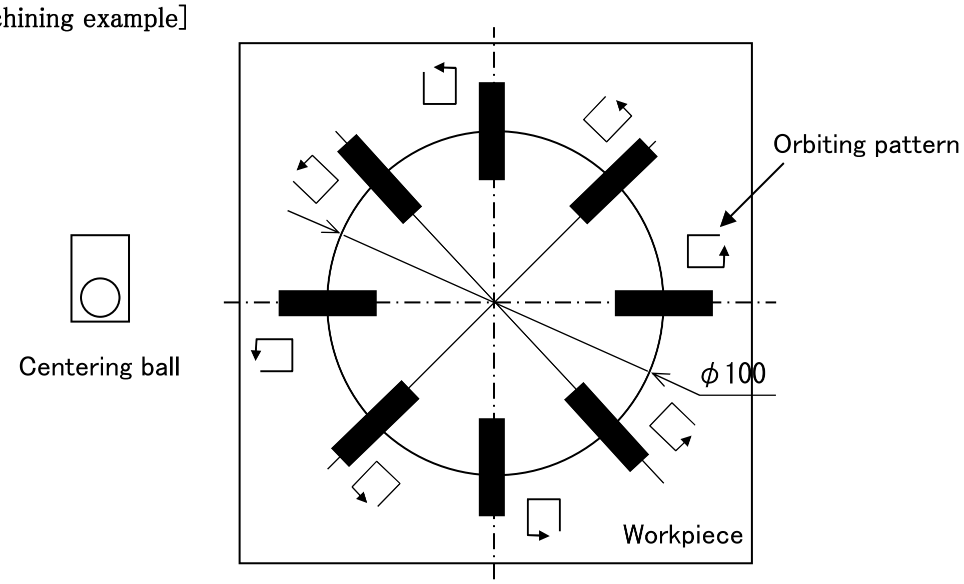
POS : Line/Grid (G111)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55
X	＊	START CORD. X AXIS [u, t]	-20.0
Y	＊	(ABS) Y AXIS [u, t]	10.0
Z	＊	Z AXIS [u, t]	5.0
P	＊	PITCH WIDTH I AXIS [u, t]	20.0
Q	＊	II AXIS [u, t]	0
U	／	MC EXTENT I AXIS START (n-th)	1
V	／	PROCESSION END (n-th)	3
I	／	II AXIS START (n-th)	
J	／	END (n-th)	
M	／	HOLE START (n-th)	
N	／	END (n-th)	
B	／	ROTATE ANGLE [0.001deg]	
K	／	SQUARE (1:ON)	
L	／	INDEX DEVICE (1:C AXIS, 2:IDX, 3:DH)	1
A	／	INDEX ANGLE [deg]	180.0
D	／	ELECT. ROT. OFFSET (1:ON)	1
S	／	C AXIS SYNC PATTERN (1:ON)	
T	／	OPPOSITE (1:ON)	

15.3 Index machining 3 (use of C axis synchronous index function)

In a machining that requires a complex indexing unlike a simple indexing such as 0° and 180°, the electrode and the orbiting pattern must also be rotated in the index direction.

[Machining example]

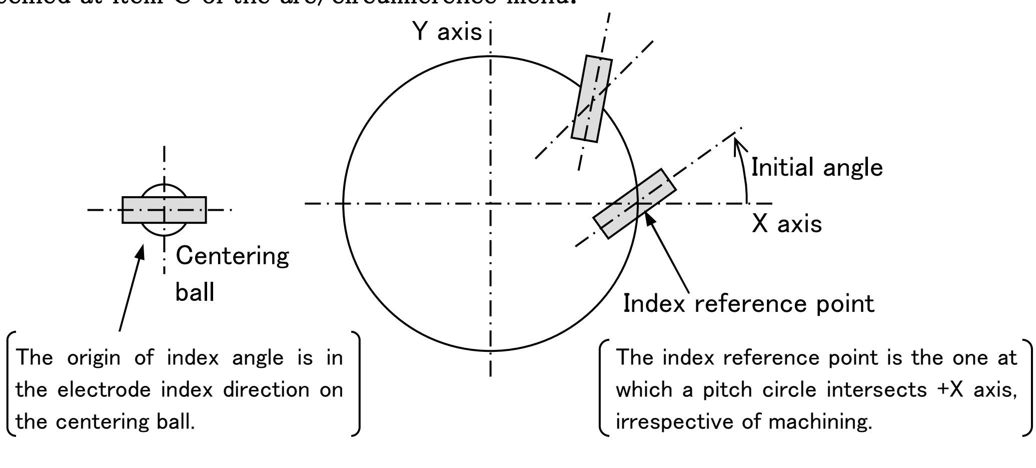


As shown above, the function that rotates the electrode and the orbiting pattern in the index direction is called "C axis synchronous index function".

It is used in the arc/circumference menu of model plan.

・ Initial angle (C)

The electrode index angle at the index reference point is called "initial angle". It is specified at item C of the arc/circumference menu.



POS : Arc/Circumference (G112)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	
X	＊	CENTER CORD. X AXIS [u, t]	
Y	＊	(ABS) Y AXIS [u, t]	
Z	＊	Z AXIS [u, t]	
C	／	C AXIS [deg]	
R	＊	RADIUS [u, t]	
P	／	(1)PITCH ANGLE [deg]	
:	:	:	

Set initial angle.

・Orbiting pattern angle (A)

The orbiting pattern rotation angle (A) can be set in each machining menu. This angle is only used when the orbiting pattern is to be rotated on the basis of the electrode in the index origin (the electrode index angle on the centering ball).

The C axis synchronous index function adds index angle to the orbiting pattern rotation angle (A), and the orbiting pattern is then rotated.

[Procedure]

① For the electrode rotation compensate function and centering method, refer to clause 15.2.

②Model plan input example

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	
Z	＊	MC DEPTH [u, t]	-5.0
R	＊	ELECTRODE REDUCTION [u, t]	0.2
E	＊	MODEL DATA No.	123
I	／	START OF PROCESS No.	6
J	／	END OF PROCESS No.	13
O	／	FINISH PROCESS No.	13
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT.ANGLE [deg]	
S	／	JUMP AMOUNT [code, u, t]	7
:	:	:	

Set initial orbiting pattern rotation angle. (No required in this case)

POS : Arc/Circumference (G112)

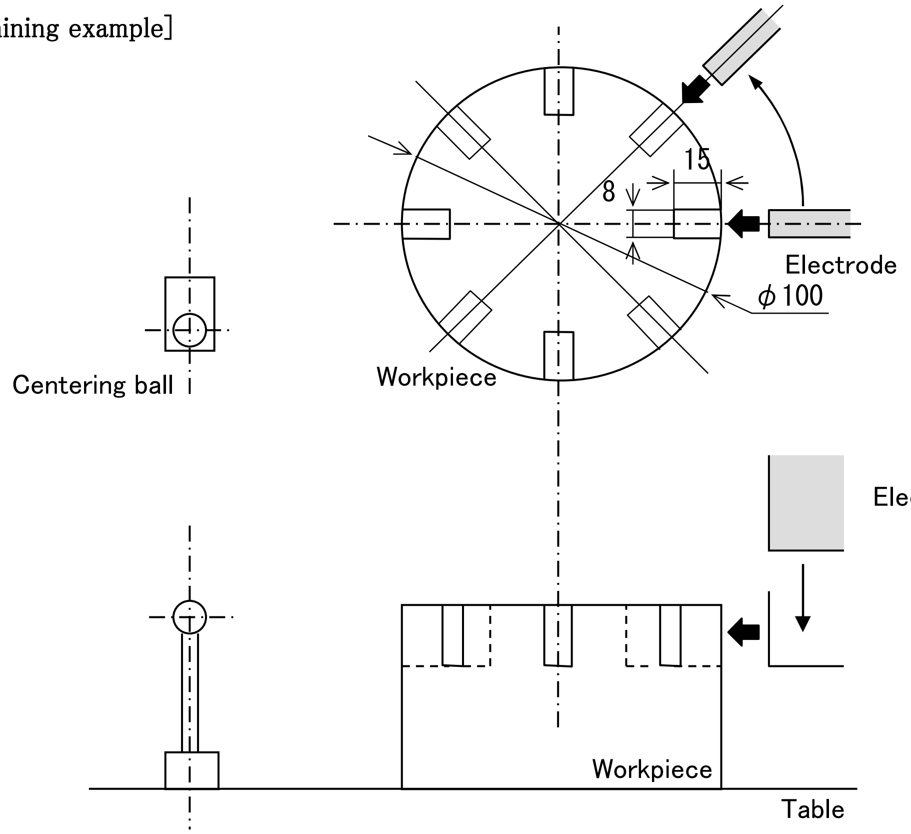
Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55
X	＊	CENTER CORD. X AXIS [u, t]	0
Y	＊	(ABS) Y AXIS [u, t]	0
Z	＊	Z AXIS [u, t]	5.0
C	／	C AXIS [deg]	0
R	＊	RADIUS [u, t]	50.0
P	／	(1)PITCH ANGLE [deg]	
N	／	(2)DIVIDE EQUALLY NUMBER	8
B	／	START POI.ANGLE [deg]	
M	＊	HOLES [pcs.]	8
O	／	C AXIS SYNC INDEX (1:ON)	1
D	／	ELECT. ROT. OFFSET (1:ON)	1
T	／	OPPOSITE (1:ON)	

Set initial angle.

15.4 Index machining 4 (use of C axis synchronous index function)

This paragraph describes a machining example in which machining direction is changed in addition to the electrode indexing.

[Machining example]



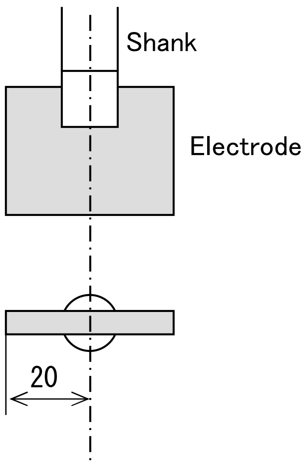
The electrode and machining direction can be rotated according to the index angle by setting the C axis synchronous index function.

・Note on making an electrode

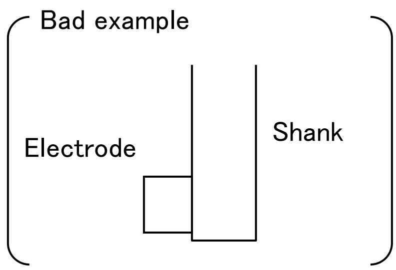
Even in a machining that uses only a part of end face of electrode as shown above, the electrode shape should be the one that easily halves the dimension in the center. Otherwise, the centering work as described in clause 15.2 (g) is required.

[Example of electrode form]

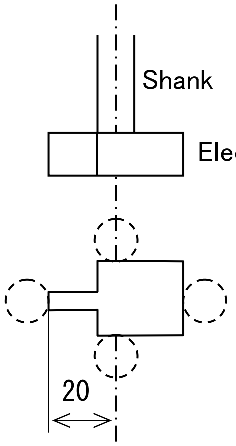
i)



The electrode has enough size to perform centering against the centering ball.



ⅱ) The electrode form is suitable for centering

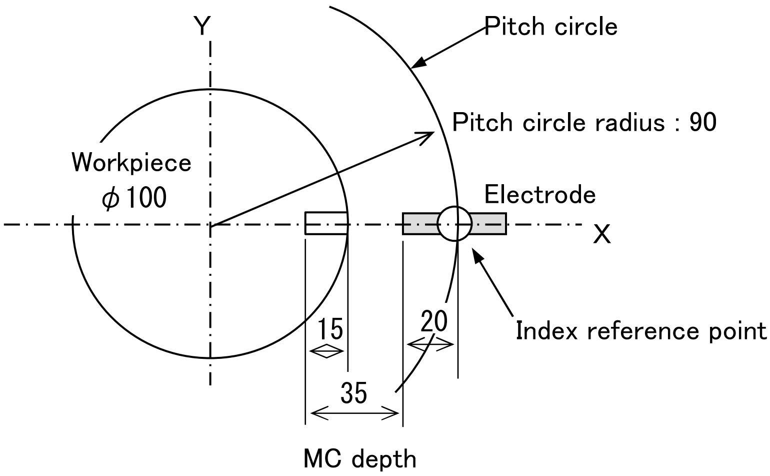


As shown above, design the electrode form so that it can be centered against the centering ball.

・Setting the machining depth and pitch circle radius

The machining depth must be set with INC value.

Also, the pitch circle radius should be large enough while taking into account the workpiece diameter and electrode diameter.



Assuming that the pitch circle radius is 90,

Machining depth = 90 − 50 − 20 + 15

= 35

The machining direction is the one at the index reference point.

It will be automatically changed according to the index angle.

MC : Bottom stopped − simple (G101)

Address	Attri.	Talk items		Set value
N	／	ABS/INC	(90/91)	91
Q	／	MC AXIS	(1:X, 2:Y, 3:Z)	1
Z	＊	MC DEPTH	[u, t]	-35.0
R	＊	ELECTRODE REDUCTION	[u, t]	0.2
E	＊	MODEL DATA No.		123
:	:	:		

Set INC mode.

・Input of positioning height

Enter the positioning height at the beginning of program since the Z axis in the arc/circumference menu is specified at the machining position.

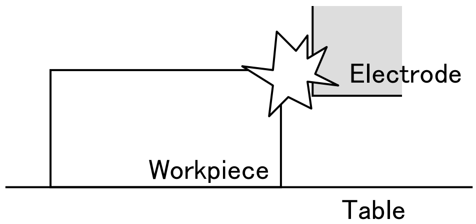
G55 G90;

G00 Z5.0; ← Positioning height

Machining model

Positioning model(G112)

※ If the positioning height is not specified, be sure to raise the electrode above the workpiece by manual operation. Otherwise, the electrode can hit against the workpiece.



[Procedure]

① For the electrode rotation compensate function and centering method, refer to clause 15.2.

②Model plan input example

G55 G90;

G00 Z5.0; ← Positioning height

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	91
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	1
Z	＊	MC DEPTH [u, t]	-35.0
R	＊	ELECTRODE REDUCTION [u, t]	0.2
E	＊	MODEL DATA No.	123
I	／	START OF PROCESS No.	6
J	／	END OF PROCESS No.	13
O	／	FINISH PROCESS No.	13
D	／	SIDE REMAIN AMOUNT COMP [%]	
:	:	:	

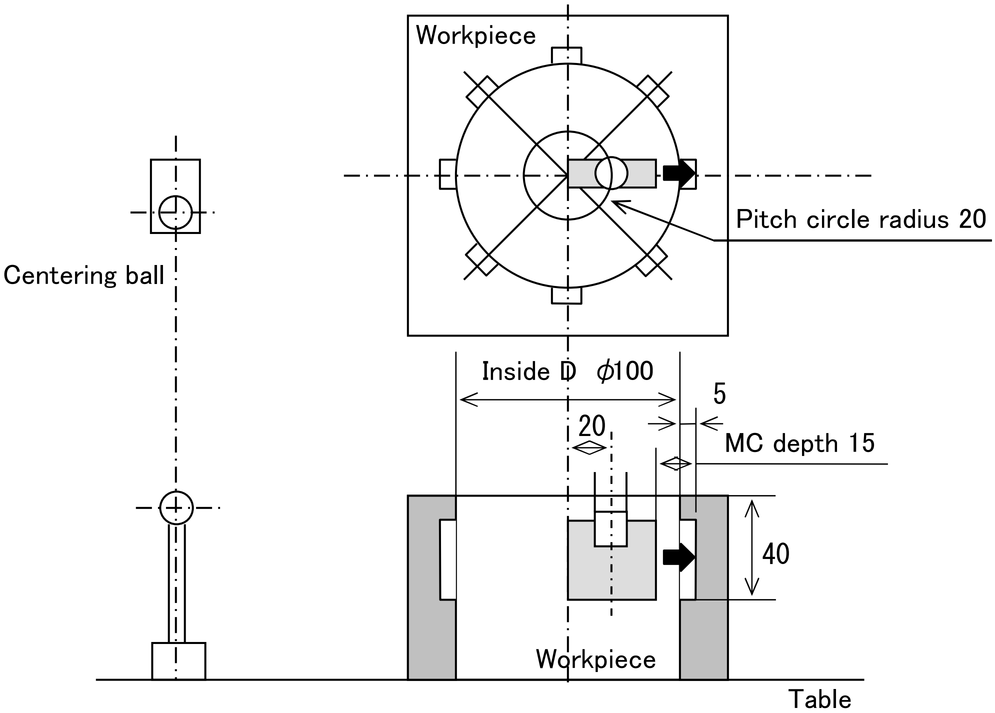
↓

POS : Arc/Circumference (G112)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55
X	＊	CENTER CORD. X AXIS [u, t]	0
Y	＊	(ABS) Y AXIS [u, t]	0
Z	＊	Z AXIS [u, t]	-19.8 ← Subtract the electrode reduction (R).
C	／	C AXIS [deg]	0
R	＊	RADIUS [u, t]	90.0
P	／	(1)PITCH ANGLE [deg]	
N	／	(2)DIVIDE EQUALLY NUMBER	8
B	／	START POI.ANGLE [deg]	
M	＊	HOLES [pcs.]	8
O	／	C AXIS SYNC INDEX (1:ON)	1
D	／	ELECT. ROT. OFFSET (1:ON)	1
T	／	OPPOSITE (1:ON)	

15.5 Index machining 5 (use of C axis synchronous index function)

This paragraph describes a machining example in clause 15.4 with exception that the machining direction is from inside to outside.



The positioning height must be set in the same reason as in clause 15.4.
Also, additional items should be set in the same manner as in clause 15.4.

[Procedure]

① For the electrode rotation compensate function and centering method, refer to clause 15.2.

②Model plan input example

G55 G90;

G00 Z5.0; ← Positioning height

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	91
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	1
Z	＊	MC DEPTH [u, t]	15.0
R	＊	ELECTRODE REDUCTION [u, t]	0.2
E	＊	MODEL DATA No.	123
I	／	START OF PROCESS No.	6
J	／	END OF PROCESS No.	13
O	／	FINISH PROCESS No.	13
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT.ANGLE [deg]	
S	／	JUMP AMOUNT [code, u, t]	
:	:	:	

↓

POS : Arc/Circumference (G112)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55
X	*	CENTER CORD. X AXIS [u, t]	0
Y	*	(ABS) Y AXIS [u, t]	0
Z	*	Z AXIS [u, t]	-39.8
C	／	C AXIS [0.001deg]	0
R	*	RADIUS [u, t]	20.0
P	／	(1)PITCH ANGLE [deg]	
N	／	(2)DIVIDE EQUALLY NUMBER	8
B	／	START POI.ANGLE [deg]	
M	*	HOLES [pcs.]	8
O	／	C AXIS SYNC INDEX (1:ON)	1
D	／	ELECT. ROT. OFFSET (1:ON)	1
T	／	OPPOSITE (1:ON)	

Subtract the electrode reduction (R).

16. USE OF ATC

The following three kinds of ATC are available.

Select one according to the workpiece and accuracy required.

Type	Contents	Application	Difficulty
ATC–1	Work coordinate system	Not suitable for plural workpiece	Easy
ATC–2	Centering ball Work coordinate system Local coordinate system	High precision Plural workpieces Not suitable for complex electrode	Difficult
ATC–3	Work coordinate system Electrode offset Local coordinate system	Plural workpieces	Difficult

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16.1 ATC-1

This method sets the origin of work coordinate system (G54 to G61) individually for respective electrode.

[Procedure]

① Set the origin by changing and centering the work coordinate system for each electrode.

Example)

Electrode No.	Work coordinate system No.
1	G54
2	G55
3	G56
4	G57
5	G58
6	G59
7	G60
8	G61

② Model plan input example

Input example when the electrode 1 is already in the spindle.

MC : Single MC (G100)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
X	／	MC DEPTH X AXIS [u, t]	
Y	／	Y AXIS [u, t]	
Z	／	Z AXIS [u, t]	-9.5
C	／	C AXIS [ANGLE]	
W	／	AUTO DEPTH MAX. TRAVEL [u, t]	
L	／	MC LAST STOP (1:ON)	
E	＊	MC COND No.	1309
U	／	REMAIN AMOUNT [u, t]	
:	:	:	

POS : Line/Grid (G111)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	54
X	＊	START CORD. X AXIS [u, t]	0
Y	＊	(ABS) Y AXIS [u, t]	0
Z	＊	Z AXIS [u, t]	5.0
P	＊	PITCH WIDTH I AXIS [u, t]	20.0
Q	＊	II AXIS [u, t]	0
U	／	MC EXTENT I AXIS START (n-th)	1
V	／	PROCESSION END (n-th)	4
I	／	II AXIS START (n-th)	
J	／	END (n-th)	
M	／	HOLE START (n-th)	
:	:	:	

Work coordinate system No. associated with electrode No.1

AUX : ATC (G131)

Address	Attri.	Talk items	Set value
M	／	ATC RTN PRO. (1:Z-X-Y, 2:Z-Y-X)	3
F	／	ROBOT CHUCK (1:U, 2:D, 3:R, 4:L)	
T	／	ELECTRODE No.	2
S	／	SPINDLE ELEC. No.	1
O	／	ELECT.OFFSET No. (LOCAL SET)	
W	／	END WORK CORD. SYS.	55
X	／	COORDINATE X AXIS [u, t]	0
Y	／	(ABS) Y AXIS [u, t]	0
Z	／	Z AXIS [u, t]	20.0
C	／	C AXIS [0.001deg]	
N	／	MACHINING PROGRAM O No.	
D	／	WORK TANK DOWN (ROBOT ONLY)	

This may be omitted at the next electrode change.

Work coordinate system No. associated with electrode No.2.

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	
Z	＊	MC DEPTH [u, t]	-10.0
R	＊	ELECTRODE REDUCTION [u, t]	0.25
E	＊	MODEL DATA No.	123
I	／	START OF PROCESS No.	4
J	／	END OF PROCESS No.	13
O	／	FINISH PROCESS No.	13
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT.ANGLE [deg]	
:	:	:	

POS : Line/Grid (G111)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55
X	＊	START CORD. X AXIS [u, t]	0
Y	＊	(ABS) Y AXIS [u, t]	0
Z	＊	Z AXIS [u, t]	5.0
P	＊	PITCH WIDTH I AXIS [u, t]	20.0
Q	＊	II AXIS [u, t]	0
U	／	MC EXTENT I AXIS START (n-th)	1
V	／	PROCESSION END (n-th)	4
I	／	II AXIS START (n-th)	
J	／	END (n-th)	
M	／	HOLE START (n-th)	
:	:	:	

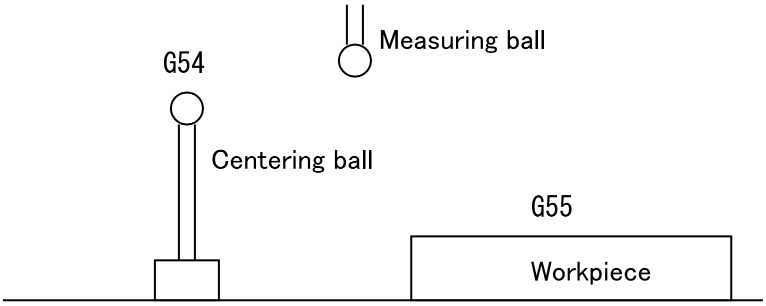
Work coordinate system No. associated with electrode No.2.

This number is omissible if already entered in ATC menu.

Enter in the same manner for the electrode No.3 and subsequent electrodes.

16.2 ATC-2

This method uses a centering ball to adjust position immediately after electrode change during machining, thereby suitable for high precision machining.
However, the use of a complex electrode makes centering difficult. It is, therefore, necessary to standardize holders and to prepare the reference part on the electrode.
[Procedure]
① Attach a centering ball onto the spindle and set the origin of G54 work coordinate system to the centering ball, and the origin of G55 to the workpiece.



・Setting origin of work coordinate system (G54) to centering ball

MEA : Measure/Sphere (G125)

Address	Attri.	Talk items	Set value
R	*	SPINDLE BALL DIA. [u,t]	10.0
P	*	TABLE BALL DIA. [u,t]	10.0
F	／	MEASURE RATE [m,i/min]	
Q	／	ROT.ANGLE [deg]	
K	／	RETRACT VALUE [u,t]	
W	／	SET G54 (1:YES)	1
B	／	ROTATE AXIS CENTER COMP (1:ON)	
M	／	SAVE MEASURED BALL DIA. TO.NO.	
E	／	MEA.ERROR LMT.(CENT. DIA.) [u,t]	

Enter each dimension.

・Setting origin of work coordinate system (G55) to workpiece

MEA : Plate/Column (G122)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y,2:Z-X,3:Y-Z)	
X	／	AXIS TRAVEL X AXIS [u,t]	100.0
Y	／	(INC) Y AXIS [u,t]	80.0
Z	／	Z AXIS [u,t]	-15.0
R	／	SPINDLE BALL DIA. [u,t]	
Q	／	ELECT.MEA-PART MEA ⅢAXIS [u,t]	
F	／	MEASURE RATE [m,i/min]	
A	／	ROT. ANGLE [deg]	
K	／	RETRACT VALUE [u,t]	5.0
W	／	WORK CORD. No. TO SET	55
O	／	MEASURE CORD. SYSTEM No.	
N	／	ELECTRODE OFFSET	
S	／	ELECTRODE OFFSET 2	
M	／	MEASURE ELECTRODE OFFSET	
B	／	ⅠCENTERING OFS ⅡAXIS (INC) [u,t]	
C	／	ⅡCENTERING OFS ⅠAXIS (INC) [u,t]	
U	／	SHIFT AT HEIGHT MEA. Ⅰ AXIS [u,t]	
V	／	(INC) Ⅱ AXIS [u,t]	
D	／	C 180deg ROTATE MEASURE (1:ON)	
L	／	ANGLE MEA.DIRECTION (1:+Y,3:+X)	
P	／	MEASURE [u,t]	

Enter each dimension.

Work coordinate system No.

② Model plan input example

Input example when electrode No.1 is already on the centering ball.

MEA : Electrode/Sphere (G126)

Address	Attri.	Talk items	Set value
P	／	TABLE BALL DIA. [u, t]	10.0
U	／	ELECT.MEA-PART MEA. X AXIS [u, t]	20.0
V	／	Y AXIS [u, t]	15.0
C	／	Z AXIS [u, t]	10.0
I	／	X CENTERING OFFSET X AXIS [u, t]	
J	／	(INC) Y AXIS [u, t]	
A	／	Y CENTERING OFFSET X AXIS [u, t]	
B	／	(INC) Y AXIS [u, t]	
Q	／	Z CENTERING OFFSET X AXIS [u, t]	
W	／	(INC) Y AXIS [u, t]	
F	／	MEASURE RATE [m, i/min]	
K	／	RETRACT VALUE [u, t]	
D	／	LOCAL CORD.SYSTEM SET (1:XYZ, 2:Z)	1
N	／	ELECTRODE OFFSET	
S	／	ELECTRODE OFFSET 2	
H	／	PARALLEL ADJ.(4:+X, 5:-X, 6:+Y, 7:-Y)	
T	／	MEASURE PITCH [u, t]	
M	／	MEASURE COUNT	
X	／	MEASURE ERROR LIMIT [mm]	
O	／	SAVE MEASURED ELECT. DIA.TO NO.	
E	／	MEA. ERROR LMT (ELECT.DIA.) [u, t]	

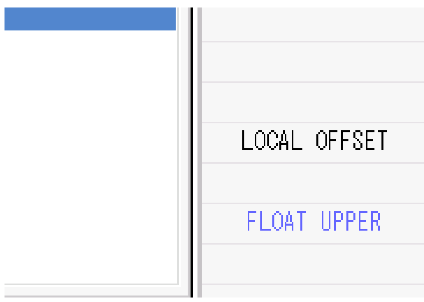
Enter each dimension.

A local coordinates system is set.

※ The offset value of local coordinate system are displayed on SET – LOCAL OFFSET screen.

※ "LOCAL OFFSET" is displayed in the status display area on the screen when the local coordinate system is used.

CRT Screen



MC : Single MC (G100)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
X	／	MC DEPTH X AXIS [u, t]	
Y	／	Y AXIS [u, t]	
Z	／	Z AXIS [u, t]	-9.5
C	／	C AXIS [ANGLE]	
W	／	AUTO DEPTH MAX. TRAVEL [u, t]	
L	／	MC LAST STOP (1:ON)	
E	*	MC COND No.	1309
U	／	REMAIN AMOUNT [u, t]	
R	／	PATTERN RADIUS [u, t]	
P	／	MODE/PATTERN	
A	／	ROT. ANGLE [deg]	
:	:	:	

↓

POS : Line/Grid (G111)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55
X	*	START CORD. X AXIS [u, t]	0
Y	*	(ABS) Y AXIS [u, t]	0
Z	*	Z AXIS [u, t]	5.0
:	:	:	

Enter work cord. system No. used for workpiece.

↓

AUX : ATC (G131)

Address	Attri.	Talk items	Set value
M	／	ATC RTN PRO. (1:Z-X-Y, 2:Z-Y-X)	3
F	／	ROBOT CHUCK (1:U, 2:D, 3:R, 4:L)	
T	／	ELECTRODE No.	2
S	／	SPINDLE ELEC. No.	1
O	／	ELECT.OFFSET No. (LOCAL SET)	
W	／	END WORK CORD. SYS.	54
X	／	COORDINATE X AXIS [u, t]	0
Y	／	(ABS) Y AXIS [u, t]	0
Z	／	Z AXIS [u, t]	10.0
C	／	C AXIS [deg]	
N	／	MACHINING PROGRAM O No.	
D	／	WORK TANK DOWN (ROBOT ONLY)	

This may be omitted at the next electrode change

Relocate each axis to the position where centering can be done by a centering ball.

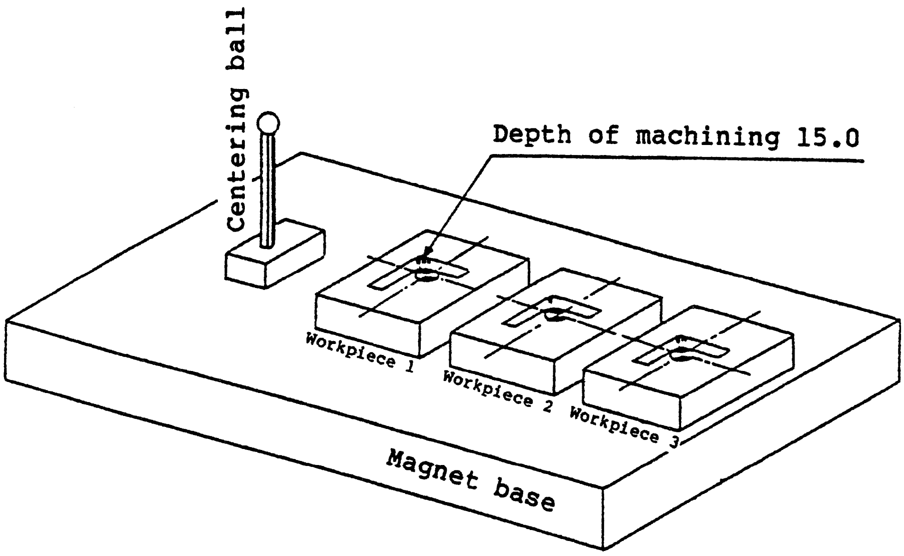
↓

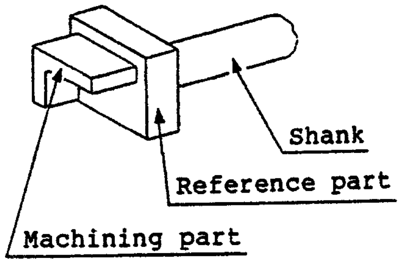
Hereafter, enter data in the same manner as that of electrode No.1.

16.3 ATC-3

The ATC-3 corrects the origin of work coordinate system specified for each workpiece by using the electrode offset data that stores the amount of deviation of electrode used.
It sets the origin of work coordinate system (G54 to G61) individually for each workpiece and centering ball using a measuring ball. In addition, it enters the deviation of each electrode to the measuring ball into the offset number.

[Machining example]





Electrodes:

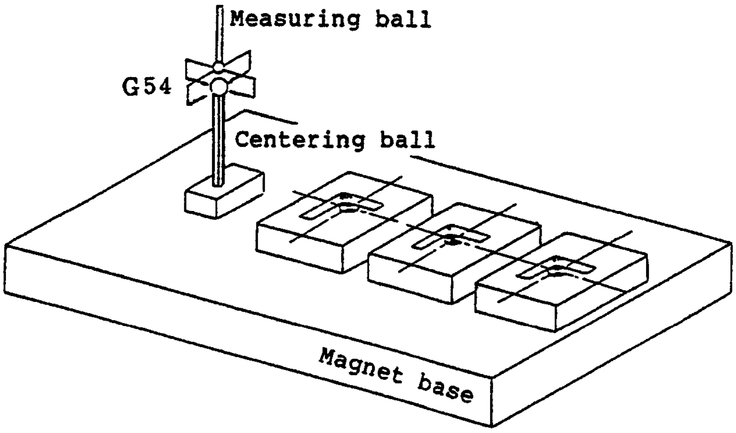
For rough machining 1 pc ; reduction 0.3

For finish machining 2 pcs; reduction 0.15

Three workpieces mounted on the magnet base are to be machined, as shown above. Assume that the contents and dimensions of machining for three workpieces are same.
The electrode is provided with reference part so that centering to the centering ball is easy.

[Procedure]

① Measure the centering ball position using a measuring ball, and designate this point as origin of G54.

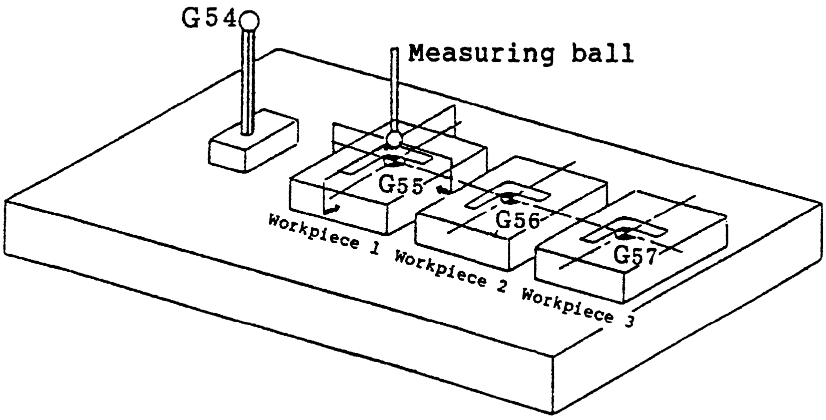


MEA : Measure/Sphere (G125)

Address	Attri.	Talk items	Set value
R	*	SPINDLE BALL DIA. [u, t]	10.0
P	*	TABLE BALL DIA. [u, t]	10.0
F	／	MEASURE RATE [m, i/min]	
Q	／	ROT. VALUE [deg]	
K	／	RETRACT VALUE [u, t]	1
W	／	SET G54 (1:YES)	
B	／	ROTATE AXIS CENTER COMP (1:ON)	
M	／	SAVE MEASURED BALL DIA. TO NO.	
E	／	MEA. ERROR LMT. (CENT. DIA.) [u, t]	

Enter ball diameter used.

② Measure each workpiece position using a measuring ball, and set the origin of individual work coordinate system to the reference point of each workpiece.



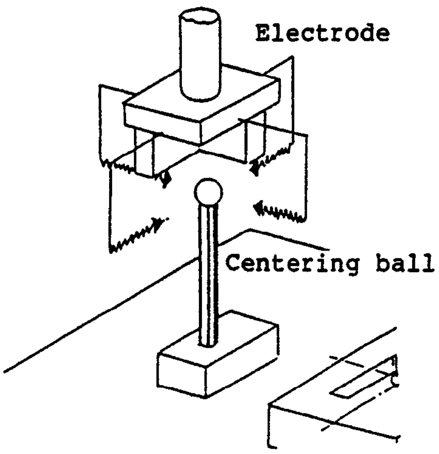
MEA : Plate/Column (G122)

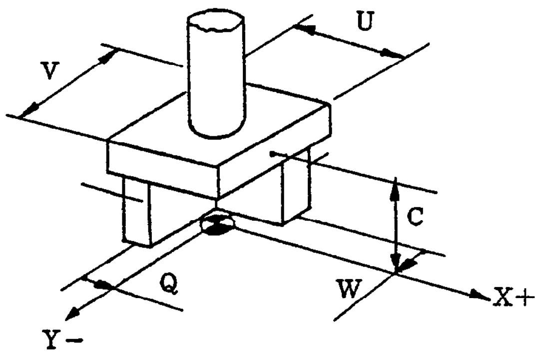
Address	Attri.	Talk items	Set value
H	/	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
X	/	AXIS TRAVEL X AXIS [u, t]	100.0
Y	/	(INC) Y AXIS [u, t]	80.0
Z	/	Z AXIS [u, t]	-15.0
R	/	SPINDLE BALL DIA. [u, t]	
Q	/	ELECT. MEA-PART MEA ⅢAXIS [u, t]	
F	/	MEASURE RATE [m, i/min]	5.0
A	/	ROT. ANGLE [deg]	
K	/	RETRACT VALUE [u, t]	2.0
W	/	WORK CORD. No. TO SET	55
O	/	MEASURE CORD. SYSTEM No.	
N	/	ELECTRODE OFFSET	
S	/	ELECTRODE OFFSET 2	
M	/	MEASURE ELECTRODE OFFSET	
B	/	ⅠCENTERING OFS ⅡAXIS (INC) [u, t]	
C		ⅡCENTERING OFS ⅠAXIS (INC) [u, t]	
U	/	SHIFT AT HEIGHT MEA. ⅠAXIS [u, t]	
V	/	(INC) ⅡAXIS [u, t]	
D	/	C 180deg ROTATE MEASURE (1:ON)	
L	/	ANGLE MEA. DIRECTION (1:+Y, 3:+X)	
P	/	MEASURE PITCH [u, t]	

Enter each dimension.

Work coordinate system No.

③ Enter the amount of deviation of each electrode to the measuring ball into the offset number associated with each electrode.





MEA : Electrode/Sphere (G126)

Address	Attri.	Talk items	Set value
P	/	TABLE BALL DIA. [u, t]	10.0
U	/	ELECT. MEA-PART MEA. X AXIS [u, t]	20.0
V	/	Y AXIS [u, t]	20.0
C	/	Z AXIS [u, t]	10.0
I	/	X CENTERING OFFSET X AXIS [u, t]	
J	/	(INC) Y AXIS [u, t]	
A	/	Y CENTERING OFFSET X AXIS [u, t]	
B	/	(INC) Y AXIS [u, t]	
Q	/	Z CENTERING OFFSET X AXIS [u, t]	5.0
W	/	(INC) Y AXIS [u, t]	-5.0
F	/	MEASURE RATE [m, i/min]	
K	/	RETRACT VALUE [u, t]	2.0
D	/	LOCAL CORD. SYSTEM SET (1:XYZ, 2:Z)	
N	/	ELECTRODE OFFSET	1
S	/	ELECTRODE OFFSET 2	
H	/	PARALLEL ADJ. (4:+X, 5:- X, 6:+Y, 7:-Y)	
T	/	MEASURE PITCH [mm]	
M	/	MEASURE COUNT	
X	/	MEASURE ERROR LIMIT [mm]	
O	/	SAVE MEASURED ELECT. DIA. TO NO.	
E	/	MEA. ERROR LMT (ELECT. DIA.) [u, t]	

Enter each data by referring to the above figures.

Enter offset number associated with each electrode.

④ Model plan input example

The following program shows when machining is started with a rough electrode in the spindle.

AUX : Coordinate system set (G130)

Address	Attri.	Talk items	Set value
W	／	WORK CORD. SYSTEM	
X	／	SET CORD. X AXIS [u,t]	
Y	／	Y AXIS [u,t]	
Z	／	Z AXIS [u,t]	
C	／	C AXIS [deg]	
L	／	LOCAL CORD. SYSTEM SET (1:ON)	1
I	／	SET CORD. X AXIS [u,t]	
J	／	Y AXIS [u,t]	
K	／	Z AXIS [u,t]	
B	／	C AXIS [deg]	
O	／	ELECT. OFFSET No. (LOCAL SET)	1
T	／	WORK ROTATION (0:OFF,1:ON)	

Assume that the offset number of the first electrode (for rough machining) is "1".

↓

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X,2:Y,3:Z)	
Z	∗	MC DEPTH [u,t]	-15.0
R	∗	ELECTRODE REDUCTION [u,t]	0.3
E	∗	MODEL DATA No.	123
I	／	START OF PROCESS No.	3
J	／	END OF PROCESS No.	8
O	／	FINISH PROCESS No.	15
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT.ANGLE [deg]	
S	／	JUMP AMOUNT [code, u,t]	7
T	／	CYCLE [code,0.001sec]	4
F	／	SPEED [code,m.i/min]	6
K	／	CLAMP START PROCESS No.	
M	／	TIME CONTROL MC START PROC.No.	
U	／	1PROCESS [min]	
V	／	2PROCESS [min]	
W	／	3PROCESS [min]	

↓

POS : Plural coordinates (G114)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y,2:Z-X,3:Y-Z)	
W	／	CORD. SYSTEM G54(1:use)	
U	／	G55(1:use)	1
V	／	G56(1:use)	1
I	／	G57(1:use)	1
J	／	G58(1:use)	
K	／	G59(1:use)	
O	／	G60(1:use)	
P	／	G61(1:use)	
Q	／	START CORD. SYSTEM No.	
R	／	END CORD. SYSTEM No.	
X	∗	MACHINING CORD. X AXIS [u,t]	0
Y	∗	(ABS) Y AXIS [u,t]	0
Z	∗	Z AXIS [u,t]	5.0
L	／	INDEX DEVICE (1:C AXIS,2:IDX,3:DH)	
A	／	INDEX ANGLE [deg]	
D	／	ELECT.ROT.OFFSET (1:ON)	
S	／	C AXIS SYNC PATTERN (1:ON)	
T	／	OPPOSITE (1:ON)	

↓

AUX : ATC (G131)

Address	Attri.	Talk items	Set value
M	／	ATC RTN PRO. (1:Z-X-Y, 2:Z-Y-X)	3
F	／	ROBOT CHUCK (1:U, 2:D, 3:R, 4:L)	
T	／	ELECTRODE No.	2
S	／	SPINDLE ELEC. No.	1
O	／	ELECT.OFFSET No. (LOCAL SET)	2
W	／	END WORK CORD. SYS.	55
X	／	COORDINATE X AXIS [u,t]	0
Y	／	(ABS) Y AXIS [u,t]	0
Z	／	Z AXIS [u,t]	30.0
C	／	C AXIS [deg]	
N	／	MACHINING PROGRAM O No.	
D	／	WORK TANK DOWN (ROBOT ONLY)	

This may be omitted at the next electrode change

Assume that the offset number of the second electrode (for finish machining) is “2”.

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	
Z	＊	MC DEPTH [u,t]	-15.0
R	＊	ELECTRODE REDUCTION [u,t]	0.15
E	＊	MODEL DATA No.	123
I	／	START OF PROCESS No.	7
J	／	END OF PROCESS No.	13
O	／	FINISH PROCESS No.	13
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT.ANGLE [deg]	
S	／	JUMP AMOUNT [code, u,t]	7
T	／	CYCLE [code, 0.001sec]	4
F	／	SPEED [code, m.i/min]	6
K	／	CLAMP START PROCESS No.	
M	／	TIME CONTROL MC START PROC.No.	
U	／	1PROCESS [min]	
V	／	2PROCESS [min]	
W	／	3PROCESS [min]	

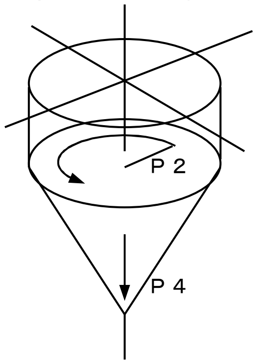
POS : Plural coordinates (G114)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	CORD. SYSTEM G54(1:use)	
U	／	G55(1:use)	1
V	／	G56(1:use)	1
I	／	G57(1:use)	1
J	／	G58(1:use)	
K	／	G59(1:use)	
O	／	G60(1:use)	
P	／	G61(1:use)	
Q	／	START CORD. SYSTEM No.	
R	／	END CORD. SYSTEM No.	
X	＊	MACHINING CORD. X AXIS [u,t]	0
Y	＊	(ABS) Y AXIS [u,t]	0
Z	＊	Z AXIS [u,t]	5.0
L	／	INDEX DEVICE (1:C AXIS, 2:IDX, 3:DH)	
A	／	INDEX ANGLE [deg]	
D	／	ELECT.ROT.OFFSET (1:ON)	
T	／	OPPOSITE (1:ON)	

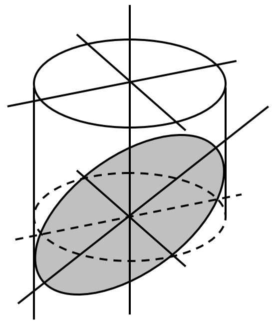
Hereafter, enter data in the same manner as that of electrode No.2.

17. IRREGULAR SHAPES MACHINING (BOTTOM STOPPED-COMPLEX MENU)

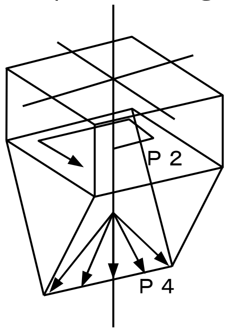
17. 1 Drill-shape machining‥‥‥ 17－2



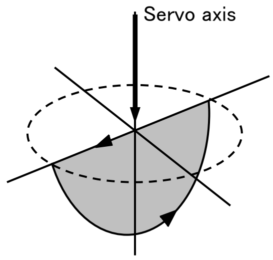
17. 5 Bottom inclined machining‥17－13



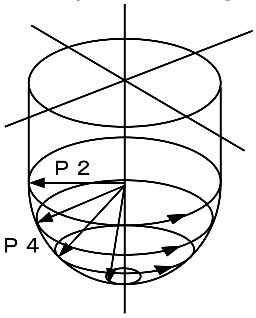
17. 2 Wedge-shape machining‥‥‥17－3



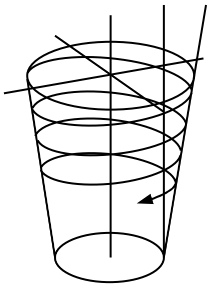
17. 6 Servo axis orbiting machining‥‥‥ 17－18



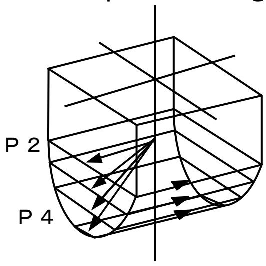
17. 3 Sphere-shape machining‥‥17－6



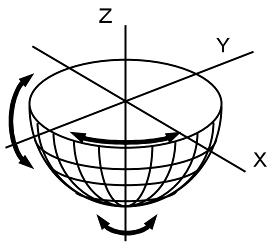
17. 7 Taper machining‥‥‥‥ 17－22



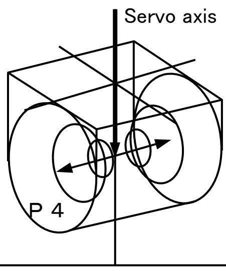
17. 4 Column-shape machining‥‥17－8



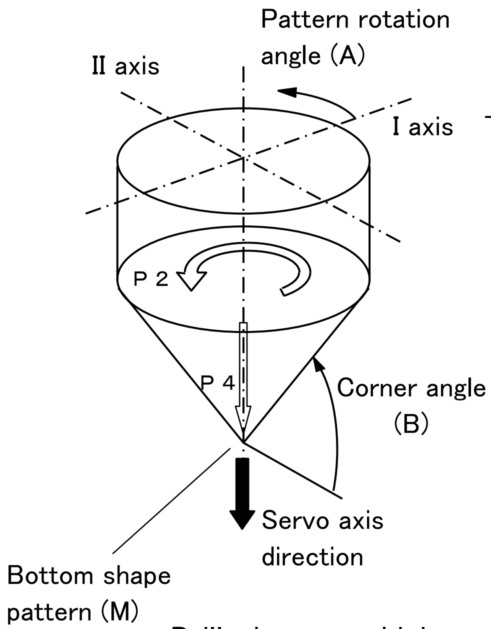
17. 8 3-D machining‥‥‥‥‥ 17－23



17. 9 Half-shape machining ‥‥‥‥ 17－26



17. 1 Drill-shape machining



Items	Setting values
Machining method (L)	3,13,23,93
Pattern (P)	Excluding 0505,5050
Rotation angle (A)	±360.0
Side taper angle (K)	Not used
Bottom shape pattern (M)	0
Corner angle (B)	0.1～89.0

Fig. 17.1 Drill-shape machining

[Description]

(a) The figure 17.1 shows an example when the pattern (P) is 1111.
The pattern (P) specifies the above shape.

(b) The orbiting function is turned off if the electrode reduction (R) is 0.

(c) The bottom remaining amount is compensated by the corner angle (B).

(d) Use only 3, 13, 23 or 93 for the machining method (L). It changes into the operation of the table below in the input value of the machining method (L).

Machining method	L23 ⇔ L13 ⇔ L93
Important point	Removal rate ⇔ machining accuracy

(e) The pattern offset can be used.

(f) The side taper angle (K) cannot be used.

17. 2　Wedge-shape machining

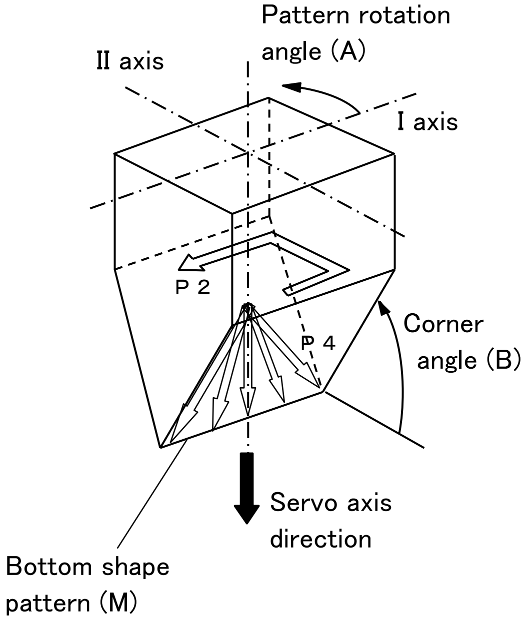


Fig. 17.2　Drill-shape machining

Items	Setting values
Machining method (L)	3,13,23,93
Pattern (P)	Excluding 0505,5050
Rotation angle (A)	±360.0
Side taper angle (K)	Not used
Bottom shape pattern (M)	5050
Corner angle (B)	0.1～89.0

[Description]

(a) The figure 17.2 shows an example when the pattern (P) is 2222.
The pattern (P) specifies the above shape.

(b) The pattern function is turned off if the electrode reduction (R) is 0.

(c) The bottom remaining amount is compensated by the corner angle (B).

(d) Use only 3, 13 or 23 for the machining method (L). It changes into the operation of the table below in the input value of the machining method (L).

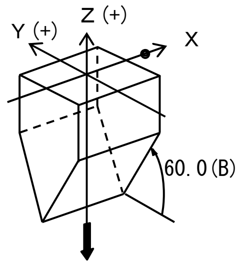
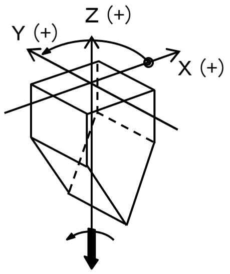
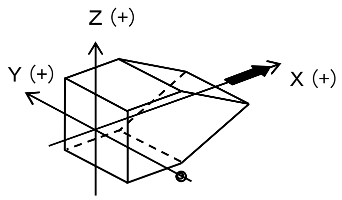
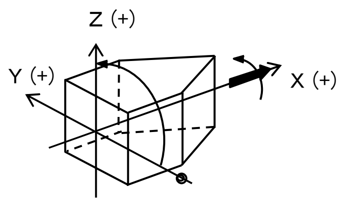
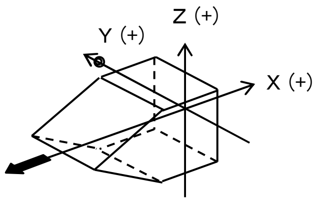
Machining method	L23 ⇔ L13 ⇔ L93
Important point	Removal rate ⇔ machining accuracy

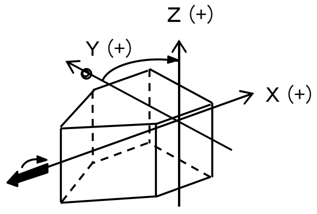
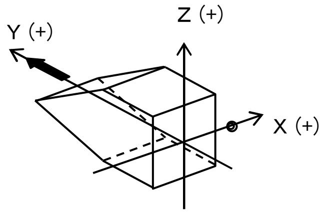
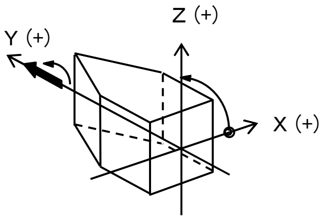
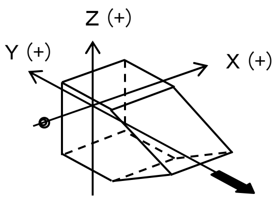
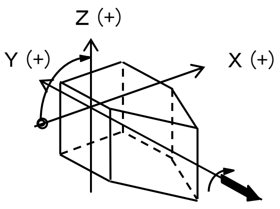
(e) The pattern radius at the leading end is 5 μm.

(f) The pattern offset can be used.

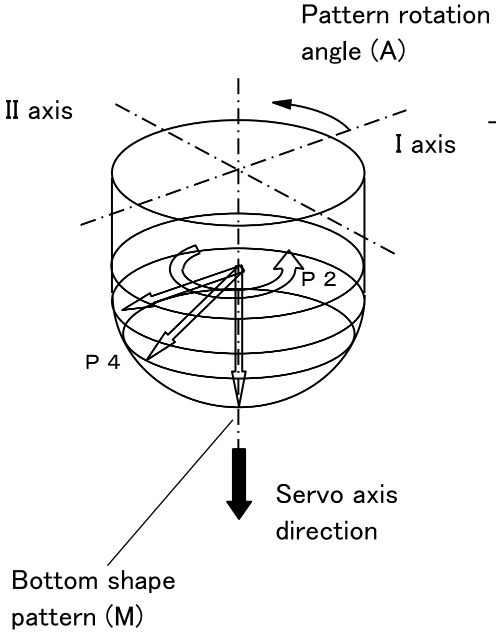
(g) The side taper angle (K) cannot be used.

Setting example of wedge-shape machining

	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
① 	Z (−)	2222	0	−	5050	60. 0	3 13 23 93	Yes
②  Rotate ① by 90°	Z (−)	2222	90. 0	−	5050	60. 0	3 13 23 93	Yes
③ 	X (+)	2222	0	−	5050	60. 0	3 13 23 93	Yes
④  Rotate ③ by 90°	X (+)	2222	90. 0	−	5050	60. 0	3 13 23 93	Yes
⑤ 	X (−)	2222	0	−	5050	60. 0	3 13 23 93	Yes

	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
⑥  Rotate ⑤ by 90°	X (−)	2222	90.0	—	5050	60.0	3 13 23 93	Yes
⑦ 	Y (+)	2222	0	—	5050	60.0	3 13 23 93	Yes
⑧  Rotate ⑦ by 90°	Y (+)	2222	90.0	—	5050	60.0	3 13 23 93	Yes
⑨ 	Y (−)	2222	0	—	5050	60.0	3 13 23 93	Yes
⑩  Rotate ⑨ by 90°	Y (−)	2222	90.0	—	5050	60.0	3 13 23 93	Yes

17. 3 Sphere-shape machining



Items	Setting values
Machining method (L)	3,13,23,73,93
Pattern (P)	Excluding 0505,5050
Rotation angle (A)	±360.0
Side taper angle (K)	Not used
Bottom shape pattern (M)	0
Corner angle (B)	0

Fig. 17.3 Sphere-shape machining

[Description]

(a) The figure 17.3 shows an example when the pattern (P) is 1111.
The pattern (P) specifies the above shape.

(b) The pattern function is turned off if the electrode (R) is 0.

(c) Use only 3, 13 , 23 , 73 or 93 for the machining method (L).

(d) The pattern offset can be used.

(e) The leading end is not the pattern radius.

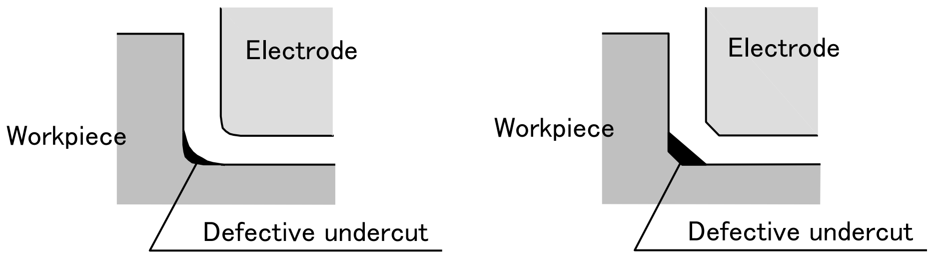
(f) The side taper angle (K) cannot be used.

(g) Minimum divisions are 3. (0 degrees, 45 degrees, 90 degrees)

(h) It is divided by the regular number for the start process with Orbiting, too.

Sphere-shape machining example

A defective undercut by rough electrode occurs if usual orbiting method is used when the bottom of electrode is reduced by the radius compensation (offset). As a result, those portions that cannot be finished by finish electrode will appear.



In this case, use of sphere-shape machining can prevent undercut by rough electrode.

[Program example]

MC : Bottom stopped – complex (G102)

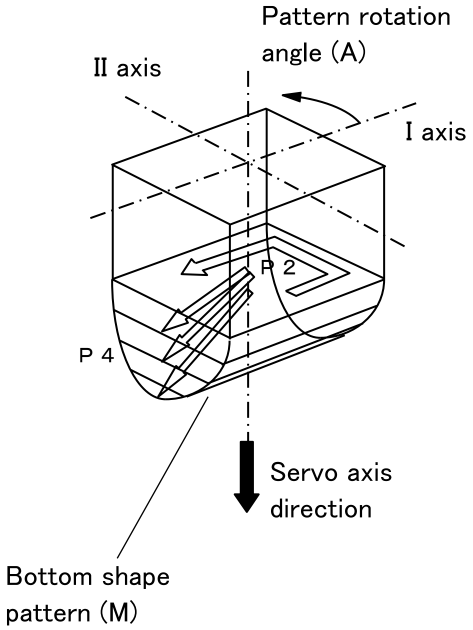
Address	Attri.	Talk items	Set value	
N	/	ABS/INC (90/91)		
X	/	MC DEPTH X AXIS [u,t]		
Y	/	Y AXIS [u,t]		
Z	/	Z AXIS [u,t]	-30.0	
C	/	C AXIS [ANGLE]		
R	*	ELECTRODE REDUCTION [u,t]	0.3	
E	*	MODEL DATA No.	123	
I	/	START OF PROCESS No.	5	
J	/	END OF PROCESS No.	12	
O	/	FINISH PROCESS No.	12	
D	/	SIDE REMAIN AMOUNT COMP [%]		
H	/	BOTTOM REMAIN AMOUNT COMP [%]		
L	/	MC METHOD	93	
P	/	PATTERN	1111	
A	/	ROT. ANGLE [deg]		
K	/	SIDE TAPER ANGLE [deg]		
M	/	BOTTOM SHAPE PATTERN	0	Sphere-shape
B	/	CORNER ANGLE [deg]	0	
S	/	JUMP AMOUNT [code:u,t]		
T	/	CYCLE [code:0.001sec]		
F	/	SPEED [code:m,i/min]		
U	/	TIME CONTROL MC START PROC.No.		
V	/	PROCESS CONTROL TIME [min]		

When three-dimensional (3D) electrode reduction is taken, use the machining method properly referring to the table below.

Machining method	L13M0B0 ⇔ L93M0B0 ⇔ L73M0B0
Electrode reduction	More than 0.15mm ⇔ 0.15～0.1mm ⇔ under 0.1mm
Important point	Removal rate ⇔ machining accuracy

Machining method L*8M0B0 (section 17.8, 3D finish) is recommended,
in case electrical discharge area is 150mm or more.

17. 4 Column-shape machining



Items	Setting values
Machining method (L)	3,13,23,73,93
Pattern (P)	Excluding 0505,5050
Rotation angle (A)	±360.0
Side taper angle (K)	Not used
Bottom shape pattern (M)	5050
Corner angle (B)	0

Fig. 17.4 Column-shape machining

[Description]

(a) The figure 17.4 shows an example when the pattern (P) is 2222.
The pattern (P) specifies the above shape.

(b) The pattern function is turned off if the electrode reduction (R) is 0.

(c) Use only 3, 13, 23, 73 or 23 for the machining method (L). With reference from the table below, its operation changes with respect to the input value of the machining method (L).

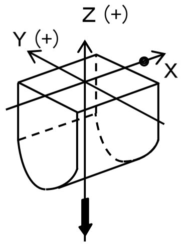
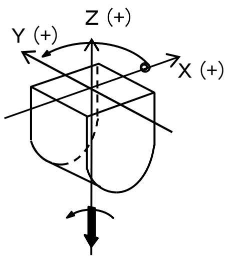
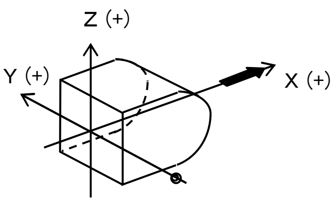
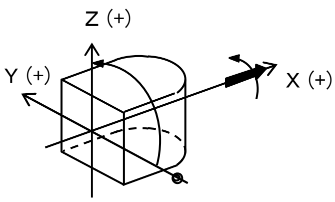
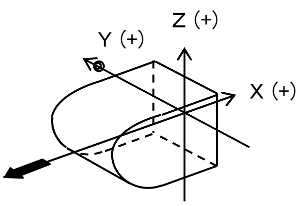
Machining method	L23 ⇔ L13 ⇔ L93
Important point	Removal rate ⇔ machining accuracy

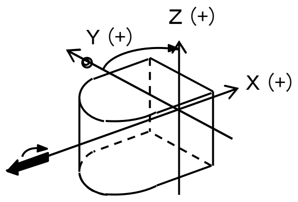
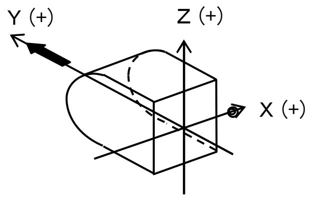
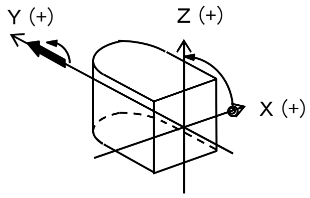
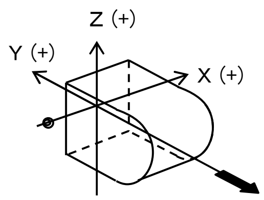
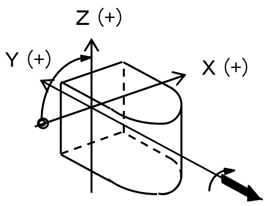
(d) The pattern offset can be used.

(e) The pattern radius at the leading end is 5 μ m.

(f) The side taper angle (K) cannot be used.

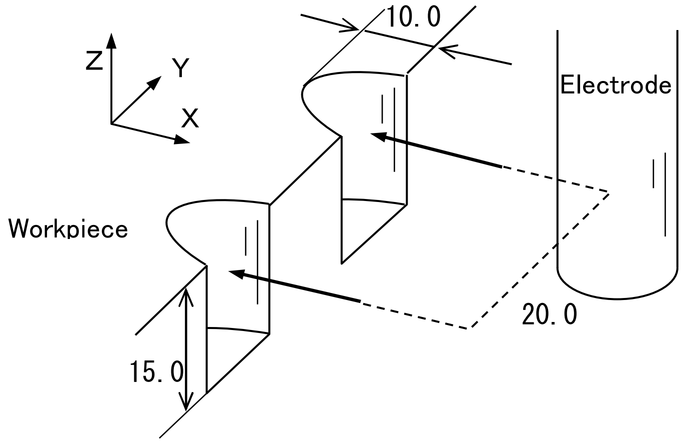
Setting example of column-shape machining

	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
① 	Z (−)	2222	0	—	5050	0	3 13 23 73 93	Yes
②  Rotate ① by 90°	Z (−)	2222	90. 0	—	5050	0	3 13 23 73 93	Yes
③ 	X (+)	2222	0	—	5050	0	3 13 23 73 93	Yes
④  Rotate ③ by 90°	X (+)	2222	90. 0	—	5050	0	3 13 23 73 93	Yes
⑤ 	X (−)	2222	0	—	5050	0	3 13 23 73 93	Yes

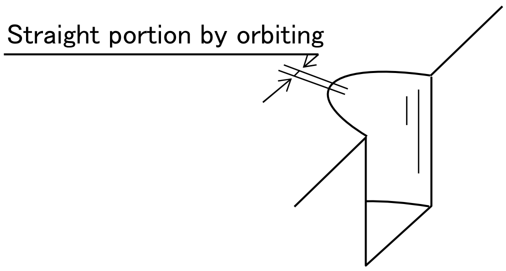
	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
⑥  Rotate ⑤ by 90°	X (−)	2222	90.0	—	5050	0	3 13 23 73 93	Yes
⑦ 	Y (+)	2222	0	—	5050	0	3 13 23 73 93	Yes
⑧  Rotate ⑦ by 90°	Y (+)	2222	90.0	—	5050	0	3 13 23 73 93	Yes
⑨ 	Y (−)	2222	0	—	5050	0	3 13 23 73 93	Yes
⑩  Rotate ⑨ by 90°	Y (−)	2222	90.0	—	5050	0	3 13 23 73 93	Yes

Column-shape machining example

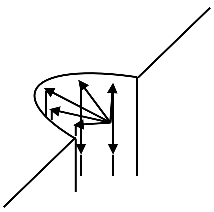
Horizontal servo machining by a column electrode



In a horizontal servo machining as shown above, usual finishing method causes arc portion to be varied.



In this case, the use of column-shape machining does not allow variation of arc portion.



In addition, the bottom in Z direction is also finished.

[Program example]

MC : Bottom stopped – complex (G102)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
X	／	MC DEPTH X AXIS [u, t]	-10.0
Y	／	Y AXIS [u, t]	
Z	／	Z AXIS [u, t]	
C	／	C AXIS [ANGLE]	
R	*	ELECTRODE REDUCTION [u, t]	0.2
E	*	MODEL DATA No.	123
I	／	START OF PROCESS No.	7
J	／	END OF PROCESS No.	12
O	／	FINISH PROCESS No.	12
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	23
P	／	PATTERN	2222
A	／	ROT. ANGLE [deg]	90.0
K	／	SIDE TAPER ANGLE [deg]	
M	／	BOTTOM SHAPE PATTERN	5050
B	／	CORNER ANGLE [deg]	0
S	／	JUMP AMOUNT [code:u, t]	
T	／	CYCLE [code:0.001sec]	
F	／	SPEED [code:m, i/min]	
U	／	TIME CONTROL MC START PROC.No.	
V	／	PROCESS CONTROL TIME [min]	

Set 13 when shape accuracy is important.

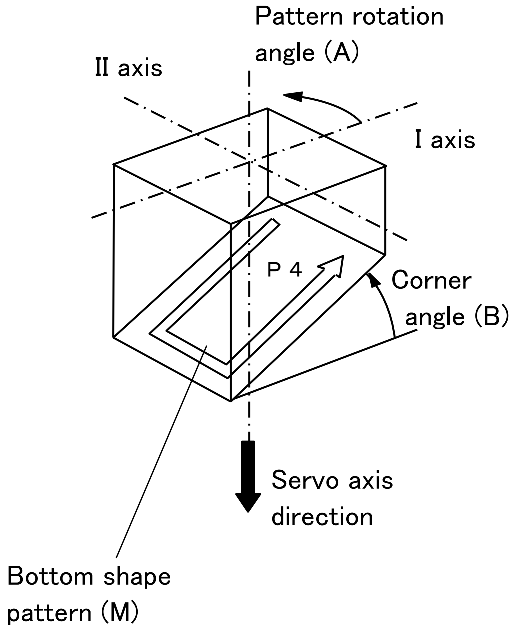
Column-shape

POS : Dispersed (G113)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	
X	*	START CORD. X AXIS [u, t]	20.0
Y	*	(ABS) Y AXIS [u, t]	0
Z	*	Z AXIS [u, t]	-14.8
U	／	No.2 HOLE (ABS) I AXIS [u, t]	20.0
V	／	II AXIS [u, t]	-20.0
I	／	No.3 HOLE (ABS) I AXIS [u, t]	
J	／	II AXIS [u, t]	
K	／	No.4 HOLE (ABS) I AXIS [u, t]	
B	／	II AXIS [u, t]	
C	／	No.5 HOLE (ABS) I AXIS [u, t]	
P	／	II AXIS [u, t]	
Q	／	No.6 HOLE (ABS) I AXIS [u, t]	
R	／	II AXIS [u, t]	
L	／	INDEX DEVICE(1:C AXIS, 2:IDX, 3:DH)	
A	／	INDEX ANGLE [deg]	
D	／	ELECT.ROT.OFFSET (1:ON)	
S	／	C AXIS SYNC PATTERN (1:ON)	
T	／	OPPOSITE (1:ON)	

Set a small value Because of consider-ation of electrode reduction.

17.5 Bottom inclined machining



Items	Setting values
Machining method (L)	*1,*2,*3,*4,*5
Pattern (P)	Excluding 0505,5050
Rotation angle (A)	±360.0
Side taper angle (K)	Settable
Bottom shape pattern (M)	Same as Pattern
Corner angle (B)	0.1～60.0

Fig. 17.5 Bottom inclined machining

[Description]

(a) The figure 17.5 shows an example when the pattern (P) is 2222.
The pattern (P) specifies the above shape. In bottom inclined machining, the same pattern must be set to the pattern (P) and the bottom shape pattern (M).

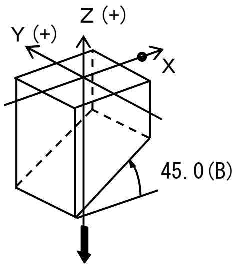
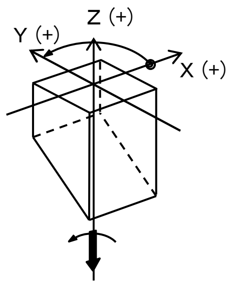
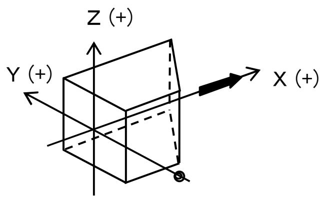
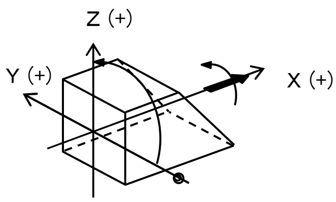
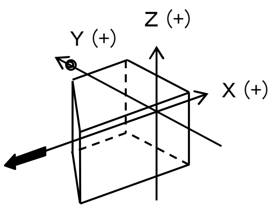
(b) The pattern function is turned off if the electrode reduction (R) is 0.

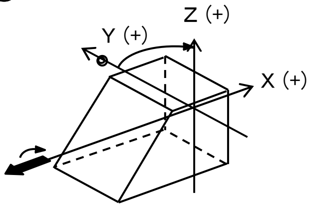
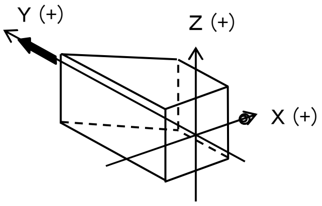
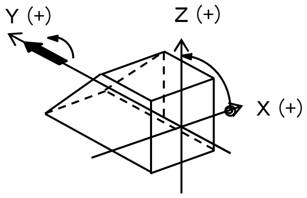
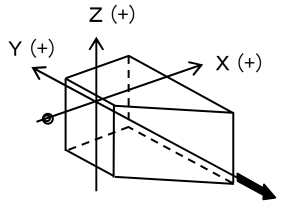
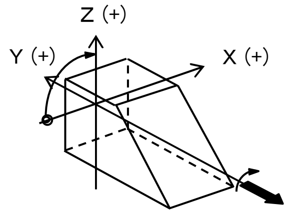
(c) The bottom remaining amount is compensated by the corner angle (B).

(d) Use *1, *2, *3, *4, or *5 for the machining method (L). 2nd digit "*" means accuracy level. Refer to manual "MODEL PLAN" for details.

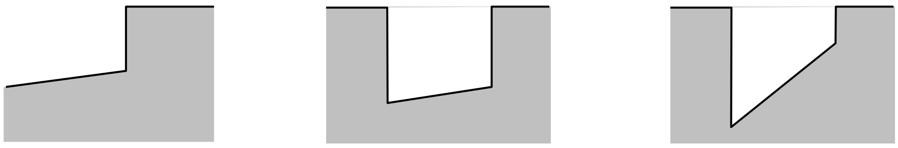
(e) The pattern offset can be used.

Setting example of bottom inclined machining

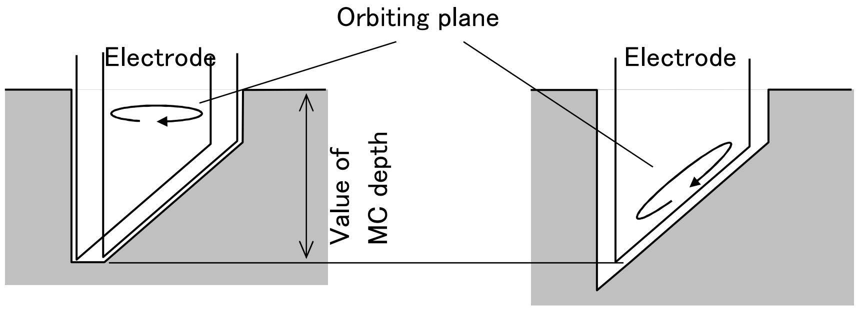
	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
① 	Z (−)	2222	0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes
②  Rotate ① by 90°	Z (−)	2222	90.0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes
③ 	X (+)	2222	0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes
④  Rotate ③ by 90°	X (+)	2222	90.0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes
⑤ 	X (−)	2222	0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes

	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
⑥  Rotate ⑤ by 90˚	X (−)	2222	90.0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes
⑦ 	Y (+)	2222	0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes
⑧  Rotate ⑦ by 90˚	Y (+)	2222	90.0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes
⑨ 	Y (−)	2222	0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes
⑩  Rotate ⑨ by 90˚	Y (−)	2222	90.0	—	2222	45.0	*1 *2 3 13 23 *4 *5	Yes

Bottom stopped machining with the bottom inclined



A usual orbiting machining with an inclined bottom is shown above. The electrode orbits on an orbiting plane perpendicular to the servo axis, resulting in poor machining efficiency, variations of depth dimension and bottom shape. In this case, use bottom inclined machining.



Usual orbiting machining

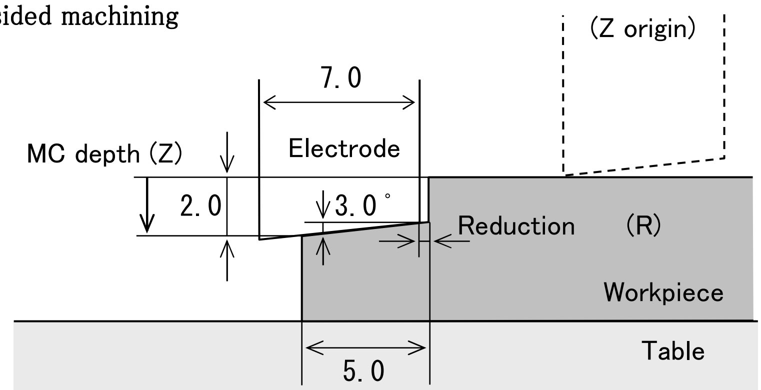
- Flat portion appears on the bottom.
- Machining efficiency is low since the inclined bottom is machined only when electrode moves to the right (above figure) in the orbiting motion.

Bottom inclined machining

- Note the value of MC depth.
- Depth input is specified orbiting center position.
- Note that the leading edge is deeper and the inclined face is shallower than those in usual orbiting machining.

The value of MC depth in bottom inclined machining specifies MC depth at the orbiting center. The value, therefore, should be changed according to the contents of machining as shown below.

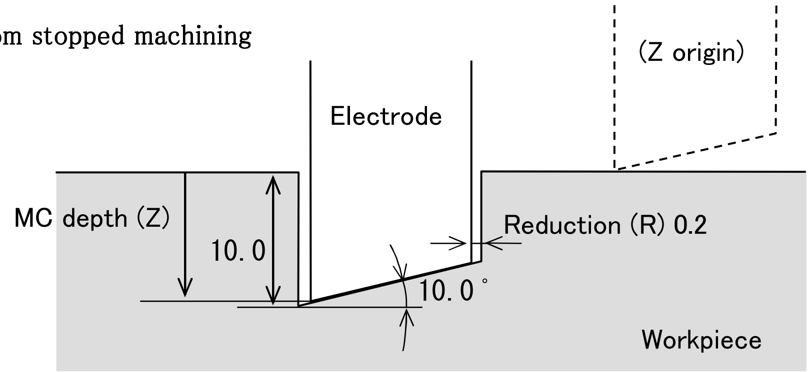
(a)Open-sided machining



$$\text{MC depth (Z)} = -2.0 - [(7.0 + 0.1) - 5.0] \times \tan 3.0^{\circ}$$

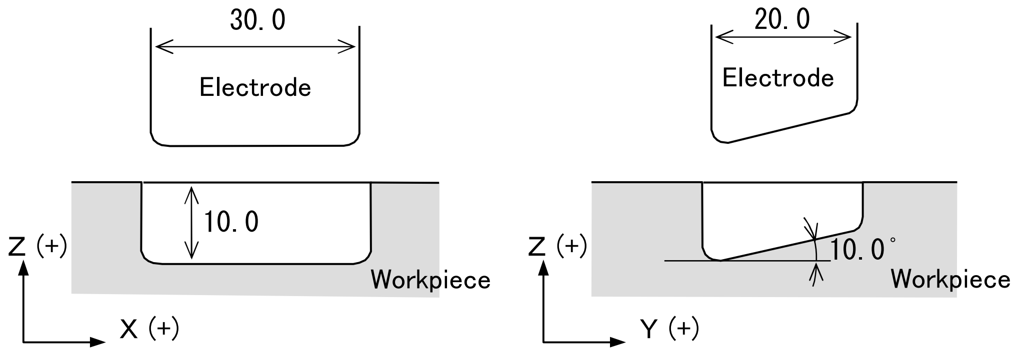
$$\fallingdotseq -2.110$$

(b)Bottom stopped machining



$$\text{MC depth (Z)} = -10.0 + 0.2 \times \tan 10.0^\circ$$
$$\fallingdotseq -9.965$$

[Machining example]



The bottom is inclined in Y direction and electrode reduction is 0.5mm.

[Program example]

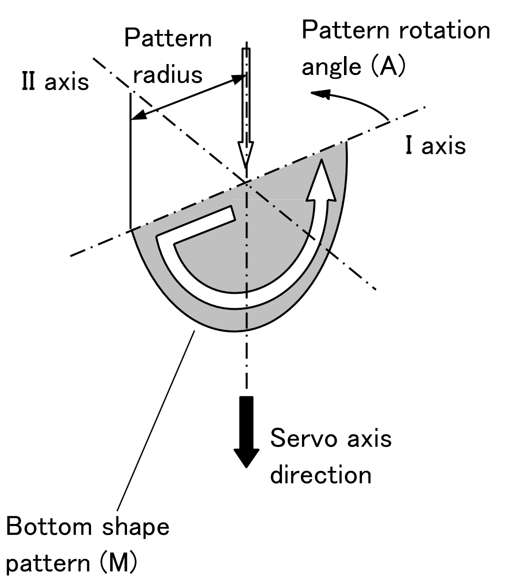
MC : Bottom stopped – complex (G102)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
X	／	MC DEPTH X AXIS [u, t]	
Y	／	Y AXIS [u, t]	
Z	／	Z AXIS [u, t]	-9. 912
C	／	C AXIS [ANGLE]	
R	＊	ELECTRODE REDUCTION [u, t]	0. 5
E	＊	MODEL DATA No.	123
I	／	START OF PROCESS No.	1
J	／	END OF PROCESS No.	12
O	／	FINISH PROCESS No.	12
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT. ANGLE [deg]	90. 0
K	／	SIDE TAPER ANGLE [deg]	
M	／	BOTTOM SHAPE PATTERN	2222
B	／	CORNER ANGLE [deg]	10. 0
S	／	JUMP AMOUNT [code:u, t]	
T	／	CYCLE [code:0. 001sec]	
F	／	SPEED [code:m, i/min]	
U	／	TIME CONTROL MC START PROC. No.	
V	／	PROCESS CONTROL TIME [min]	

(Description of a position model block is omitted.)

When the bottom incline direction is other than +X direction, use the rotation angle (A).

17.6 Servo axis orbiting machining



Items	Setting values
Machining method (L)	3,13,23
Pattern (P)	5050
Rotation angle (A)	±360.0
Side taper angle (K)	Not used
Bottom shape pattern (M)	Standard pattern
Corner angle (B)	0～89.0

Fig. 17.6 Servo axis orbiting machining

[Description]

(a) The figure 17.6 shows an example when the bottom shape pattern (M) is 1111.
The pattern (P) 5050 specifies a motion pattern as viewed toward the servo axis direction.

(b) The orbiting motion on the plane including the servo axis does not start if the bottom remaining amount of model data is smaller than the electrode reduction (R).

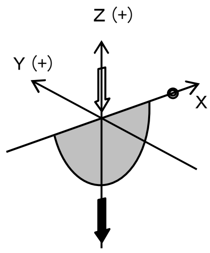
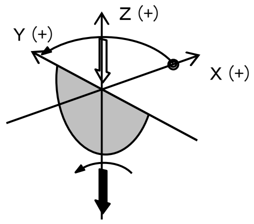
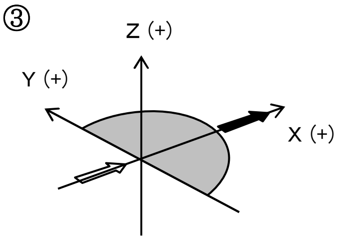
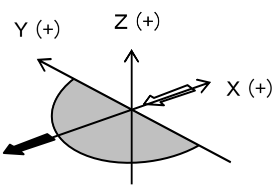
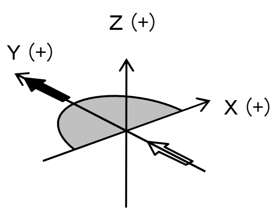
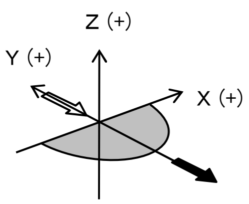
(c) The pattern function is turned off if the electrode reduction (R) is 0.

(d) The bottom remaining amount is compensated by the corner angle (B). The servo axis orbiting machining finishes the workpiece by feeding the electrode in the servo axis direction only. Accordingly, set the corner angle (B) according to the electrode side taper angle.

(e) Use only 3, 13 or 23 for the machining method (L).

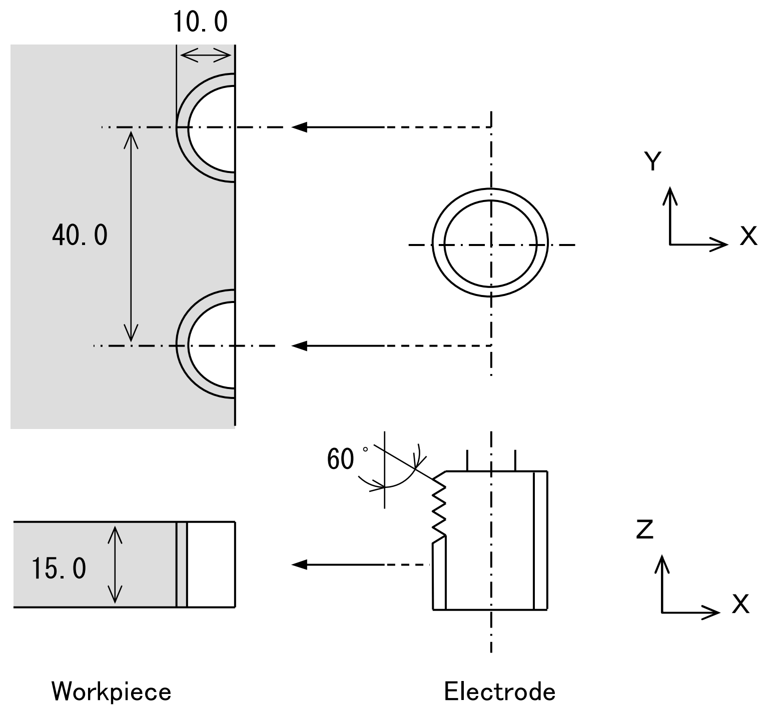
(f) The pattern offset and the side taper angle (K) cannot be used.

Setting example of servo axis orbiting machining

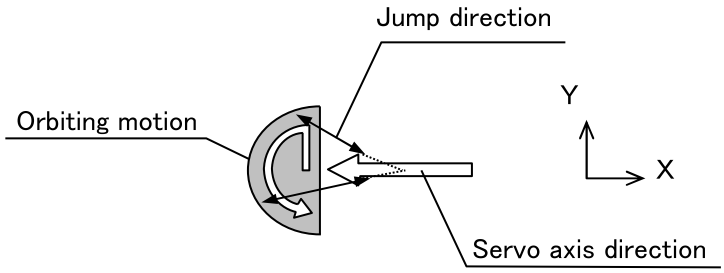
	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
① 	Z (−)	5050	0	—	1111	60. 0	3 13 23	No
②  Rotate ① by 90˚	Z (−)	5050	90. 0	—	1111	60. 0	3 13 23	No
③ 	X (+)	5050	0	—	1111	60. 0	3 13 23	No
④ 	X (−)	5050	0	—	1111	60. 0	3 13 23	No
⑤ 	Y (+)	5050	0	—	1111	60. 0	3 13 23	No
⑥ 	Y (−)	5050	0	—	1111	60. 0	3 13 23	No

Servo axis orbiting machining example

Thread cutting by horizontal servo operation



In such a machining as shown above, an orbiting motion even in Z axis direction causes the leading edge of the thread to be flat. In this case, a designation of servo axis orbiting generates an orbiting motion as shown below, which does not change the edge shape of thread.



[Program example]

MC : Bottom stopped – complex (G102)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
X	／	MC DEPTH X AXIS [u,t]	-10.0
Y	／	Y AXIS [u,t]	
Z	／	Z AXIS [u,t]	
C	／	C AXIS [ANGLE]	
R	*	ELECTRODE REDUCTION [u,t]	0.2
E	*	MODEL DATA No.	123
I	／	START OF PROCESS No.	106
J	／	END OF PROCESS No.	12
O	／	FINISH PROCESS No.	12
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	5050
A	／	ROT. ANGLE [deg]	
K	／	SIDE TAPER ANGLE [deg]	
M	／	BOTTOM SHAPE PATTERN	1111
B	／	CORNER ANGLE [deg]	60.0
S	／	JUMP AMOUNT [code:u,t]	
T	／	CYCLE [code:0.001sec]	
F	／	SPEED [code:m,i/min]	
U	／	TIME CONTROL MC START PROC.No.	
V	／	PROCESS CONTROL TIME [min]	

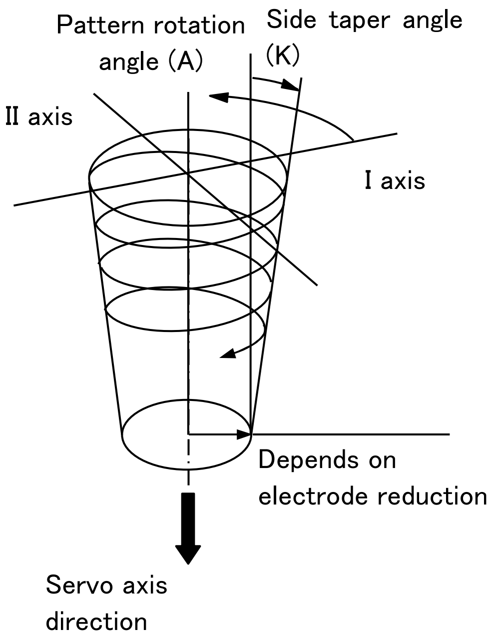
Servo axis orbiting

Edge angle of thread

POS : Dispersed (G113)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y,2:Z-X,3:Y-Z)	
W	／	WORK CORD. SYSTEM	
X	*	START CORD. X AXIS [u,t]	20.0
Y	*	(ABS) Y AXIS [u,t]	0
Z	*	Z AXIS [u,t]	-15.0
U	／	No.2 HOLE (ABS) I AXIS [u,t]	20.0
V	／	II AXIS [u,t]	-20.0
I	／	No.3 HOLE (ABS) I AXIS [u,t]	
J	／	II AXIS [u,t]	
K	／	No.4 HOLE (ABS) I AXIS [u,t]	
B	／	II AXIS [u,t]	
C	／	No.5 HOLE (ABS) I AXIS [u,t]	
P	／	II AXIS [u,t]	
Q	／	No.6 HOLE (ABS) I AXIS [u,t]	
R	／	II AXIS [u,t]	
L	／	INDEX DEVICE(1:C AXIS,2:IDX,3:DH)	
A	／	INDEX ANGLE [deg]	
D	／	ELECT.ROT.OFFSET (1:ON)	
S	／	C AXIS SYNC PATTERN (1:ON)	
T	／	OPPOSITE (1:ON)	

17.7 Taper machining



Items	Setting value
Machining method (L)	Refer to Description (e).
Pattern (P)	Any
Rotation angle (A)	±360.0
Side taper angle (K)	0～89.0

Fig. 17.7 Taper machining

[Description]

(a) The figure 17.7 is an example toward after it machining it to an example when the pattern (P) is 1111,and the specified position the bottom from the top.

(b) The side taper angle parameter (K) is "B" in the through machining menu. The setting value range is ±89.0.

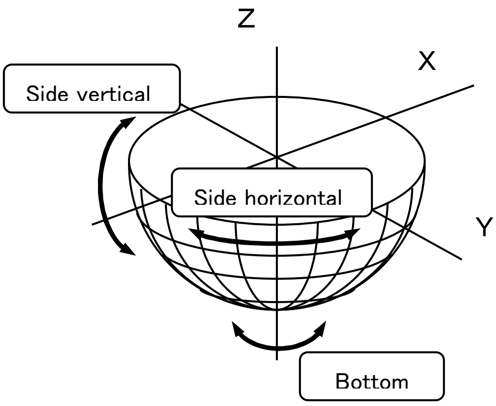
(c) The radius at the end point is determined by the electrode reduction (R). The radius at the start point varies with the side taper angle (K).

(d) The alarm occurs, if the pattern radius exceed 16mm by setting the side taper angle (K).

(e) The machining method (L) doesn't usually operate. There is movement by two kinds of toward the bottom movement and upper toward after it machines it to the bottom once the upper surface of work from the bottom of work.

(f) The pattern offset can be used.

17.8 3-D machining



Items	Setting values
Machining method (L)	8,18,28
Pattern (P)	1111
Rotation angle (A)	Not used
Side taper angle (K)	Not used
Bottom shape pattern (M)	0
Corner angle (B)	0

Fig. 17.8 3-D machining

[Description]

(a) It is effective only in Z axis machining.

(b) Use only 8, 18 or 28 for the machining method (L).

(c) Use only 1111 for the orbiting pattern (P).

(d) The pattern function is turned off if the electrode reduction (R) is 0.

(e) The rotation angle (A) and the side taper angle (K) cannot be used.

(f) The pattern offset cannot be used.

(g) Set time control machining.

3-D machining is used for the machining by the electrode of three dimension shape of total shape.

There are the following problems in usual orbiting because three dimension electrode made by three dimensions CAD・CAM is reduced in all directions and, the shape is not accurately transcribed.

①The roughness electrode processes too much in the corner part of the bottom.
And the finish electrode cannot finish up.

②Slight shape is artificial in the corner part of the bottom (R: 0.1 – 0.3).
The problem of ② cannot be solved though sphere-shape machining in clause 18.3 can solve the problem of ①.

3-D machining is the machining method which can solve the problems ①② on account of repeating orbit in all directions (bottom, side horizontal and side vertical).

The number of orbiting directions is different depending on the machining method.

Machining method	Application	Number of directions
8	Rough machining	8
18	High accuracy machining	24
28	Standard accuracy machining	16

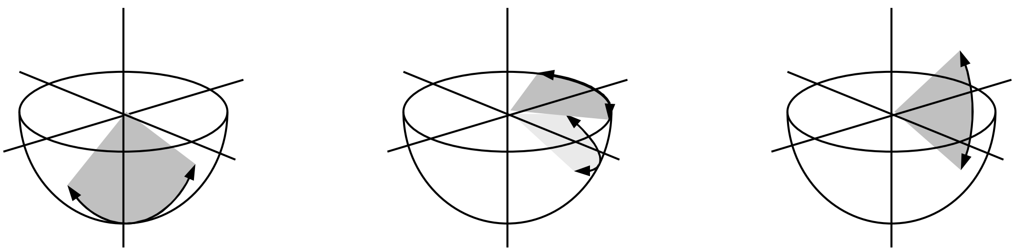
Set the time control machining. The standard of setting is shown.

Machining method	Time control
8	20 minutes or more
18	45 minutes or more
28	30 minutes or more

Set the time control longer when the discharge area is larger.

"REMAIN TIME" on COND – MDL MONITOR screen is remainder time in the divided direction of each orbit (bottom, side horizontal, and side vertical) and no remainder time of the process of the machining.

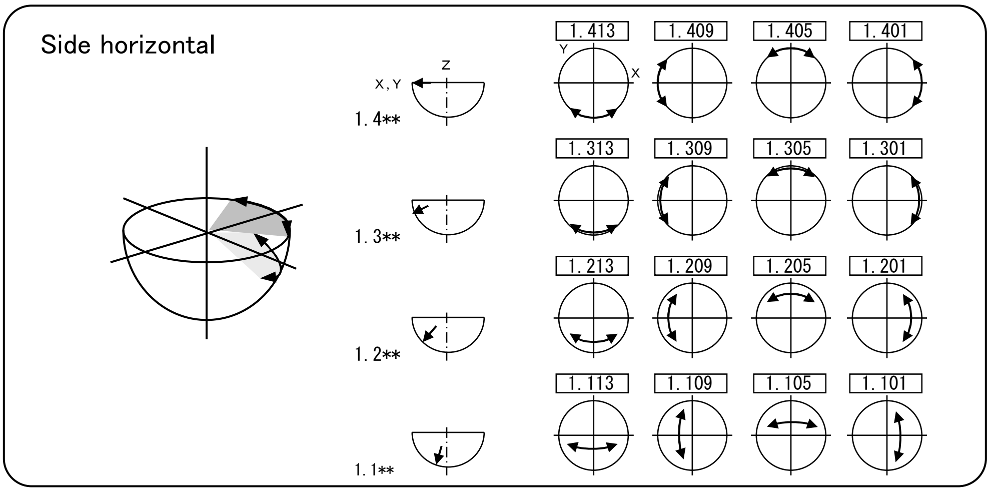
An imitative chart of the direction of each orbit is shown.

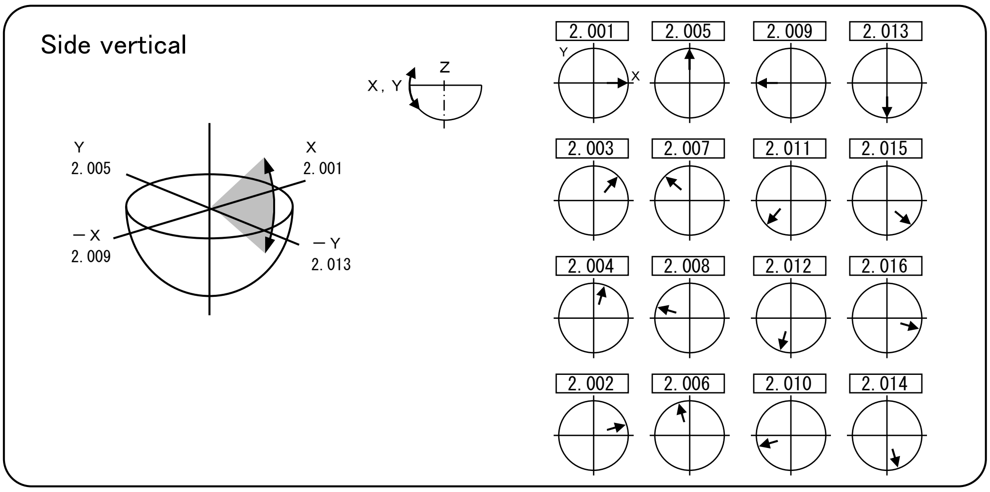


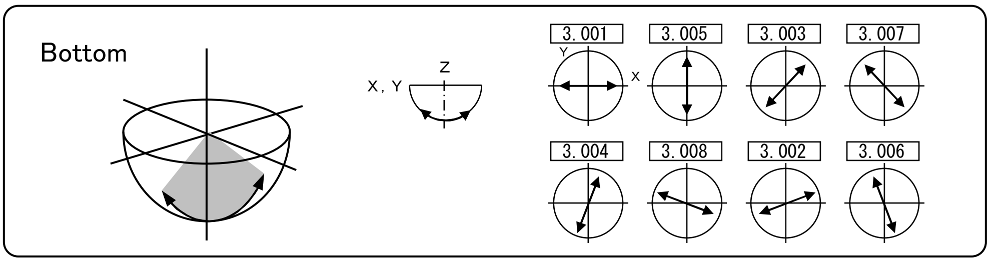
Bottom　　Side horizontal　　Side vertical

The orbiting direction in machining is displayed in the electrode reduction Ⅰ and Ⅱ on COND – MDL MONITOR screen as follows.

Ⅰ :Orbiting direction (It is changed in order.)







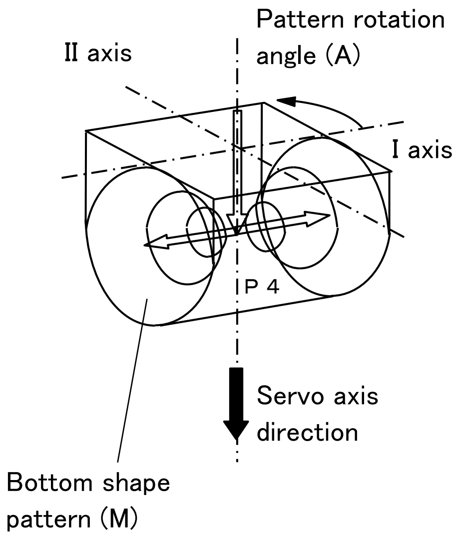
Ⅱ ： Machining completion situation

＊.###

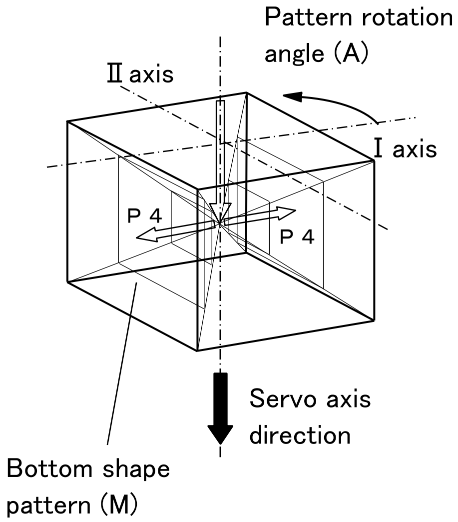
： Number of the remainder of machining points
When this number becomes 0, the machining is the end.

＊ ： Frequency of machining

17.9 Half-shape machining



(Fig a)



(Fig b)

Fig. 17.9 Half-shape machining

Items	Setting values
Machining method (L)	3,13,23
Pattern (P)	2222,2002, 0220
Rotation angle (A)	±360.0
Side taper angle (K)	Not used
Bottom shape pattern (M)	Standard pattern
Corner angle (B)	Not used

[Description]

(a) Use only 2222 for the pattern (P).

(b) The figure 17.9 (Fig a) shows an example when the bottom shape pattern (P) is 1111, and the figure 17.9 (Fig b) shows an example when the bottom shape pattern is 2222. the bottom shape pattern (P) specifies the bottom shape. The bottom machining is executed ± directions on I axis.

(c) Use only 3, 13 or 23 for the machining method (L).

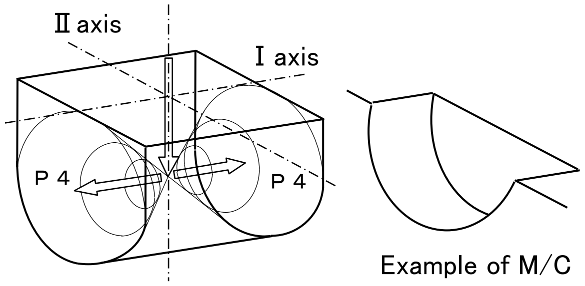
(d) In horizontal machining, use only 0, 90.0, or −90.0 for the rotation angle (A).

(e) The pattern function is turned off if the electrode reduction (R) is 0.

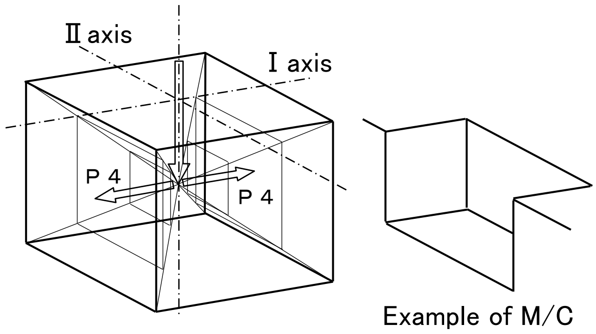
(f) The side taper angle (K) and the corner angle (B) cannot be used.

(g) The pattern offset can be used.

Half-shape machining of G102 (BOTTOM STOPPED-COMPLEX) is useful function when uniform surface finish or high profile accuracy is required.



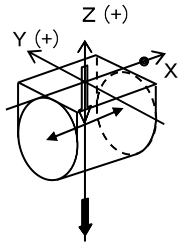
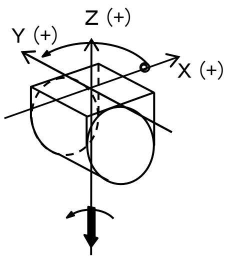
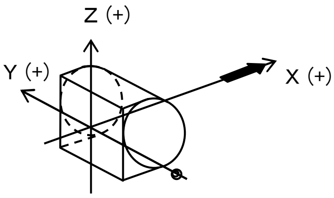
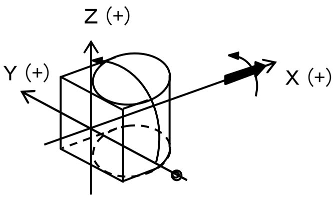
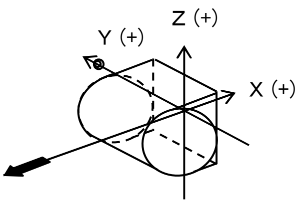
Orbiting pattern P=2222
Bottom shape pattern M=1111

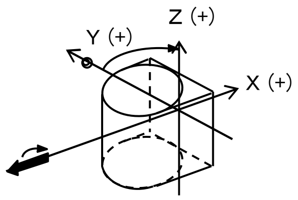
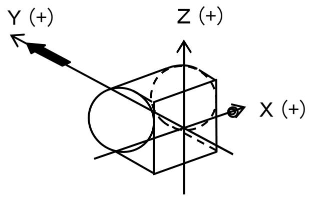
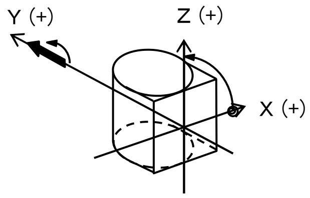
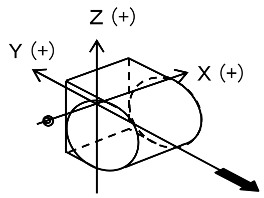
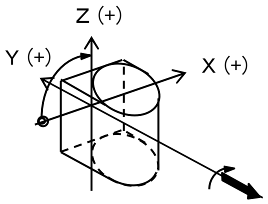


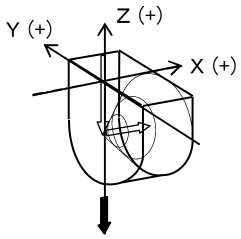
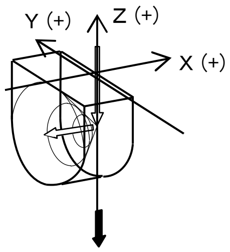
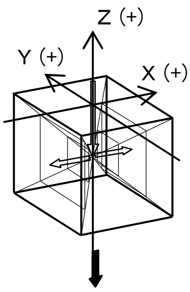
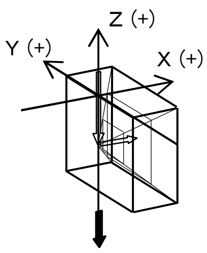
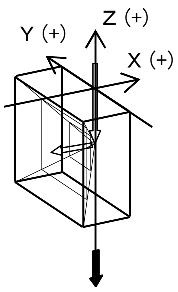
Orbiting pattern P=2222
Bottom shape pattern M=2222

One side half-shape machining can be specified by G102 item P : Orbiting pattern = ″2002″ or ″0220″ , because both side machining is not necessary in open side machining like above.

Setting example of half-shape machining
(when the bottom shape pattern (P) is 1111 it is the same.)

	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
① 	Z (−)	2222	0	—	1111	—	3 13 23	Yes
②  Rotate ① by 90°	Z (−)	2222	90.0	—	1111	—	3 13 23	Yes
③ 	X (+)	2222	0	—	1111	—	3 13 23	Yes
④  Rotate ③ by 90°	X (+)	2222	90.0	—	1111	—	3 13 23	Yes
⑤ 	X (−)	2222	0	—	1111	—	3 13 23	Yes

	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
⑥  Rotate ⑤ by 90°	X (−)	2222	90.0	—	1111	—	3 13 23	Yes
⑦ 	Y (+)	2222	0	—	1111	—	3 13 23	Yes
⑧  Rotate ⑦ by 90°	Y (+)	2222	90.0	—	1111	—	3 13 23	Yes
⑨ 	Y (−)	2222	0	—	1111	—	3 13 23	Yes
⑩  Rotate ⑨ by 90°	Y (−)	2222	90.0	—	1111	—	3 13 23	Yes

	MC direction X, Y, Z	Pattern P	Rotation angle A	Side taper angle K	Bottom shape pat. M	Corner angle B	MC method (valid)	Pattern offset (Y/N)
⑪ 	Z (−)	2002	0	—	1111	—	3 13 23	Yes
⑫ 	Z (−)	0220	0	—	1111	—	3 13 23	Yes
⑬ 	Z (−)	2222	0	—	2222	—	3 13 23	Yes
⑭ 	Z (−)	2002	0	—	2222	—	3 13 23	Yes
⑮ 	Z (−)	0220	0	—	2222	—	3 13 23	Yes

18. APPLICATIONS OF THE POSITIONING MODEL

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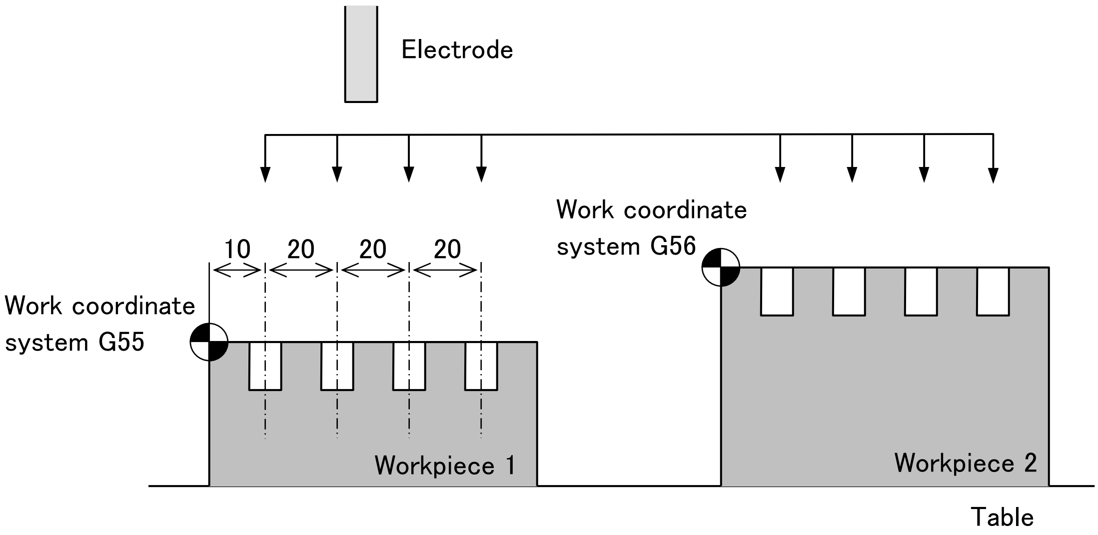
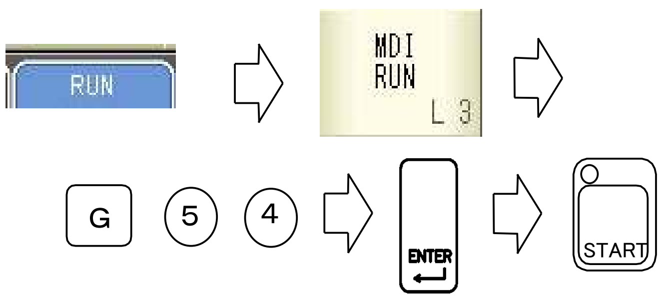
18. 1　Similar multi-piece machining on plural workpieces



[Procedure]

(a) Change over the coordinate system in the MDI mode.



(Each coordinate system G54–G61 can be used.)

(b) Using the touch sensing function in the manual mode, determine the origin.

(c) For workpiece 2, determine the origin by changing over the coordinate system to another G code in the same manner as in workpiece 1.

[Program]

MC : Bottom stopped – simple (G101) etc.

↓

POS : Line/Grid (G111)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55 ← Workpiece 1
X	*	START CORD. X AXIS [u, t]	10.0
Y	*	(ABS) Y AXIS [u, t]	0
Z	*	Z AXIS [u, t]	5.0
P	*	PITCH WIDTH I AXIS [u, t]	20.0
Q	*	II AXIS [u, t]	0
U	／	MC EXTENT I AXIS START (n-th)	1
V	／	PROCESSION END (n-th)	4
I	／	II AXIS START (n-th)	
J	／	END (n-th)	
M	／	HOLE START (n-th)	
:	:	:	

↓

POS : Line/Grid (G111)

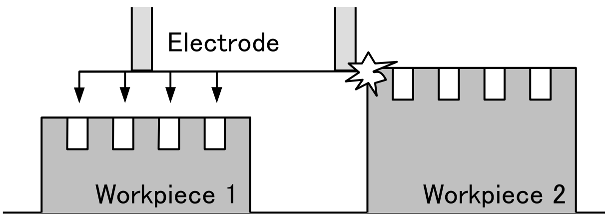
Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	56 ← Workpiece 2
X	*	START CORD. X AXIS [u, t]	10.0
Y	*	(ABS) Y AXIS [u, t]	0
Z	*	Z AXIS [u, t]	5.0
P	*	PITCH WIDTH I AXIS [u, t]	20.0
Q	*	II AXIS [u, t]	0
U	／	MC EXTENT I AXIS START (n-th)	1
V	／	PROCESSION END (n-th)	4
I	／	II AXIS START (n-th)	
J	／	END (n-th)	
M	／	HOLE START (n-th)	
:	:	:	

M30 ;

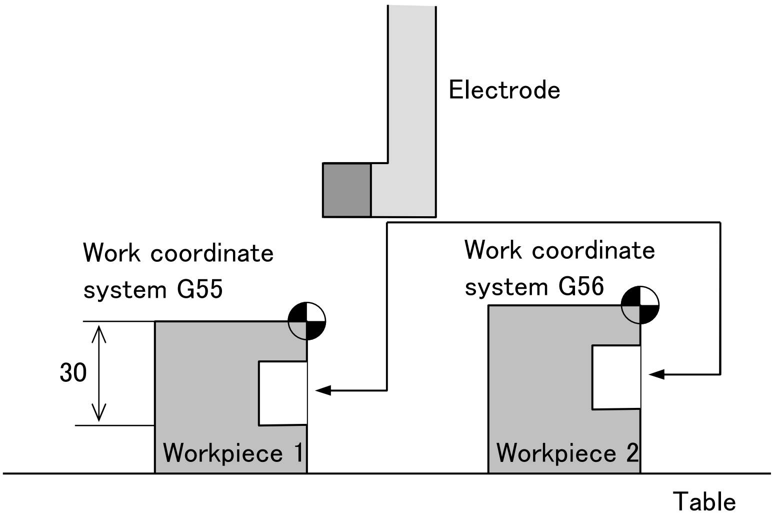
[Note]

The electrode position at the time of program start is automatically stored, and this position is used as travel height for a multi–piece machining.

As such, raise the electrode to a safe height for travel either by manual or program operation before program start to prevent collision.



18.2 Horizontal side face machining on plural workpieces



[Procedure]

(a) Set the coordinate system G55–G56 for each workpiece, and determine the origin. (Same manner as in clause 18.1).

(b) The origin must be determined again, if the electrode is changed.
In this case, determine the origin of all coordinate systems that use G55 or G56.
However, the use of following function requires the origin of only the workpiece 1 (G55) to be re-set; origin resetting for the other systems may be omitted.
① Local coordinate system
② G92X___Y___Z___L1;

[Program]

G55G00Z10.0; ← Position the head at travel height. (Manual operation allowed.)

↓

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	1
Z	*	MC DEPTH [u, t]	-15.0
R	*	ELECTRODE REDUCTION [u, t]	0.2
E	*	MODEL DATA No.	123
I	／	START OF PROCESS No.	6
J	／	END OF PROCESS No.	13
O	／	FINISH PROCESS No.	13
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT. ANGLE [deg]	
:	:	:	

↓

POS : Dispersed (G113)

Address	Attri.	Talk items		Set value
H	／	PLANE	(1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM		55
X	*	START CORD.	X AXIS [u, t]	5.0
Y	*	(ABS)	Y AXIS [u, t]	0
Z	*		Z AXIS [u, t]	-29.8
U	／	No.2 HOLE (ABS)	I AXIS [u, t]	
V	／		II AXIS [u, t]	
I	／	No.3 HOLE (ABS)	I AXIS [u, t]	
J	／		II AXIS [u, t]	
:	:	:		

Positioning to right side of workpiece.

Short depth by electrode reduction.

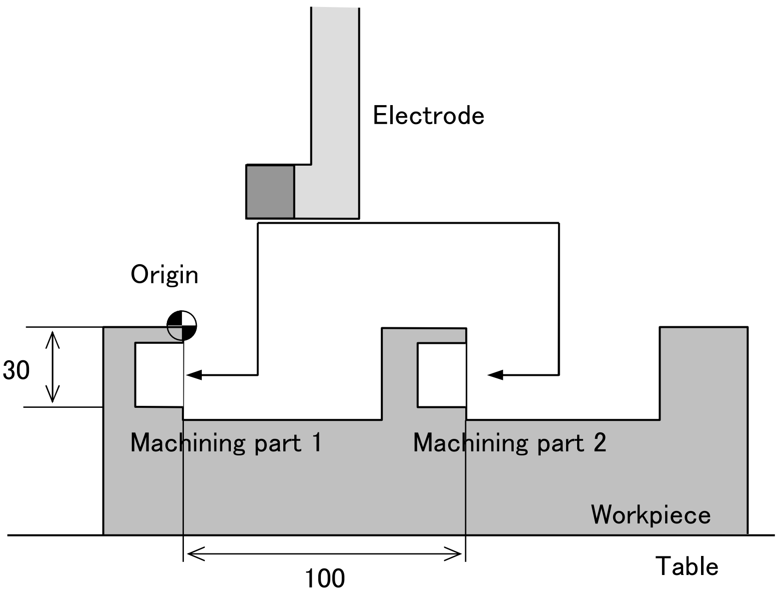
↓

POS : Dispersed (G113)

Address	Attri.	Talk items		Set value
H	／	PLANE	(1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM		56
X	*	START CORD.	X AXIS [u, t]	5.0
Y	*	(ABS)	Y AXIS [u, t]	0
Z	*		Z AXIS [u, t]	-29.8
U	／	No.2 HOLE (ABS)	I AXIS [u, t]	
V	／		II AXIS [u, t]	
I	／	No.3 HOLE (ABS)	I AXIS [u, t]	
J	／		II AXIS [u, t]	
:	:	:		

M30 ;

18.3 Multi-piece horizontal machining



[Procedure]

(a) Set the origin (do not change the work coordinate system).

[Program]

G00Z10.0; ← Position the head at travel height.

↓

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	91
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	1
Z	＊	MC DEPTH [u, t]	-20.0
R	＊	ELECTRODE REDUCTION [u, t]	0.2
E	＊	MODEL DATA No.	123
I	／	START OF PROCESS No.	6
J	／	END OF PROCESS No.	13
O	／	FINISH PROCESS No.	13
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT. ANGLE [deg]	
:	:	:	

↓

POS : Dispersed (G113)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	55
X	＊	START CORD. X AXIS [u, t]	5.0 ← Positioning to right side of workpiece.
Y	＊	(ABS) Y AXIS [u, t]	0
Z	＊	Z AXIS [u, t]	-29.8 ← Short depth by electrode reduction.
U	／	No. 2 HOLE (ABS) I AXIS [u, t]	105.0
V	／	II AXIS [u, t]	0
I	／	No. 3 HOLE (ABS) I AXIS [u, t]	
J	／	II AXIS [u, t]	
:	:	:	

M30 ;

19. PROGRAMMING EXAMPLES IN NC LANGUAGE

This section describes a major part of programming by the use of NC language.
For details, refer to the instruction manual Programming.

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19.4	Combination of model plan (position) and NC program	19－4

19. 1 Machining program

```
G76;                (Jump on)
G74R30P01111;       (Orbiting)
G83E1205Z-10.0;     (Machining)
M30;                (Program end)
```

19. 2 Subprogram

① Simple calling

```
O10  →  G76;
        G74R30P01111;
        G83E1205Z-10.0;
        M99;     (Subprogram end)
O15  →  M98 O10 R(  ) P(  )
        M30;
```

O10: Subprogram No.

R( ): Repetitions

P( ): Start block No.

※ R and P are omittable.
※ M98 P___L___N___ can be used as well as
M98 O___R___P___.

② Modal calling

```
O10  →  G76;
        G74R30P01111;
        G83E1205Z-10.0;
        M99;     (Subprogram end)
O15  →  G66 P10 L(  );
```

L( ): Repetitions

P10: Subprogram No.

```
        X__Y__;
        X__Y__;
        X__Y__;
          :
        G67;     (Modal cancel)
        M30;
```

The O10 subprogram is executed every time when the X__Y__ traverse is made.

19.3 Combination of model plan (machining) and NC program

O10 → MC : Single MC (G100)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	90
X	／	MC DEPTH X AXIS [u,t]	
Y	／	Y AXIS [u,t]	
Z	／	Z AXIS [u,t]	-10.0
C	／	C AXIS[rot./ANGLE]	
W	／	AUTO DEPTH MAX. TRAVEL [u,t]	
L	／	MC LAST STOP (1:ON)	
E	*	MC COND. No.	1205
U	／	REMAIN AMOUNT [u,t]	
R	／	PATTERN RADIUS [u,t]	
P	／	MODE/PATTERN	
A	／	ROT. ANGLE [deg]	
B	／	CIRCUIT SPEED [m.i/min]	
S	／	JUMP AMOUNT [code,u,t]	7
T	／	CYCLE [code,0.001sec]	4
F	／	SPEED [code,m,i/min]	8
I	／	CLAMP AMOUNT [u,t]	
H	／	TIME CONTROL TIME [min]	
M	／	START MC COND. No. (DF[%])	
D	／	START J. CYCLE [code,0.001sec]	
V	／	START MC REMAIN AMOUNT [u,t]	

↓

POS : Point (G110)

Address	Attri.	Talk items	Set value
N	*	ABS/INC (90/91)	91
W	／	WORK CORD.SYSTEM	
X	*	COORDINATES X AXIS [u,t]	0
Y	*	Y AXIS [u,t]	0
Z	*	Z AXIS [u,t]	0
L	／	INDEX DEVICE(1:C AXIS,2:IDX,3:DH)	
A	／	INDEX ANGLE [deg]	
D	／	ELECT.ROT.OFFSET (1:ON)	
S	／	C AXIS SYNC PATTERN (1:ON)	
E	／	MACHINING (MC COND. No.)	

Always use the Point menu and specify the amount of traverse to “0” in incremental mode.

G90;
M99;

O15 → G66P10L( );
X__Y__;
X__Y__;
X__Y__;
X__Y__;
:
:
G67;
M30;

19.4 Combination of model plan (position) and NC program

O10 → G90;
G76;
G74R3OP01111;
G83E1205Z-10.0;
M99;

O15 → MC : Package (G105)

Address	Attri.	Talk items	Set value
O	／	CALL PROGRAM No.	10
N	／	P.MODEL COMBINATION (1:OFF)	
X	／	PARAMETER 1 (VARIABLE No. #24)	
Y	／	2 (#25)	
Z	／	3 (#26)	
C	／	4 (#3)	
E	／	5 (#8)	
:	:	:	

↓

POS : Line/Grid (G111)

Address	Attri.	Talk items	Set value
H	／	PLANE (1:X-Y, 2:Z-X, 3:Y-Z)	
W	／	WORK CORD. SYSTEM	54
X	*	START CORD. X AXIS [u,t]	-20.0
Y	*	(ABS) Y AXIS [u,t]	-10.0
Z	*	Z AXIS [u,t]	5.0
P	*	PITCH WIDTH I AXIS [u,t]	20.0
Q	*	II AXIS [u,t]	0
U	／	MC EXTENT I AXIS START (n-th)	1
V	／	PROCESSION END (n-th)	3
I	／	II AXIS START (n-th)	
J	／	END (n-th)	
M	／	HOLE START (n-th)	
N	／	END (n-th)	
B	／	ROTATE ANGLE [deg]	
K	／	SQUARE (1:ON)	
L	／	INDEX DEVICE (1:C AXIS, 2:IDX, 3:DH)	
A	／	INDEX ANGLE [deg]	
D	／	ELECT.ROT.OFFSET (1:ON)	
S	／	C AXIS SYNC PATTERN (1:ON)	
T	／	OPPOSITE (1:ON)	

20. WHEN YOU ARE IN A DIFFICULTY

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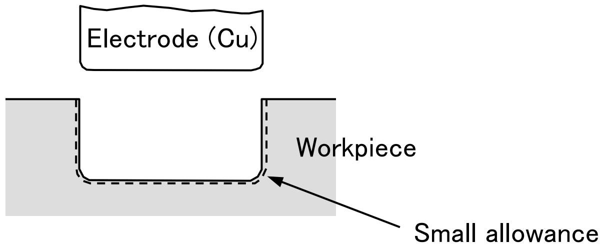
20.1 Poor initial discharge during finish machining after rough machining



In a machining of small allowance with copper electrode as shown above, initial discharge may be unfavorable. The causes will be due to:

- Machining condition
- Dielectric fluid

(a) Machining condition

The advanced NC EDM enables very low wear machining. However, the condition for very low wear machining will provide poor initial discharge. As a result, unstable machining occurs, causing abnormal wear of the electrode. Thus, the electrode wear becomes high even though a low wear condition is used.
In this case, the wear condition should positively be used.

Counter measures: Referring to Section 2, change initial machining condition to high speed condition.

(b) Dielectric fluid

The dielectric fluid is important to maintain a proper gap between the electrode and the workpiece. This is true particularly in the above machining conditions.
Here, the different type and features of the fluid will be reviewed briefly. The fluid may be grouped into 3 kinds:

- Mineral oil
- Synthetic oil
- Synthetic oil + additives

The features of them are:

Mineral oil:

- Used since ancient times
- Strong smell like kerosene
- Filter life is short.
- Machining performance

  Best performance under the above machining condition.

  The electrode wears rather largely, but it is not a critical problem.
- Cost

  Lowest. ¥150～200/liter

Synthetic oil:

- Used since 1980's.
- Little smell and less attack to skin.
- Machining performance

  There is a little difference between makers.

  Poor performance under the above machining conditions.

  Electrode wear is small.
- Cost

  1.2 to 1.5 times the mineral oil.

Synthetic oil + additives:

- Used since 1985.
- Less smell
- Machining performance

  Improves weak points of synthetic oil to raise performance to mineral oil level.

  Different characteristics between makers.
- Cost

  2.5 to 5 times the mineral oil.

Amongst the three kinds of fluids discussed above, mineral oil is the best under the said machining conditions. However, for those operators who cannot stand up to the smell like kerosene, synthetic oil should be used. In ordering the oil, designate mineral oil or synthetic oil. For the synthetic oil + additives, contact us upon introduction because of its high cost. The cost will be further improved in the future

Besides the dielectric fluid, the debris and carbon particles floating in the fluid are important factors under the said machining conditions.
Seasoned dielectric fluid enables stable machining.

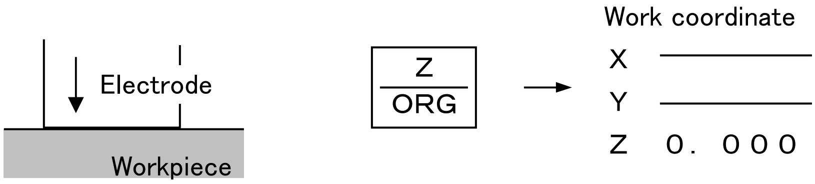
20. 2 The depth of machining varies

Check the following items sequentially, though there will be various causes in this problem.

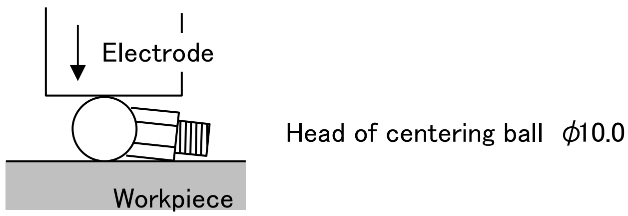
(a) Is centering in the machining depth direction OK?

Unlike the centering method of the milling machine, the NC EDM uses electrical touch sensing function for the centering. For this reason, even the slightest burr or debris present is detected during centering.

To reconfirm the centering, at first clean the electrode and workpiece surface thoroughly, then perform centering to set the origin of Z axis.



Next, prepare the standard centering ball supplied. Remove the head of centering ball, and insert it between the electrode and the workpiece. Again, perform centering by the touch sensing.

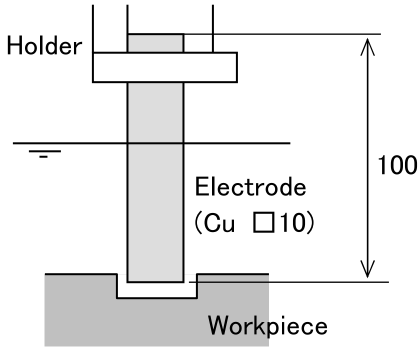


Here, read the Z value of the work coordinate. Is it very much smaller than 10.0? If the value is above 9.990, the centering technique is done well.

Since a centering method using the centering ball provides high centering accuracy, refer to Section 15 “How to use a centering ball”.

(b) Isn't finish machining started immediately after rough machining?

During rough machining, the discharge generates heat that elongates the electrode.



Machining condition E1308

(Roughness 45 μRmax)

When the above machining is continued for 15 minutes, the electrode elongates 50 to 100 μ m. It will return to original length in 20 minutes if the machining is stopped. This data varies with the electrode size; the smaller electrode allows the more heat accumulation, causing the electrode to be elongated. Also, the data varies with the electrode material; a copper electrode elongates most.
The following lists the linear expansion of each material at a temperature rise of 1°C per 1000mm.

Copper	:	17 μm
Copper tungsten	:	9 μm
Graphite	:	8 μm
Steel	:	11 μm
Aluminum	:	23 μm

Therefore, finish machining should not be executed immediately after rough machining. In particular, for a machining of short machining time, the machining operation finishes before the heat accumulated during rough machining can be radiated completely.
Consequently, machining ends with the electrode elongated. As a result, the depth of the machining is deeper or it becomes deeper gradually in a multi-piece machining.

[Counter measures]

Avoid continuous machining from rough to finish.

× Rough machining ——→ Finish machining

○ Rough → Semi-finish, Semi-finish → Finish machining
(Semi-finish starts with about 20 μ mRmax)

・In a multi-piece machining,

Split machining into 2 processes as shown below.

Rough → Semi-finish

Semi-finish → Finish

・In a one-piece machining,

Rough → Semi-finish

Wait for 20 minutes (dwell function)

Semi-finish → Finish

Furthermore, rough surface may be left depending on the heat generated during rough → semi-finish machining. To avoid this, the machining depth (Z) of rough → semi-finish machining should be shallow by 50 μ m.

[Machining that requires a care]

Electrode material : Copper

Electrode size : Below □15

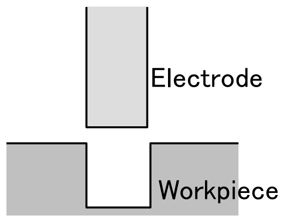
Initial condition : Above 40 μmRmax

[Machining example]

Electrode : Cu, □10, 1pc

Reduction per side : 0.25

Machining depth : 10.0mm



MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	
Z	＊	MC DEPTH [u, t]	-9.95
R	＊	ELECTRODE REDUCTION [u, t]	0.23
E	＊	MODEL DATA No.	121
I	／	START OF PROCESS No.	2
J	／	END OF PROCESS No.	9
O	／	FINISH PROCESS No.	13
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT. ANGLE [deg]	
S	／	JUMP AMOUNT [code, u, t]	7
T	／	CYCLE [code, 0.001sec]	3
F	／	SPEED [code, m. i/min]	8
K	／	CLAMP START PROCESS No.	
M	／	TIME CONTROL START PROCESS No.	
U	／	1ST PROCESS [min]	
V	／	2ND PROCESS [min]	
W	／	3RD PROCESS [min]	

+0.05 because of thermal expansion

−0.02 because of thermal expansion

↓

POS : Dispersed (G113) etc.

↓

AUX : G function (G133)

Address	Attri.	Talk items	Set value
L	／	ABS/INC (90/91)	
P	／	WORK LIMIT (0:OFF, 1:ON)	
U	／	CORD. X AXIS START [u, t]	
A	／	END [u, t]	
V	／	Y AXIS START [u, t]	
B	／	END [u, t]	
W	／	Z AXIS START [u, t]	
C	／	END [u, t]	
R	／	DWELL TIME [0.001sec]	1200 → 20 minutes
D	／	G CODE (DIRECT VALUE)	

↓

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	
Z	*	MC DEPTH [u, t]	-10.0
R	*	ELECTRODE REDUCTION [u, t]	0.25
E	*	MODEL DATA No.	121
I	／	START OF PROCESS No.	8
J	／	END OF PROCESS No.	13
O	／	FINISH PROCESS No.	13
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT. ANGLE [deg]	
S	／	JUMP AMOUNT [code, u, t]	7
T	／	CYCLE [code, 0.001sec]	3
F	／	SPEED [code, m. i/min]	8
K	／	CLAMP START PROCESS No.	
M	／	TIME CONTROL MC START PROC. No.	
U	／	1PROCESS [min]	
V	／	2PROCESS [min]	
W	／	3PROCESS [min]	

↓

POS : Dispersed (G113) etc.

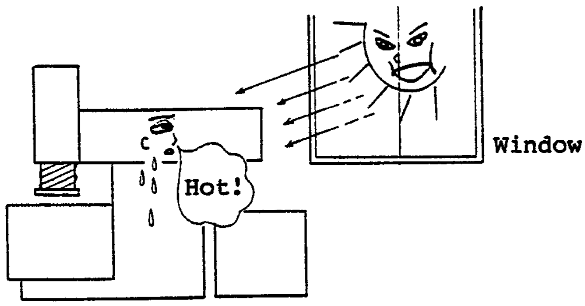
M30 ;

(c) Does ambient temperature fluctuation affect machining?

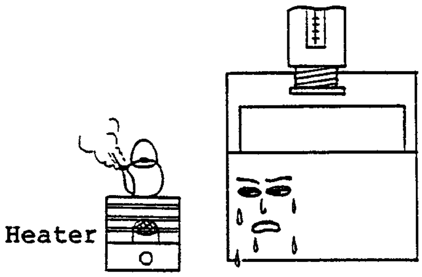
Some may think that the machine is very resistant. However, the machine is susceptible to the temperature changes. Temperature gap between machine portions causes positional error (thermal deformation). In spite of ongoing commitment to research and development against the thermal deformation, it cannot be overcome completely because of the fundamental that metal expands or contracts with temperature changes.

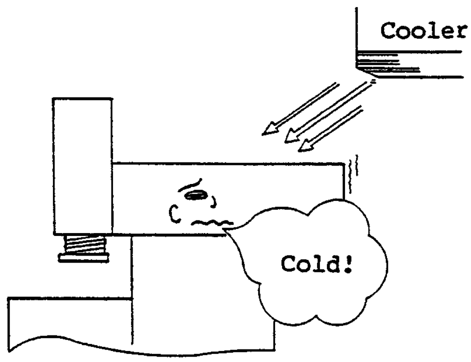
Below are some points to consider in reducing the effects of temperature change.

i) Is the machine exposed to direct sun light?



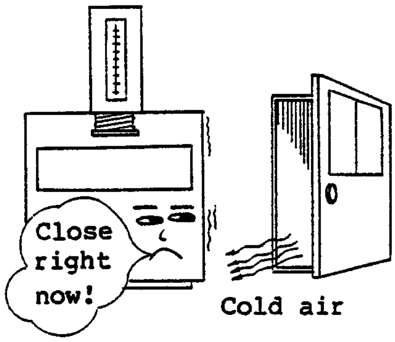
ii) Is the machine installed near a heating apparatus or air conditioner?





iii) Is the machine installed near a door?

Double doors should be provided in a cold district in the winter.



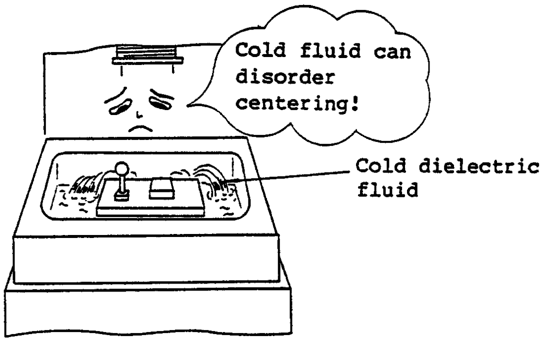
ⅳ) Does the room temperature change suddenly?

The machine can operate normally in the temperature range 0 to 30 °C so long as it is constant. However, the machine will underperform by temperature fluctuations, unlike mankind who is resistive to:

・ A heating apparatus used suddenly in the morning.
・ A cooling unit used suddenly when it is hot.

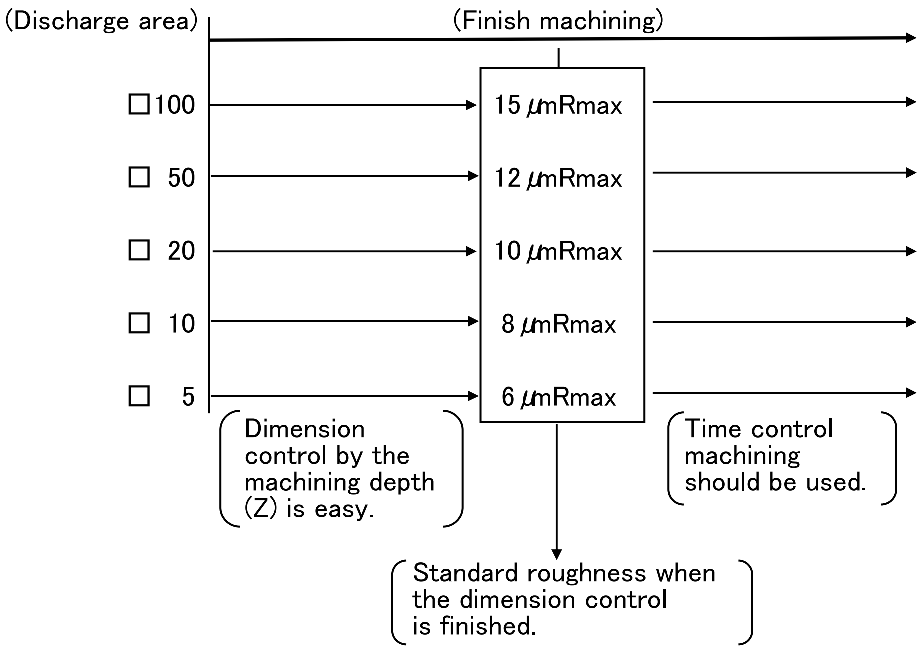
ⅴ) The time duration in which the room temperature changes the most in a typical day will be between 6 to 10 in the morning. A centering work conducted during this time requires extreme care. The depth of machining will be deeper in this time zone.

ⅵ) When the machine has been stopped for a while since the previous machining, circulate the dielectric fluid for at least one hour before a centering work.
(Because there is possibility of a large temperature gap between dielectric fluid and machine body.)

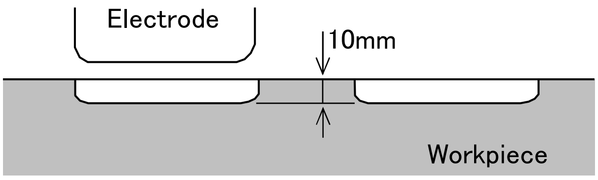


(d) Is the roughness properly set according to the discharge area?

"The discharge area □100 is finished to 15 μ mRmax" presents the same difficulty as the machining that "the discharge area □10 is finished to 5 μ mRmax".
This fact is very important in a multi-piece machining where the discharge area is very large.
It is recommended that <u>to control the dimension by the machining depth (Z), the machining should end with proper roughness according to the discharge area</u>. Then, the surface should be finished by the time control machining, so that the variation in the machining depth can be reduced as well as generation of better surface roughness.



[Machining example]



Electrode: Cu □100 2pcs
Reduction : Rough 0.3
Finish 0.2
Workplace: Prepared by a milling.

[Rough machining program]

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	
Z	*	MC DEPTH [u, t]	-9.95
R	*	ELECTRODE REDUCTION [u, t]	0.28
E	*	MODEL DATA No.	25
I	／	START OF PROCESS No.	7
J	／	END OF PROCESS No.	12
O	／	FINISH PROCESS No.	15
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT. ANGLE [deg]	
S	／	JUMP AMOUNT [code, u, t]	8
T	／	CYCLE [code, 0.001sec]	8
F	／	SPEED [code, m. i/min]	4
K	／	CLAMP START PROCESS No.	
M	／	TIME CONTROL MC START PROC. No.	
U	／	1PROCESS [min]	
V	／	2PROCESS [min]	
W	／	3PROCESS [min]	

+0.05 because of thermal expansion

–0.02 because of thermal expansion

↓

POS : Dispersed (G113) etc.

[Finish machining program 1]　finishing by dimension control

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	
Z	*	MC DEPTH [u, t]	-10.0
R	*	ELECTRODE REDUCTION [u, t]	0.2
E	*	MODEL DATA No.	25
I	／	START OF PROCESS No.	10
J	／	END OF PROCESS No.	13
O	／	FINISH PROCESS No.	15
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT. ANGLE [0.001deg]	
S	／	JUMP AMOUNT [code, u, t]	8
T	／	CYCLE [code, 0.001sec]	8
F	／	SPEED [code, m. i/min]	4
K	／	CLAMP START PROCESS No.	
M	／	TIME CONTROL MC START PROC. No.	
U	／	1PROCESS [min]	
V	／	2PROCESS [min]	
W	／	3PROCESS [min]	

↓

(At this time, if the machining depth varies, change the machining depth setting (Z).)

POS : Dispersed (G113) etc.

[Finish machining program 2]　Finishing by time control

MC : Bottom stopped – simple (G101)

Address	Attri.	Talk items	Set value
N	／	ABS/INC (90/91)	
Q	／	MC AXIS (1:X, 2:Y, 3:Z)	
Z	*	MC DEPTH [u, t]	-10.02
R	*	ELECTRODE REDUCTION [u, t]	0.22
E	*	MODEL DATA No.	25
I	／	START OF PROCESS No.	12
J	／	END OF PROCESS No.	15
O	／	FINISH PROCESS No.	15
D	／	SIDE REMAIN AMOUNT COMP [%]	
H	／	BOTTOM REMAIN AMOUNT COMP [%]	
L	／	MC METHOD	13
P	／	PATTERN	2222
A	／	ROT. ANGLE [0.001deg]	
S	／	JUMP AMOUNT [code, u, t]	8
T	／	CYCLE [code, 0.001sec]	8
F	／	SPEED [code, m. i/min]	4
K	／	CLAMP START PROCESS No.	
M	／	TIME CONTROL MC START PROC. No.	13
U	／	1PROCESS [min]	30
V	／	2PROCESS [min]	60
W	／	3PROCESS [min]	60

Set within 50 μm in case of time control.

(Do not exceed 50 μm because initial machining in the 1st process executes time control up to 0.1mm allowance.)

↓

POS : Dispersed (G113) etc.

20.3 Rough surface remains

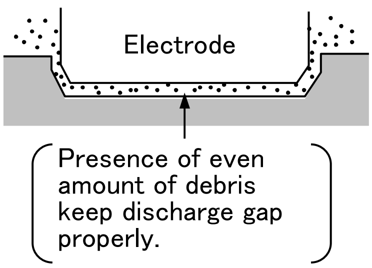
Refer to 20.2 (b) above. During rough machining, the electrode will elongate due to heat. Therefore, in the process of rough → semi-finish, reduce each setting of the machining depth (Z) and the electrode reduction (R).

[Standard] Electrode reduction (R) : −0.02mm
Machining depth (Z) : +0.05mm

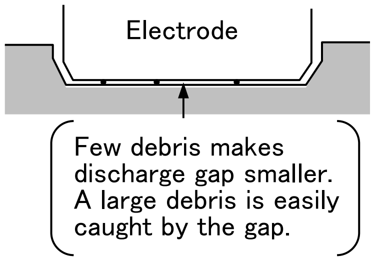
20.4 Initial discharge is bad, generating pin holes in a machining with small depth and large electrode

In re-machining, the machining area is cleaned, and the debris between electrode and workpiece is cleaned off. As a result, the discharge gap becomes small temporarily. Under this condition, the debris in the fluid is easily caught, causing the initial discharge to be worsened or pin holes to be made.

Normal machining



Machining just after cleaning



In such case, set the servo jump function. For this purpose, insert the servo jump function before all machining model block, as shown below.

AUX :.Special setting (G132)

Address	Attri.	Talk items	Set value
D	／	STARTING COND. No.	
C	／	HQSF μSC DENSITY [g/l]	
Q	／	EXP P-PULSE	
A	／	A-JUMP	
E	／	F-JUMP	
K	／	STEP ANGEL [0.001deg]	
S	／	SUPER SPARK	
M	／	CYCLE JUMP MODE	
R	／	NO.OF JUMP	
U	／	JUMP AMOUNT [code,u,t]	
V	／	CYCLE [code,0.001sec]	
W	／	NUMBER OF TIMES	10
O	／	DISCHARGING JUMP (1:ON)	
P	／	SERVO JUMP AMOUNT [u,t]	
L	／	JUMP METHOD	
X	／	ARBITRARY JUMP X AXIS [u,t]	
Y	／	Y AXIS [u,t]	
Z	／	Z AXIS [u,t]	
B	／	POLARITY REVERSE CYCLE [min]	
:	:	:	

10 → 10～20 μm will be proper.

↓

MC : Bottom stopped – simple (G101) etc.

POS : Dispersed (G113) etc.

M30 ;

20.5 A corner is not properly machined in a machining of small workpiece such as a connector

In such a case, use the machining method 7.
However, only a square shape can be used. The machining method 7 does not use the orbiting function.