5. SELECTION GUIDE OF DD ACTUATORS

5.1 Selection of Megatorque Motors

The following points should be taken into account when selecting a megatorque motor:
① Load applied to a motor (load inertia J, axial load and moment load, and holding torque necessary during stoppage) ② positioning accuracy, ③ positioing time, ④ static and dynamic accuracy of motor, ⑤ environmental conditions, ⑥ brake
For details, see the descriptions below:

(1) Load applied motors

① Load inartia J
The amount of inartia of the load connected to a Megatorque motor has great influence upon the acceleration and deceleration performance. Therefore, a motor size should be determined by calculating the amount of inertia J of a connected load. In general, the load inertia is much larger than the rotor inertia. The table below shows the range of inertia of loads connected with a motor according to the application.
Note that some load requires dummy inertia. See the Note 1.

Ranges of Load Inertia J According to Applications

(kg・m²)

application \ Motor size	0408	0608	0810	1010	1410
High speed indexing	0.01~0.05	0.05~0.2	0.11~0.45	0.18~0.75	0.31~1.25
Standard	0.05~0.5	0.2~2	0.45~4.5	0.75~7.5	1.25~12.5
Large inertia	0.5~1	2~2.5	4.5~5	7.5~37.5	12.5~125

② Axial load and moment load
Find a load applied to the motor. The patterns below(Fig. 5.1) show the relationship between external forces and loads. Adjust the axial load and moment load within the allowable axial and moment loads.
(For the allowable axial and moment loads, see the specifications of the Megatorque motors.)
Distances A between rotor end face and bearing

Distances A bzetween rotor end face and bearing

Motor size	0408	0608	0810	1010	1410
A (mm)	25.8	18.5	18.5	27.5	30.0

① If F is an extemal force,then
• Axial load = F_a + weight of payload
• Moment load M = 0

② If F is an extemal force,then
• Axial load = F_a + weight of payload
• Moment load M = F x L

③ If F is an extemal force,then
• Axial load = F_a + weight of payload
• Moment load M = F x (L + A)

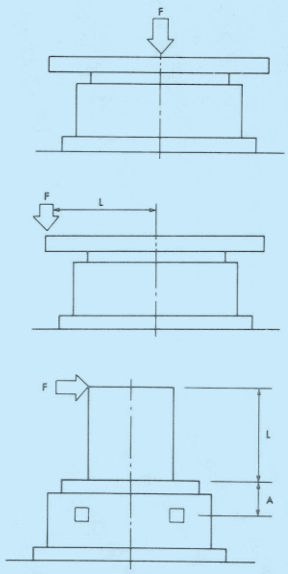

Fig. 5.1

[Example 1] The calculation of Intertia J

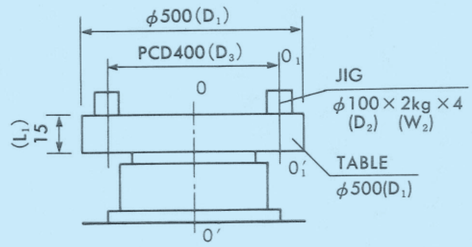

Fig. 5.2

(a) Find the inertia J_1 of the table (disk)

Mass $W_1 = \pi X \gamma X L_1 X D^2_1 \div 4$
$= 3.14X7.8X10^{-6}X15X500^2 \div 4$
$= 23(kg)$
$J_1 \quad = W_1 X D^2_1 \div 8$
$= 23X500^2 \div 8$
$= 7.19X10^5 (kg \cdot mm^2)$

(b) Find the inertia J_2 applied to the ratation axis 0_1-$0_1'$ of the jig alone.

$J_2 \quad = W_2 X D^2_2 \div 8$
$= 2X100^2 \div 8$
$= 2.5X10^3 (kg \cdot mm^2)$

(c) Finf the inertia J_3 applied to the rotarion axis 0-0′ of a single jig.

$J_3 \quad = J_2 + W_2 X D^2_3 \div 4$
$= 2.5X10^3 + 2X400^2 \div 4$
$= 8.25X10^4 (kg \cdot mm^2)$

(d) Find the total load inertia J_1

$J_T \quad = J_1 + nXJ_3$
$= 7.19X10^5 + 4X8.25X10^4$
$= 1.05X10^6 (kg \cdot mm^2)$
$= 1.05 (kg \cdot m^2)$

Therefore, the total load inertia $J_T = 1.05 (kg \cdot m^2)$

③ Holding torque necessary during stoppage

If an external force is applied to a stopping motor or an arm holding force is applied to the motor in an application as shown below(Fig. 5.3), the torque should be less than the continuous stall torque shown in the output torque characterstics. In some cases. a brake should be used together. (See the section on the series of motors with brakes.)

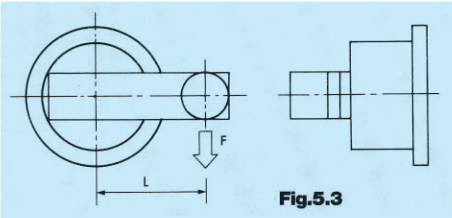

Fig.5.3

If the arm is maintained at the position shown above. torque FXL is applied to the motor.

Output Torque Characteristics (N·m)

motor size	0408		0608		0810		1010		1410	
power VAC	100	200	100	200	100	200	100	200	100	200
A	4.9	4.9	16.7	16.7	31.4	31.4	73.5	90.2	179	177
B	7.8	7.8	33.3	33.3	78.5	78.5	114	137	196	196
C	6.9	6.9	17.7	18.6	46.1	49.0	88.3	113	209	235
D	9.8	9.8	36.3	39.2	88.3	88.3	147	147	226	245

A: Maximum continious stall torque (Maximum torque which a motor can produce continuously while stalled within the rated temperature range)
B: Maximum stall torque (Maximum torque which a motor can produce while stalled)
C: Maximum continious torque (Maximum torque which a motor can produce continuously within the rated temperature range)
D: Maximum torque (Maximum torque which a motor can produce)
Note 1: The rated temperature is 130°C. (Temperature rise in the coil is 90°C at an ambient temperature of 40°C).
Note 2: For the motors not shown above, contact NSK

(2) Positioning accuracy

The positoning accuracy of the Megatorque motors is divided into the following two:

① Absolute positioning accuracy

② Repeatability

These positioning accuracies should be determined by comparing the positioning accuracy which the user requires with that of the Megatorque motor to be used.

(Example 2) The following example(Fig. 5.4) shows the possibility of using the type 0608 if the required repeatitive accuracy at a point 300mm from the center is ±0.02mm

Convert the required accuracy into angle as follows:

$\tan\theta = 0.02 \div 300$

$\theta = \tan^{-1}(0.02 \div 300)$

$= 3.8 \times 10^{-3}$(degree)

$= 14$(arc-sec.)

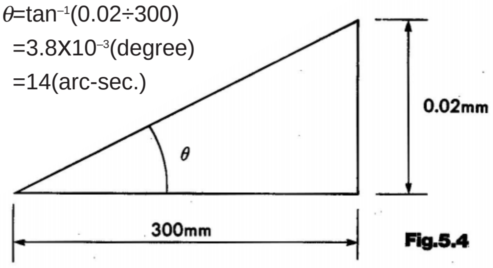

Fig.5.4

Therefore, the type 0608 may be used to meet the required positioning accuracy since ±14>±2.1

(3) Positionig time (Indexing time)

The time required for indexing the Megatorque motor may be found as shown below:

J	: load inertia	(kg·m²)
J_r	: Rotor inertia of motor	(kg·m²)
N	: Motor angular Velocity	(rps)
T	: Output torque at velocity N	(N·m)
T_M	: Load torque	(N·m)
t_1	: Rotating time	(s)
t_2	: settling time	(s)
t_3	: Positioning time	(s)
Δt	: Accelration/deceleration time	(s)
θ	: Rotation angle	(degree)
η	: Safty factor(Normally 1.5)	

$$\Delta t = \frac{(J+J_r) \times 2\pi N}{(T-T_M)} \times \eta$$

$$t_1 = \frac{\theta}{360 \times N} + \Delta t$$

$$t_3 = t_1 + t_2$$

$T, T_M, \Delta t$ and t_1 should meet the folowing conditions:

$T - T_M > 0$

$2 \times \Delta t \leqq t_1$

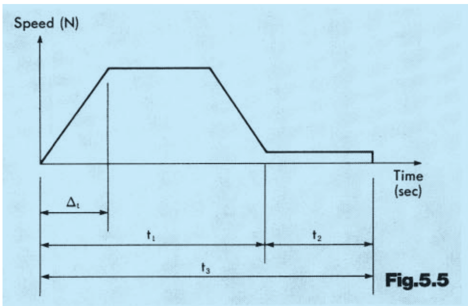

Fig.5.5

The following table shows the standard setting time, The shown settling time is for reference only since it is affected by the amount of load inertia J, mechanism righdity, etc.

Required repeatability(arc-sec.)	Settling time t_2(s)
±2~±10	0.2
±10~±100	0.1
±100~	0

Since the output torque of the Megatorque motor is liable to be reduced as the speed is increased, find a suitable pattern for the conditions of use from the speed and output torque using the above equations. The relationship the speed and output torque is shown on page A126. page A127 shows the relationship between the load inertia J and positioning time (indexing time) for a typical positioning angle.

(4) Static and dynamic accuracies of motor

① Static accuracy

The overall height of a motor depends on several connected components. The error of the standard motor height is controlled to ± 0.8 mm. In the deflection accuracy, the motors are available in two grades: The normal grade and precision grade. For accuracy standards, see the section on the precision series of products.

② Dynamic sccuracy

If a Magatorque motor is used for positioning, its torque variance or speed variance is normally no case for concern. However, if it is used continuously at low speed for roll driving, for example, its torque variance or speed variance may cause some problems. If there is a risk that torque variance or speed variance may cause some trouble, consult with NSK.

(5) Environmental conditions

The Magatorque motors for servere conditions are available in Waterproof motor and reinforced waterproof motor. See the related sections to select a suitable type of motor.

(6) Brake

6″ motors or larger are available with positive actuated and negative actuated electromagnetic brakes.
See the section on the motors with brakes to select a suitable type of motor.

Note 1: Motor Mounting and Dummy Inertia

To obtain full performance of a direct drive mechanism, a motor should be fixed securely with a rigid mechanism and the load to the motor should have high rigidity to raise the characteristic frequency of the whole mechanism. Therefor, if any of the following mechanisms are used, an additional inertia (dummy inertia) should be attached to the motor rotor:

(1) A load cannot be directly coupled with the motor. It is coupled by using a key, etc.

(2) Though a load is directly coupled, the shaft of the load is thin and is subject to twist and vibration.

(3) Because a ball screw, ets. is used as a load, the whole system has small inertia.

(4) Because a sprocket chain or gear mechanism is used for a load, the mechanism has backlash. The standard dummy inertia should be approx. 20% of the load inertia. If a reduction gear is used as a load to the motor, the inertia should meet the following condition:

$$\frac{\text{inertia not coupled directly}}{(\text{Reduction ratio})^2 \times \text{directly coupled inertia}} \leqq 5$$

Example of Dummy Inertia Attachment as shown to right.

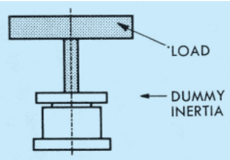

Fig.5.6

Note 2: Minimum Positioning Time Chart of Megatorque Motor System

The chart on page shows the minimumu time (tact time) for positioning a Megatorque motor system to a certain angle.
Make use of the chart in the following cases:

① The positioning angle and load inertia J are determined.
The user wants to know which size of motor should be selected for positioning within a required time.

② The positioning angle, load inertia J, and motor size are determined. The user wants to know the time of positioning.

The timing chart may be used if the following conditions are met:

•A load is directly coupled with a motor (without using a speed reducer such as gears or belt or coupling), and the load has sufficiently high rigidity. (Characteristic frequency is 50 Hz or more.)

•220 VAC is supplied to the driver unit. (If a motor runs on 100 VAC, it requires a longer Positioning time due to reduced output torque.)

•The motor is free from application of load torque.

Further consideration is required if a motor is to be used in any of the following conditions:

① The load inertia J exceeds the allowable value, which is not shown in the time chart.
Driving is not impossible, but large limitations are placed on the speed and rotational acceleration and it may take much more time the theoretical time.

② No time chart for intended positioning angle is available.
Separate calculation is required. However, the time required for a quite small angle may not be found by calculation.

③ The positioning time shall be reduced further.
The EP drive unit may be used. It is especially effective for positioning over a large angle.

The time chart shown assumes that the maximum speed is 1 rps, which may be increased to 3 rps. If the resolution is set to 153600 pulses/revolution. The time chart also assumes that the positioning setting time is 0.2 s, which be reduced if coarser positioning accuracy is allowed.

How to Use Time Chart

Example: To select a motor size which is capable of positioning a load inertia J of 0.75 kg・m^2 to 90 deg. within 0.6 sec.

① Find angle of 90 deg. in Figure 5.12.

② Draw a vertical line to the positioning of inertia J = 0. 75kg・m^2.

③ From the intersection of the curve in accordance with the motor size and the vertical line drawn in (2), draw a line toward the left to find the positioning time of the motor sizes.

0608: 0.63 sec.	1010: 0.51 sec.
0810: 0.57 sec.	1410: 0.55 sec.

④ Select 0810,1010, or 1410

Speed-Torque Characteristics

(Torque uni : FN • m)

Driver unit type is as follow.

- Four figures:motor size
- Two alphabets:MA=AC220V EM type
  MC=AC110V EM Type
  PA =AC220V EP Type

Speed (rps) \ Driver Unit Type	0408 MC	0408 MA	0608 MC	0608 MA	0608 PA	0810 MC	0810 MA	0810 PA	1010 PA	1010 MA	1010 PA	1410 MC	1410 MA	1410 PA	1413 PA	1420 PA
0.1	9.8	9.8	36.2	39.2	37.2	88.2	88.2	88.2	147	147	147	235	245	245	328	490
0.2	9.8	9.8	36.2	39.2	37.2	81.3	88.2	88.2	122	147	147	178	245	245	328	485
0.3	9.8	9.8	34.3	38.2	37.2	66.6	80.2	88.2	86.2	147	147	123	245	245	325	379
0.4	9.8	9.8	28.4	38.2	37.2	50.9	84.2	88.2	67.6	146	147	98.0	226	245	294	335
0.5	9.8	9.8	25.4	38.2	37.2	39.2	73.5	88.2	59.7	138	147	83.3	192	245	274	294
0.6	9.8	9.8	22.5	38.2	36.2	34.3	64.6	88.2	52.9	127	147	70.5	164	242	249	256
0.7	9.8	9.8	20.5	37.2	36.2	30.3	59.7	88.2	47.0	117	147	62.7	141	225	230	225
0.8	9.8	9.8	19.6	37.2	36.2	27.4	56.8	88.2	43.1	107	140	54.8	119	207	207	196
0.9	9.8	9.8	17.6	36.2	36.2	25.4	52.9	87.2	39.2	99.9	130	48.0	104	189	189	189
1.0	9.8	9.8	15.6	35.2	36.2	23.5	49.0	86.2	36.2	92.1	124	43.1	92.1	174	174	174
1.1	9.8	9.8	14.7	32.3	35.2	21.5	45.0	84.2	33.3	84.2	119	37.2	81.3	157	157	157
1.2	9.8	9.8	12.7	30.3	35.2	20.5	42.1	81.3	30.3	78.4	113	33.3	72.5	145	145	145
1.3	9.8	9.8	11.7	28.4	34.3	18.6	39.2	76.4	28.4	71.5	108	29.4	64.6	131	131	131
1.4	9.8	9.8	10.7	26.4	34.3	17.6	37.2	73.5	26.4	65.6	104	25.4	58.8	119	119	119
1.5	9.8	9.8	10.7	25.4	33.3	15.6	35.2	70.5	24.5	60.7	100	23.5	53.9	109	109	109
1.6	9.7	9.7	9.8	23.5	32.3	14.7	32.3	67.6	23.5	55.8	97.0	20.5	49.0	99.9	99.9	99.9
1.7	9.5	9.5	8.8	22.5	32.3	13.7	30.3	66.6	21.5	50.9	93.1	18.6	44.1	93.1	93.1	93.1
1.8	9.3	9.3	7.8	20.5	31.3	12.7	28.4	62.7	20.5	47.0	89.1	15.6	39.2	86.2	86.2	86.2
1.9	9.1	9.1	7.8	19.6	31.3	12.7	26.4	59.7	19.6	42.1	85.2	14.7	36.2	79.3	79.3	79.3
2.0	9.0	9.0	6.8	18.6	30.3	11.7	24.5	56.8	17.6	39.2	81.3	12.7	32.3	74.4	74.4	74.4
2.1	8.8	8.8	6.8	16.6	29.4	10.7	22.5	54.8	16.6	35.2	77.4	10.7	29.4	70.5	70.5	70.5
2.2	8.6	8.6	5.8	15.6	28.4	10.7	20.5	51.9	15.6	32.3	73.5	8.8	25.4	65.6	65.6	65.6
2.3	8.4	8.4	5.8	14.7	27.4	9.8	19.6	49.9	14.7	29.4	70.5	7.8	22.5	60.7	60.7	60.7
2.4	8.2	8.2	4.9	13.7	27.4	9.8	18.6	47.0	14.7	27.4	66.6	5.8	19.6	56.8	56.8	56.8
2.5	8.0	8.0	4.9	13.7	26.4	8.8	17.6	45.0	13.7	25.4	62.7	4.9	17.6	52.9	52.9	52.9
2.6	7.8	7.8	4.9	12.7	25.8	7.8	16.6	43.1	12.7	23.5	59.7	3.9	13.7	47.0	47.0	47.0
2.7	7.6	7.6	3.9	12.7	24.5	7.8	15.8	40.1	11.7	21.5	55.8	0.0	11.7	42.1	42.1	42.1
2.8	7.4	7.4	3.9	11.7	23.5	7.8	14.7	39.2	11.7	20.5	52.9	0.0	9.8	37.2	37.2	37.2
2.9	7.2	7.2	3.9	11.7	22.5	7.8	14.7	35.2	11.7	19.6	49.0	0.0	7.8	31.3	31.3	31.3
3.0	7.0	7.0	2.9	10.7	21.5	5.8	12.7	32.3	8.8	16.6	45.0	0.0	4.9	22.5	22.5	22.5

Minimum Positioning time Chart

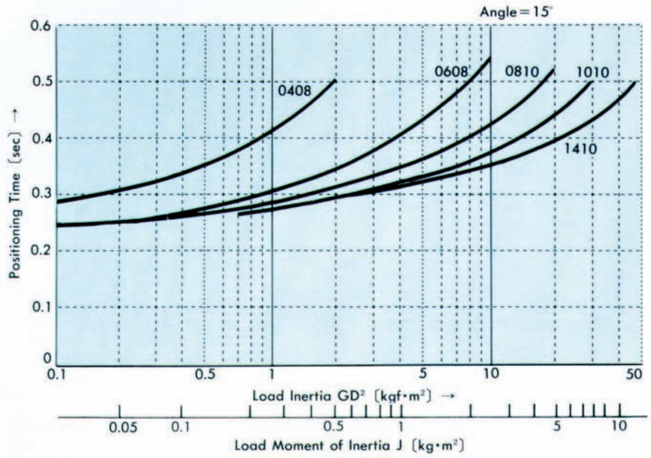

Fig.5.7

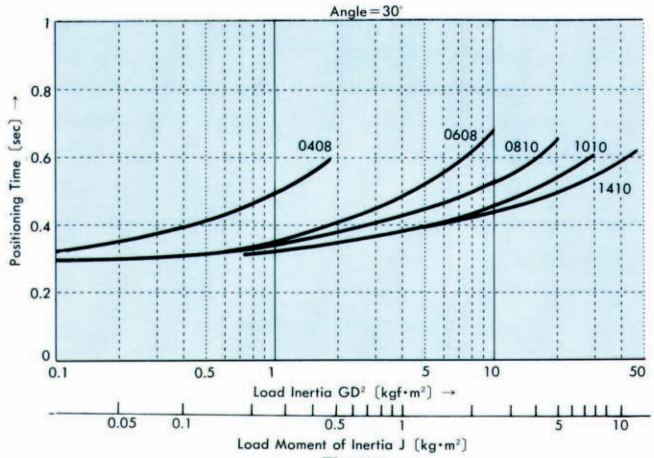

Fig.5.8

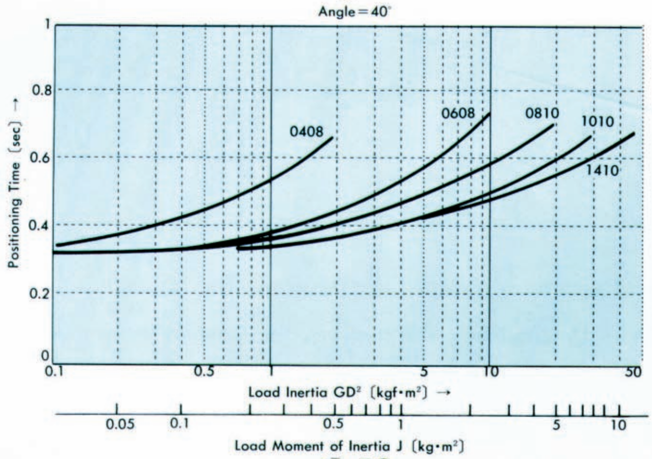

Fig.5.9

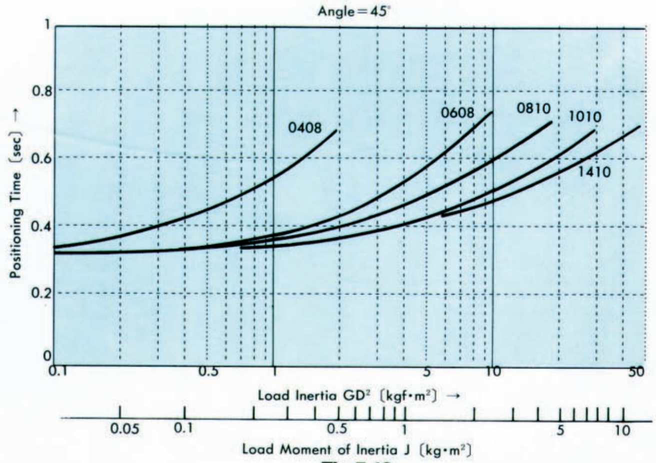

Fig.5.10

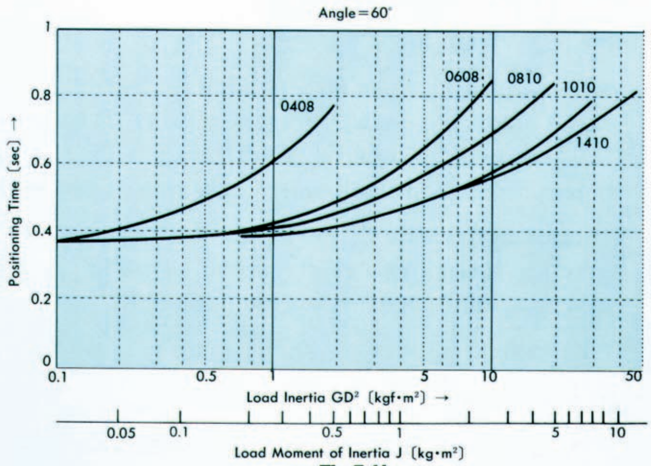

Fig.5.11

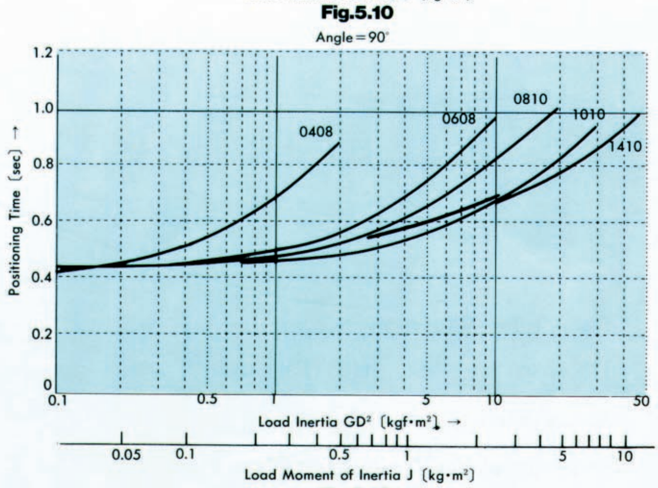

Fig.5.12

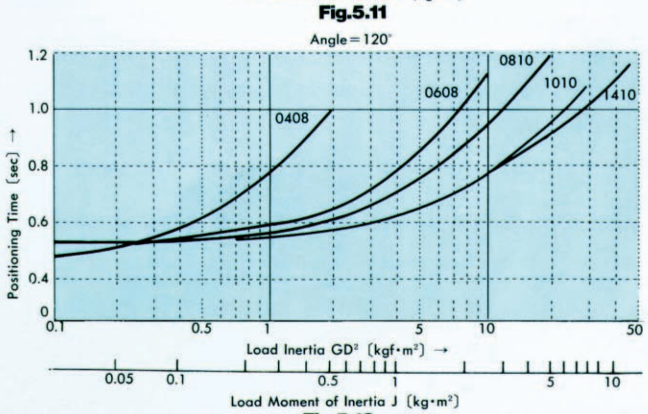

Fig.5.13

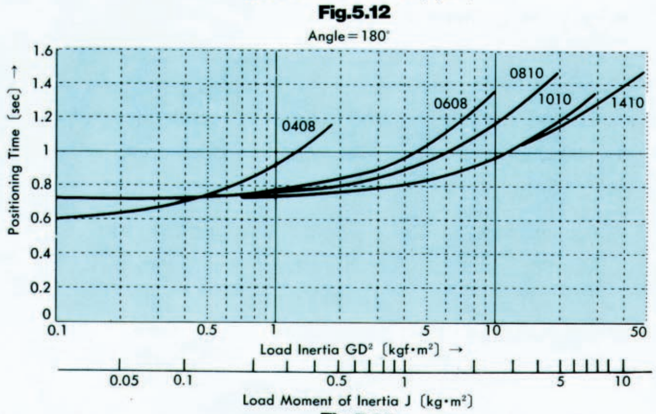

Fig.5.14

DD ACTUATORS

5.2 Selection of Megathrust Motor

To Select the correct Megathrust motor, positioning time should be taken into account.
The correct positioning time of a Megathrust motor may be found from a load applied to the slider and speed-thrust characteristics.

The calculation expressions necessary for selection are shown below.

M: Applied load (including slider mass) (kg)
V: Moving velocity (m/sec.)
F: Thrust force (N)
α: Acceleration (m/sec^2 or G)
t1: Acceleration time (s)
t_2: Moving time (s)
t_3: Settling time (s)
L: Travel (mm)
l_1: Acceleration/deceleration distance (mm)
T: Positioning time (s)
η: Safety factor (Normally 1.5)

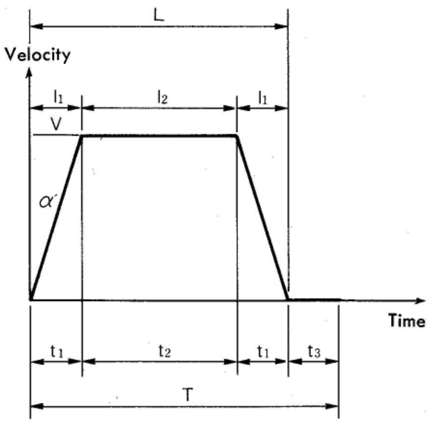

Fig.5.15

<Calculation Expressions>

•Thrust force $F=M\alpha$, velocity $V=\alpha t_1$

•Acceleration/deceleration distance

•constant velocity Travel $l_2=Vt_2$ $\quad l_1=\frac{1}{2}Vt_1=\frac{1}{2}\alpha t_1^2$

•Positioning time $T=2t_1+t_2+t_3$

> **[Selection Example 1]**
> To find the time required to move an applied load of 40 kg by 1000 mm, provided the repetitive positioning accuracy is ±10μm.

① Applied load of 40 kg : Select the type B3 motor.
② Moving. velocity : Assume that it is 600 mm/s.
V600= mm/s
③ Acceleration : Find the dynamic driving force
at 600 mm/s

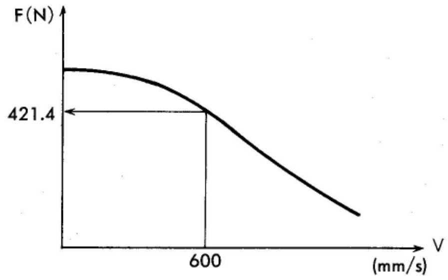

Fig.5.16

The speed-thrust force of B3 type motor

From the found dynamic driving force (safety factor: 1.5) and applied load (including the slider mass), find the acceleration.
$F=M\alpha$

Thus, $\alpha=\frac{F}{M}=\frac{421.4}{(40+15)}X\frac{1}{1.5}=5.1\text{m/s}^2$

④ Acceleration/deceleration Time : $V=\alpha t$, Thus $t_1=\frac{V}{\alpha}=\frac{0.6}{5.1}=0.117(s)$

⑤ $l_1=\frac{1}{2}Vt_1$

Thus, $l_1=\frac{1}{2}X0.6X0.117=0.035(m)=35(mm)$

⑥ Moving time : The travel at the constant speed (600 mm/s)
is found as follows:
1000 - (2X35)=930(mm)
Moving time t_2 is found as follows:

$t_2=\frac{0.93}{0.6}=1.55(s)$

The settling time t_3 is 0.2 from the table.
Thus, $T=(2Xt_1)+t_2+t_3=(2X0.117)+1.55+0.2=1.98$ s.
From the above calculations, it is shown that the type B3 motor may drive a load of 40 kg by 1000 mm within 1.98 s.

> **[Selection Example 2]**
> To find a motor type which may accelerate an applied load of 10 kg to 1200 mm/s within 0.25 s

① Acceleration : $V=\alpha t_1$

Thus, $\alpha=\frac{V}{t_1}=\frac{1.2}{0.25}=4.8(\text{m/s}^2)$

② Dynamic thrust force : Provided the type B2 motor is used,
$F=M\alpha=(10+10)X4.8=96(N)$
Thus, the dynamic thrust force at 1200 mm/s is found to be 147N from the speed -thrust force characteristics of the type B2 motor.

Since the safety factor is 1.5, $F_{B2}=147X\frac{1}{1.5}=98(N)$

Thus, the load may be driven by the type B2 motor since $F_{B2}>F$.

Speed-Thrust force Characteristics

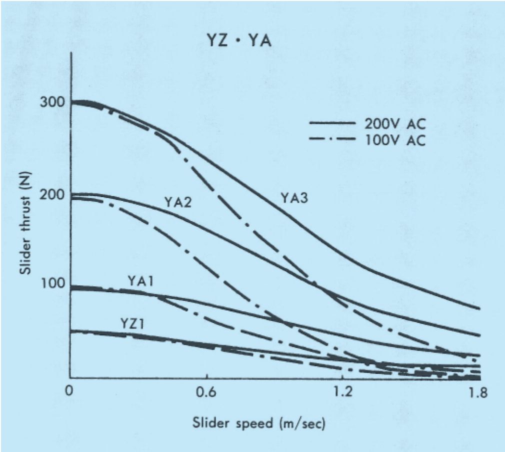

Fig. 5.17

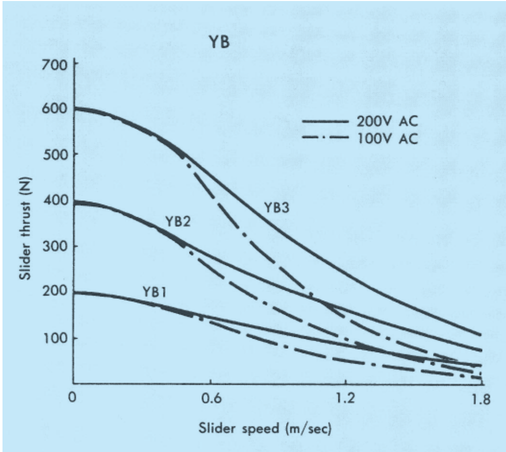

Fig. 5.18

5.3 Selection of Mega Indexer

To correctly select a Mega Indexer, workpiece size and mass, unbalanced torque, clamping torque, positioning time, and external friction torque should be taken into account.

(1) Workpiece sizes and mass

The outside dimensions of a workpiece and jig should be less than the outer diameter of the Mega Indexer table. If the Mega Indexer is used horizontally, the sum of the total mass of a workpiece and jig and machining force should be less than the allowable load applied for horizontal use. If the Mega Indexer is used vertically, the sum of the total mass and machinig force should be converted into a value for vertical use, which should be less than the allowable load applied. In other words, FP should meet the following condition:

$$F_P = \frac{L+l}{l} X F_L$$

Where, L: Distance between the table surface and gravity center of a workpiece including a jig (mm)

l: Distance between the table surface and center of the Mega Indexer bearing (mm)

F_L: Mass of a workpiece including a jig (kg)

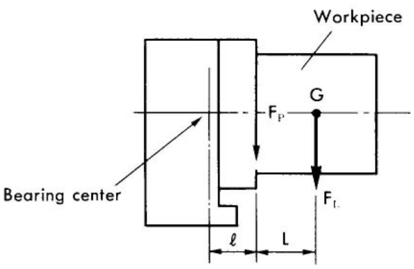

Fig. 5.19

	VT150	VS200	VS250	VS320	VS360	VS360 (Hydra-ulic)	VS400 (Hydra-ulic)
Distance between the table surface and the bearing (mm)	40	64.5	72.5	75	77.5	77.5	77.5
allowable mass in case that Mega Indexer is used vertically (N)	490	980	1960	2450	4900	4900	4900

(2) Unbalanced torque

If a Mega Indexer is to be used vertically, the user should take account of unbalanced torque which is produced when a workpiece is set on the table surface. It should be less than the allowable unbalanced torque.

(3) Clamping torque

The Mega Indexer is available in two clamping systems: pneumatic clamps (standard series), and hydraulic clamps (hydraulic clamp series). Clamping is automatically executed when the Mega Indexer performs indexing and completes positioning. The clamping torque should not be exceeded for pair machining.

(4) Positioning time

The indexing time of the Mega Indexer depends on the inertia of a workpiece. Since clamping time and unclamping time are added to the angle indexing time of the Mega Indexer, add 0.3 s to the positioning time of the Megatorque motor calculated on page A124.

For calculation, apply the following value to T (output torque at speed N) Shown on page A126.

The minimum positioning time chart of the Megatorque motors shown on page A127 may be roughly applied without calculation. In such a case, add 0.3 s to the positioning time found from the value of the Megatorque motor 0408 for the VT150, or the value of 0608 for the VS200 or VS250, or the value of 0810 for the VS320 or VS360 (with a hydraulic clamp) or VS400 (with a hydraulic clamp), or the value of 1010 for the VS360 (with a pneumatic clamp).

(5) External friction torque

If an oil seal or rotary joint is connected externally to the Mega Indexer, its friction torque will slightly reduce the output torque. If such friction torque may be produced, the sum of the friction torque and unbalanced torque should not exceed the allowable unbalanced torque.

In addition, the friction torque should be subtracted from the output torque when calculating the positioning time.