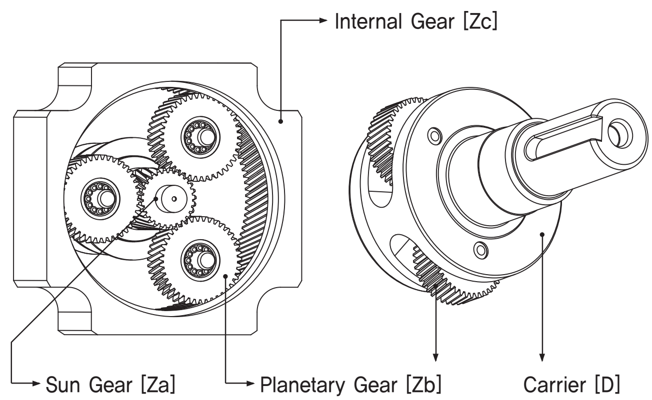
# Technical Data

▶Classification of planetary gear appliance structure/use
▶Reliability assessment terms [ I ~ V]
▶Gearheads selection examples

## ■ Planetary gear structure




The major components of Planetary gearheads are

① Sun Gear
② Planetary Gear
③ Internal Gear

and composes of **carriers** as a basic unit.

It is gear equipment with such advantageous features that it cannot only obtain a large reduction ratio but also high efficiency and precise control of power transfer while it is in a compact style.

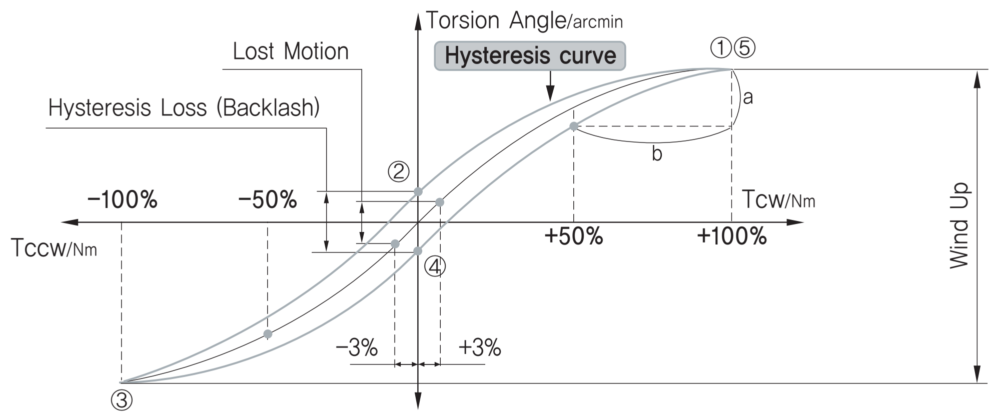
| Type | Fixed component | Input | Output | * Calculation formula of reduction ratio | Reduction ratio range | ** Planetary Gear |
|---|---|---|---|---|---|---|
| Planetary Gear | Internal Gear | Sun Gear | Carrier | $\frac{1}{\frac{Zc}{Za}+1}$ | 1/3 ~ 1/12 | Performance of simultaneous rotation and revolution |
| Star | Carrier | Sun Gear | Internal Gear | $-\frac{1}{\frac{Zc}{Za}}$ | 1/2 ~ 1/11 | Performance of revolution only |
| Solar | Sun Gear | Internal Gear | Carrier | $\frac{1}{\frac{Za}{Zc}+1}$ | 1/1.2~1/1.7 | Performance of simultaneous rotation and revolution |

* Z in a calculation formula indicates the number of teeth in each component gear, and the sign (–) means the output direction opposite to that of input.
** It means an operation condition of planetary gears only.

## ■ Classification of general uses of a planetary gearheads (by Backlash grade)

| Division | Backlash (arcmin) | Applications | Control method |
|---|---|---|---|
| High precision class | 3' or less | • robot peripheral equipment (Positioner, Slider etc.)<br>• inspection equipment, precision FA machinery, medical equipment, Index equipment<br>• packing machinery, textile machinery, machine tool | Position control |
| Precision class | 5' or less | • precision Conveyor (transfer, division, loading)<br>• logistics conveyance system (AGV, automated warehouse)<br>• injection machinery extracting equipment | Speed control |
| General class (standard class) | 10'~30' | • Conveyor, Bending Machine, Pallet Stacker<br>• printing machinery, food processing machinery, film winding machine<br>• various kinds of testing instruments | Torque control |

## ■ Hysteresis curve Torque – torsion angle diagram




## ■ Backlash Hysteresis Loss (arcmin)

In general, whenever measuring backlash, which indicates the level of a gearhead, the value measured by giving 3% of rated output torque of the gearhead toward both directions(±3%) should be read. That is, if the input shaft of the gearhead is fixed and torque is given to the output part, torsion responding to torque is incurred in the output part. In other words, In general, the torsional angle cannot return to a complete zero, leaving some value with it if a torque is fully applied until it reaches a rated value and then released to a zero, as shown in the line drawing. This is called Hysteresis Loss.

**① Normal rotation(rated output torque Tcw) ▶ ② Zero ▶ ③ Inverse rotation(rated output torque Tccw) ▶ ④ Zero ▶ ⑤ If torque values are gradually changed in the same sequence as normal rotation(rated output torque Tcw), the curve is drawn as shown in the figure [Hysteresis Curve].**

As shown in the figure, ②④ value for the zero torque part of the hysteresis curve is called Hysteresis Loss, and for the SPG's planetary gearhead(SPI□/SPL□ series), the amount of Hysteresis Loss is measured, and it is set as product backlash specification.

## ■ Lost Motion Rotational accuracy (arcmin)

Lost Motion indicates angle of torsion in the middle of hysteresis up/down curve width within ±3% of rated output torque for backlash measurement. In general cases, Lost Motion including elastic deformation of power transmission system except Hysteresis Loss is indicated in a higher value.

## ■ Torsional Rigidity (Nm/arcmin)

Difference in angle of torsion, which is measured while the input shaft is fixed and each 50% and 100% of load torque are given to the output shaft, is expressed in a proportional slope, and torsional rigidity in Fig. [Hysteresis Curve] can be indicated in the following equation.

$$T_r = \frac{b}{a}$$

$T_r$ : Torsional rigidity
a : Difference in angle of torsion when each 50% and 100% of rated output torque are given to the output shaft
b : 50% of rated output torque

## ■ Wind Up (arcmin)

It indicates a method of finding unidirectional total torsional value (average value) when a load is applied to gearhead in no load condition.

$$\theta = d + \frac{T - T_L}{T_r}$$

$\theta$ : total torsional value (arcmin)
d : permissible output torque (Nm) × 0.5 unidirectional torsional value in the torque section
T : load torque (Nm)
$T_L$ : permissible output torque (Nm) × 0.5 ( = $T_r$ × 0.5)
$T_r$ : torsional torque stiffness (Nm / arcmin)

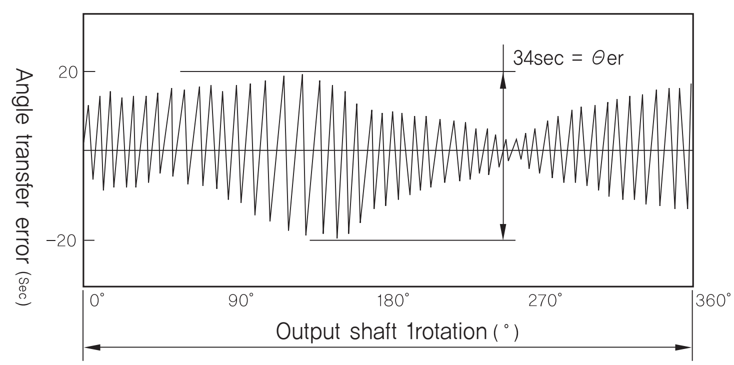
## ■ Angle transfer degree (arcmin)

angle transfer degree (or transfer error) indicates the difference between the theoretical output rotation angle and the actual output rotation angle ($\theta_{out}$) when an arbitrary rotation angle($\theta_{in}$) is instructed to enter.

$$\theta_{er} = \frac{\theta_{in}}{R} - \theta_{out}$$

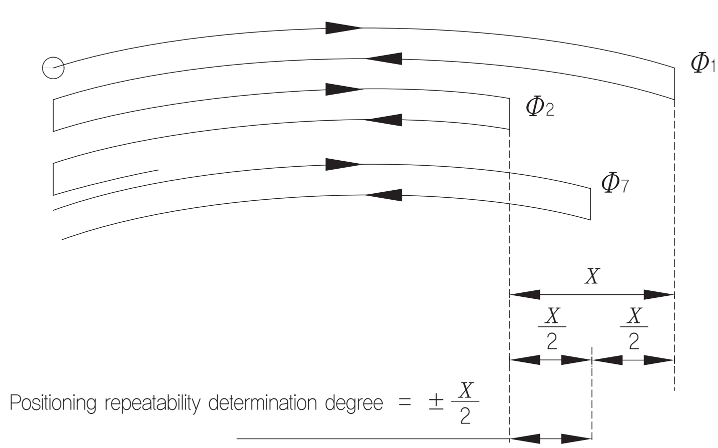
$\theta_{er}$ : angle transfer degree (or transfer error)
$\theta_{in}$ : input rotation angle
$\theta_{out}$ : actual output rotation angle
R : planetary gearbox's reduction gear ratio

Example of actual measurement




## ■ Positioning repeatability determination degree (arcmin)

A positioning repeatability determination degree (or determination error) finds the maximum difference by measuring the stop position of output shaft after it repeats the position determination seven times in the same direction at an arbitrary position. The measurement is shown in a angle and indicated in a way the ± sign is assigned to the half value of the maximum difference.




Technical Data

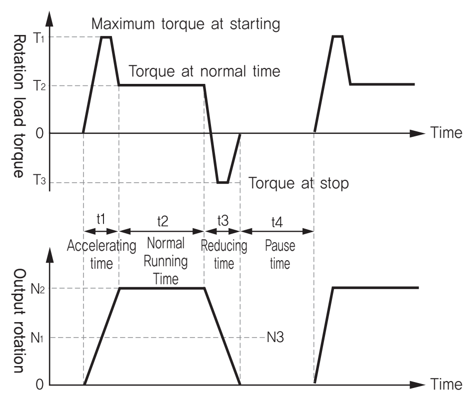
## The Life of Gearheads (hr)

In case of actual operation by assembling gearheads to the equipment, the service life hours shall be obtained through the following calculation formula as each load condition differs from case to case.

$$L_h = {}^{*}20,000 \times \frac{N_o}{N_m} \times \left( \frac{T_o}{T_m} \right)^3$$

$L_h$ : The life of gearheads (hr)
$N_m$ : Mean value output speed (rpm)①
$N_o$ : Rated output speed (rpm)
$T_m$ : Mean value load torque (kg · m)②
$T_o$ : Rated output torque (kg · m)
**∗In case of continuous operation (S1)** : 10,000hrs

### Load Cycle line graph




① $N_m$ : Mean value output speed (rpm)

$$N_m = \frac{t_1|N_1| + \cdots + t_n|N_n|}{t_1 + \cdots + t_n}$$

② $T_m$ : Mean value load torque (kg · m)

$$T_m = \sqrt[3]{\frac{t_1|N_1||T_1|^3 + \cdots + t_n|N_n||T_n|^3}{t_1|N_1| + \cdots + t_n|N_n|}}$$

(In case of Ball Bearing)

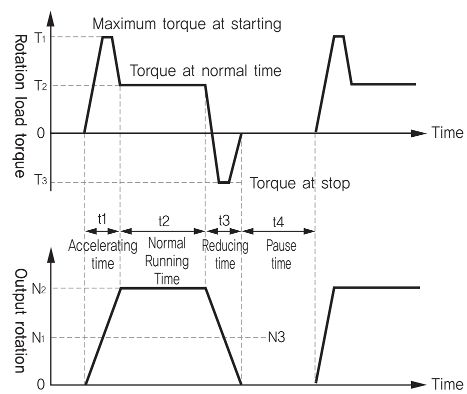
$$T_m = \sqrt[10/3]{\frac{t_1|N_1||T_1|^{10/3} + \cdots + t_n|N_n||T_n|^{10/3}}{t_1|N_1| + \cdots + t_n|N_n|}}$$

(In case of Roller Bearing)

## ■ Cycle load factor (ED)

In case of actually running gearheads after assembling it to the equipment, please refer to the gearheads selection method (24 page) and the following calculation formula at time of selecting gearheads based on the load pattern, as each load condition differs from case to case.

Load Cycle line graph




① ED : Cycle load factor (Duty Cycle)

$$ED\ (\%) = \frac{(t_1 + t_2 + t_3)}{(t_1 + t_2 + t_3 + t_4)} \times 100$$

$$\text{Operation hours}\ (T_{work}) = t_1 + t_2 + t_3\ [\text{sec}]$$

② Zh : Number of Cycle / hr

$$Z_h = \frac{3{,}600\ [s]}{(t_1 + t_2 + t_3 + t_4)}$$

③ i : Reduction of Gear ratio

$$i = \frac{\text{Maximum input speed (rpm)}}{\text{Maximum output speed (rpm)}}$$

④ Operating Condition

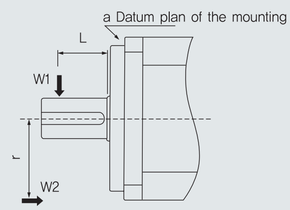
- intermittent operation($S_4/S_5$) : $ED \le 60\%$ and $T_{work} \le 20min$
- continuous operation : $ED > 60\%$ or $T_{work} > 20min$

## ■ Output shaft maximum load moment (N-mm)

The following calculation formula shows the method seeking the maximum load moment load (Mmax). Make sure that Mmax≤Mc.

$$M_{max} = W_{1max} \times L + W_{2max} \times r$$

$W_1$ : Radial Load (N, kgf)
$W_2$ : Thrust Load (N, kgf)
L, r : length (mm)
$M_c$ : load moment (N-mm, kgf-mm)




## ■ Overhang Load (O.H.L) calculation

Overhang Load (O.H.L) is referred to as the suspension load applying to a shaft. It would be the best if a planetary gearheads is directly connected with a concerned machine, but if it is linked through a chain, belt or gear, the O.H.L applying to the output shaft of a planetary gearheads shall be less than an permissible O.H.L of the planetary gearheads to be used.

$$O.H.L\,(N) = \frac{T_e \times K \times L}{R}$$

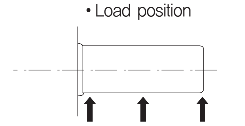
$T_e$ : correction load torque applying to an output shaft of planetary gearheads (Nm)
[Correction load torque = load torque applying to planetary gearheads(Tf)×Service Factor (Sf)]
R : radius of a pitch circle in a component such as sprocket, pulley, and gear (m)
K : co-efficient followed by a connection method (refer to table 1)
L : co-efficient followed by the position of a load applied (refer to table 2)

(table 1)

| Connection method | K |
|---|---|
| Chain, Timming Belt | 1.00 |
| Gear | 1.25 |
| V-Belt | 1.5 |
| Flat-Belt | 2.5 |

(table 2)

| Load position | L |
|---|---|
| Shaft source | 0.75 |
| Shaft middle | 1 |
| Shaft end | 1.5 |




(table 3) Service Factor by the load condition

| Load condition | Service Factor (Sf) | | |
|---|---|---|---|
| | Operation of less than 3 hrs/day | operation of 3~10hr/day | operation of more than 10 hrs /day |
| Uniform load (In case of unidirectional and continuous operation) | 1 (1) | 1 (1.25) | 1.25 (1.50) |
| Light impact load (In case of frequent reverse operation) | 1 (1.25) | 1.25 (1.50) | 1.50 (1.75) |
| Severe impact load (In case of instantaneous reversing and instantaneous stop) | 1.25 (1.50) | 1.50 (1.75) | 1.75 (2.00) |

(Note) in the case of more than 10 times of running and stopping in an hour, the co-efficient in ( ) shall be used.

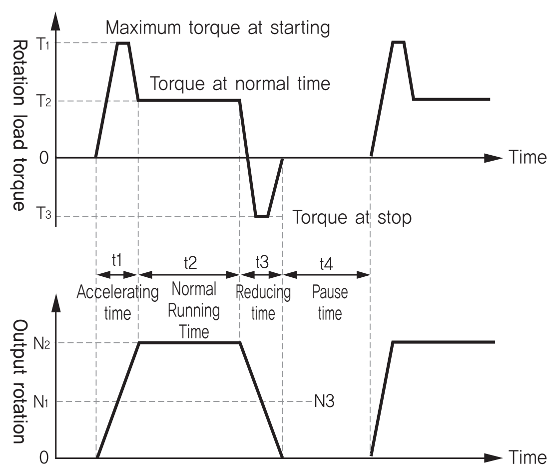
In general, there is almost no condition of continuously uniformed load in servo system. A load torque changes according to the fluctuation in an input rpm, but when it starts or stops, not only a relatively large torque is applied to, but also unexpected shock torque is placed on.

Therefore, first check the「load torque pattern」 below considering the service condition like this, and then select an appropriate gearhead model, according to 「Model selection order」.

In addition, if any of the specifications concerning a model exceeds the rated torque values, it would be better if you could examine a model higher a stage than a target model, or consider a lower load torque.

## ■ Conditions of servo system load to be used (example)

Load Cycle line graph




(table1) Condition of servo motor operation patterns (example)

| | | | |
|---|---|---|---|
| $T_1$ | Maximum torque at starting time | Nm | 100 |
| $T_2$ | Torque at normal time | Nm | 30 |
| $T_3$ | Maximum torque at stopping time | Nm | 80 |
| $N_1$ | Mean output rpm at accelerating time | rpm | 300 |
| $N_2$ | Output rpm at normal operation time | rpm | 600 |
| $N_3$ | Mean output rpm at reduction time | rpm | 300 |
| $t_1$ | Acceleration hours | sec | 0.2 |
| $t_2$ | Normal operation hours | sec | 5 |
| $t_3$ | Reduction hours | sec | 0.2 |
| $t_4$ | Stopping hours | sec | 3 |

## ■ Gearheads model selection (reference: 33 page「gearheads selection method 2」)

First, as the service condition in an example, check on the condition of servo motor operation patterns set out in the 35 page (table 1), and then select a model following the order described below.

### 1 Duty cycle ED / calculation of operation conditions

$$ED\ (\%) = \frac{(t_1 + t_2 + t_3)}{(t_1 + t_2 + t_3 + t_4)} \times 100 = \frac{(0.2 + 5 + 0.2)}{(0.2 + 5 + 0.2 + 3)} \times 100 = 64.3\%\ (>60\%)$$

Running hours ($T_{work}$) = $t_1 + t_2 + t_3$ [min] = (0.2 + 5 + 0.2)/60 [min] = 0.09 [min] (<20[min])

∴ Continuous operation $S_1$

### 2 Calculation of mean output torque ($T_m$)

$$T_m = \sqrt[3]{\frac{t_1 N_1 T_1^3 + \cdot\cdot\cdot + t_n N_n T_n^3}{t_1 N_1 + \cdot\cdot\cdot + t_n N_n}}$$

$$= \sqrt[3]{\frac{0.2 \times 300 \times 100^3 + 5 \times 600 \times 30^3 + 0.2 \times 300 \times 80^3}{0.2 \times 300 + 5 \times 600 + 0.2 \times 300}}$$

∴ $T_m$ = 38.03 [N · m]

### 3 Calculation of maximum acceleration torque [$T_{max}$]

$T_{max} = T_1 \times f_s$

$Z_h$ [Number of cycles / hr]

$$Z_h = \frac{3{,}600\ [s]}{(t_1 + t_2 + t_3 + t_4)} = \frac{3{,}600}{8.4} = 428.6\ [cycle]$$ Therefore, $f_s$ = 1 (refer to table 1 on page 33)

∴ $T_{max}$ = 100× 1 = 100 [N · m]

### 4 Determination of maximum output speed & reduction ratio

In case the maximum output speed ($N_{max}$) of gearhead is set to 600rpm,

$$\text{Reduction ratio(i)} = \frac{\text{Servo motor's maximum output speed } (N_2\ [rpm])}{\text{Gearhead's maximum output speed } (N_{max}\ [rpm])} = \frac{3{,}000}{600} = 5$$

∴ Reduction ratio(i) = 1 : 5

### 5 Gearheads selection

Compare $T_{2N}$ and $T_{2B}$ Data on the Catalog「Specifications」for the reduction ratio determined, and then the result values of $T_m$ and $T_{max}$ obtained from the calculation of ❷, ❸ above. when compared with SPI060S005 (refer to Catalog page 23)

①mean torque [$T_m < T_{2N}$) : 38.03 [N · m] < 42 [N · m] ②acceleration torque [$T_{max} < T_{2B}$] : 100 [N · m] < 126 [N · m]

∴ It is judged to be rational that SPI060S005 shall be selected.

### 6 Verification

The order of the calculations introduced above can be changed depending on a condition, but mean torque [$T_m$] and maximum acceleration torque [$T_{max}$] shall be checked without fail to set the equipment and secure the safety of the system. In addition, $T_m$ and $T_{max}$ in the calculation above is nothing but a selection method following the operation pattern of servo motor when the values are needed to set application equipment, so a separate calculation through a structural analysis of equipment setting is required for the selection of more accurate gearheads.

# Cautions at use and warranty

## Caution

Be careful of product handling.
· Be careful not to give an impact to the product with a hammer and not to cause damage from a drop at handling.

In case of directly connecting the product to the load side, pay attention to assembling.
· Be careful of direct connection such as concentricity, parallel level, tension, etc. whenever connecting the product to the load side such as a belt, a chain, etc.
· Be careful of handling the edge of the product and the key way of the output shaft. It may cause an injury.
· Do not put a hand or other foreign substance in a rotating shaft while the product drives. It may cause an injury.

Do not give an impact to the product.
· Be careful not to give an excessive impact whenever assembling a pulley, a coupling, a key, etc. to the product.

Do not exceed permissible torque at use.
· Do not give more than the instantaneous permissible maximum torque. It may cause troubles by bolts loosened on the tightening part, shaking, damage, etc.

Do not disassemble the product.
· Do neither disassemble nor reassemble the product. Otherwise the original performance may not be guaranteed.

If any abnormal condition is sensed, stop the system.
· If abnormal sound, vibration, abnormal heat, etc. occur, immediately stop the system. Otherwise it may adversely influence the system.

## Warranty

A warranty period and a warranty scope of the product is as follows.

### 1 Warranty Period

Either 2,000hour working time or 12 months after the delivery for the product, which reaches earlier, should be applied on condition of use with operation, assembling, and lubrication specified by SPG.

### 2 Warranty scope

For a fault by a defect in SPG manufacturing during the above warranty period, repair or exchange of the product should be conducted under SPG responsibilities. However, the following cases are excluded from the Warranty scope.

① Unsuitable handling or use by customers

② Remodeling or repair not by SPG without permission

③ A fault resulting from other reasons except the product

④ Such fault as attributable to natural disaster etc., which is not SPG responsibility

Warranty herein means warranty for the product.
Other losses (chance loss by loss of the machine & assembly man-hour, assembly & disassembly, and mounting costs) arising out of a failure of the product are beyond the range of SPG burdens.

# Request Information

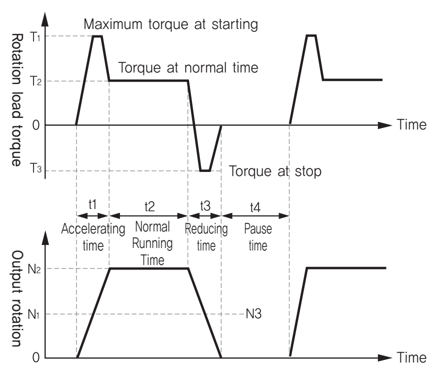
## ■ To submit SPI/SPL product questions, simply fill out the following form

| Customer | Company : | Zip/Postal Codes : | Name : | Job Title : |
|---|---|---|---|---|
| | TEL : | FAX : | E-mail : | |
| Address | | | Country : | |

| | |
|---|---|
| Operating Conditions | |
| Machine Name | |
| Application | |

| | | | |
|---|---|---|---|
| Spec. of the Gearheads | SPI☐ / SPL☐ – | Reduction Ratio i = | Backlash : arcmin |

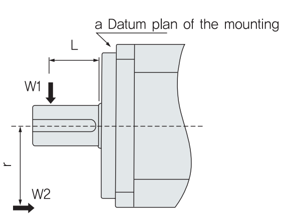
### 1. The Conditions of Load




| | starting (Max.) | Normal | Stop(Max.) | Pause time |
|---|---|---|---|---|
| N · m | T1 | T2 | T3 | – |
| rpm | N1 | N2 | N3 | – |
| sec | t1 | t2 | t3 | t4 |

| | | | |
|---|---|---|---|
| Running Time | Cycle/day | Day/year | year |

### 2. The Load Conditions of Output Shaft




| | | | |
|---|---|---|---|
| W1 : | kg | L : | mm |
| W1 : | kg | r : | mm |

### 3. The Mounting Direction

☐ Horizontality ☐ Verticality ☐ ☐

The Outline figure of Mounting

### 4. The Specifications of Input Side

☐ Servo motor ☐ other ( )

| | |
|---|---|
| Capacity | W |
| Nominal Torque | N · m |
| Input Speed | rpm |
| Output Shaft Dimensions | Ø = , ℓ mm |

### 5. Others