Gearheads

Role of Gearheads

Gearheads have played an important role in the development of motors. Initially when there were only AC motors based on simple rotation of the motor, gearheads were used primarily as speed changing devices to change the motor speed and also to amplify torque. As motors with variable speed function were developed, the purpose of gearheads shifted from gear change to torque amplification. Furthermore, when the need for position control and speed control emerged, stepping motors and servo motors became popular and gearheads were used not only to amplify torque, but also to increase resistance to inertial force and lower stepping motor vibration. In addition, needs for motors with high positioning accuracy created a different demand from AC motor gears for gearheads with no backlash and offering high accuracy.
Based on the above, Oriental Motor developed a series of gearheads, each providing appropriate characteristics so as not to affect the characteristics of the motors with which they were assembled. Since AC motor gearheads are used continuously, primarily for transmission of power, they are designed with priority on ensuring high permissible torque, long life, noise reduction and extensive gear ratios. On the other hand, stepping motor and servo motor gearheads are designed mainly to ensure high accuracy, high permissible torque and high speed (servo motor) to support their primary applications that often require high positioning accuracy. The details of these gearheads are explained below.

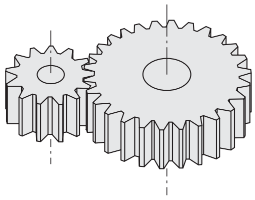
Gearheads for AC Motors

AC motors as general power generators have a long history, and gearheads assembled with AC motors also have a long history. Accordingly, these gearheads are used in a wide range of fields where the demands of the user including noise reduction, high strength and long life, to extensive gear ratio variations and environmental resistance are diverse. Oriental Motor has been developing and offering the best gearhead products in a timely manner to meet these diverse needs. The following gives an introduction to our gearheads classified by their structure.

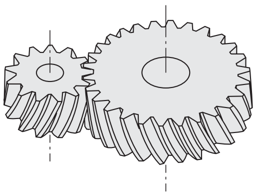
Parallel Shaft Gearhead

Parallel shaft gearheads are the most commonly used gear mechanisms today. Oriental Motor's parallel shaft gearheads use spur gears and helical gears.
In particular, helical gears have been adopted for their contribution to noise reduction and high strength.

● Spur Gears
A cylindrical gear whose tooth trace consists of parallel straight lines.

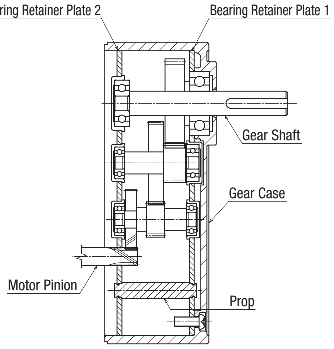


● Helical Gears
A cylindrical gear whose tooth trace consists of a helical curve. Since their meshing ratios are higher than spur gears, helical gears are quieter and stronger. However, caution must be exercised in the design stage because helical gears receive loads in the axial direction.



Both types of gearheads employ a motor pinion associated with a quicker peripheral speed of meshing and one considered most effective in reducing noise. Both gearheads employ a helical gear as well to mesh with this motor pinion to make the gearhead quieter.
As an example, the structure of the **GN-KF** gearhead is shown.

GN-KF Gearhead



GN-KF Gearhead

For use with general AC motors, many of which are still constant-speed motors, it is necessary to change the gear ratio in order to support a wide range of speed. Many AC motor series offer 20 gear ratios from 3 to 180 to meet a wide range of needs.

●Right-Angle Gearheads (Hollow shaft and solid shaft)

The right-angle gearhead is designed for greater ease of use by allowing effective installation in a limited space or reducing the number of power transmission components such as couplings (hollow shaft gearhead). Oriental Motor offers right-angle hollow shaft gearheads, and right-angle solid shaft gearheads that use worm gears or crossed helical gears and hypoid gears. With both types of right-angle gearheads, the right-angled part is located in the final stage. Accordingly, the gear cutting specification of the input part is the same with parallel shaft gearheads (**GN**, **GE**, **GU**). In other words, you can change from parallel shaft gearheads to right-angle gearheads without changing the motors.

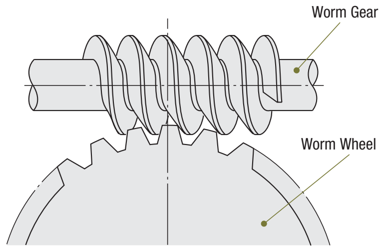
Hollow Shaft Type

Solid Shaft Type

◇Worm Gears

The worm gear transmits power using a threaded worm that has a minimum of 1 or 2 teeth, and a worm wheel that meshes with the worm. The worm gear has a long history equivalent to the spur gear, but its applications have been limited compared to the spur gear because of machining problems and lower efficiency. At Oriental Motor, however, we have incorporated worm gears into our products to take advantage of their ability to allow a right-angle axis configuration and support high gear ratios, while increasing the lead angle to improve efficiency compared to normal worm gears.

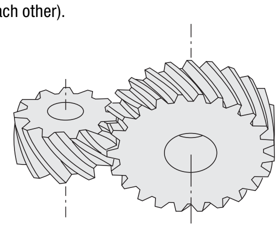
● Worm Gears
The worm gear transmits power using a threaded worm that has one or more teeth, and a worm wheel that meshes with the worm.

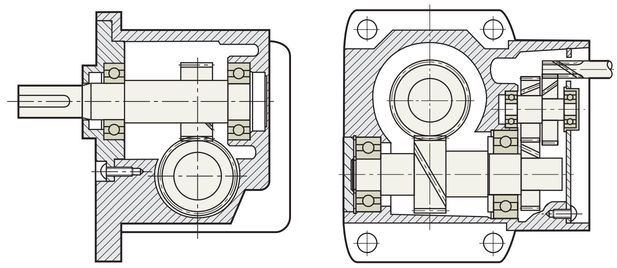


◇Crossed Helical Gears

The crossed helical gear is a stand-alone standard helical gear. The difference from the parallel shaft helical gear is that while meshing parallel shaft helical gears have the same torsion angle and opposite helix directions, crossed helical gears have their torsion angle designed to ensure a right-angle axis configuration. Crossed helical gears are often used with relatively light loads due to its point contact characteristics. In Oriental Motor's right-angle gearheads, they are mainly used at low gear ratios.

● Crossed Helical Gears
Helical gears are used for skew shafts (neither perpendicular nor parallel to each other).





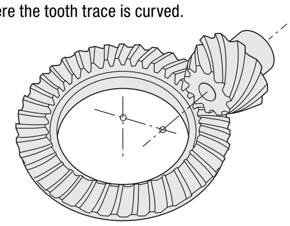
Structure of Crossed Helical Gear in Right-Angle Gearhead

◇Hypoid Gears

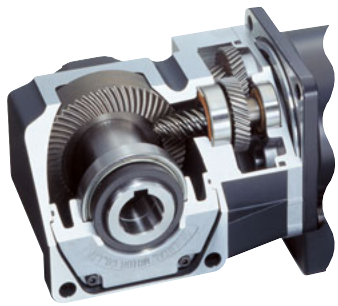
Hypoid gears have generally been used for differential gears of automobiles. The hypoid gear is positioned between the bevel gear whose offset is 0, and the worm gear that has the largest offset, and can achieve high strength and high efficiency. Compared to the bevel gear, the hypoid gear can suppress vibration or support a higher gear ratio by offsetting the pinion gear. Oriental Motor's gearhead structures adopt this hypoid gear in their final stage, which means that the motor and gears can be separated.

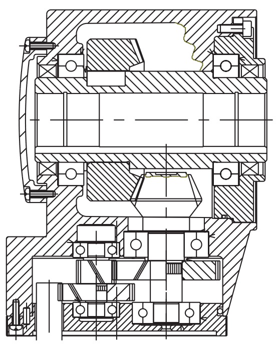
● Offset: Unlike the bevel gear, the hypoid gear has two axes that do not cross with each other, but are mutually skewed. This amount of skew is called an "offset."

● Hypoid Gears
A conical gear designed to transmit power between skew gear shafts, where the tooth trace is curved.



Right-Angle Shaft and Combination Types
BH Series





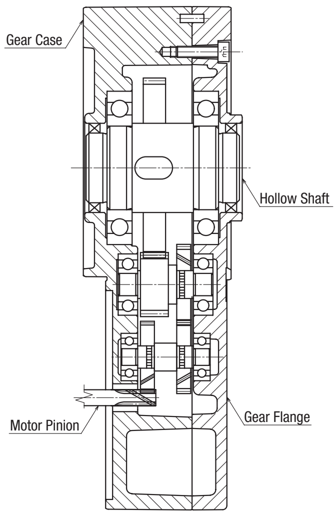
Structural Drawing of the Hypoid Gear

Gearheads for Brushless Motors

Brushless motors used for speed control have high maximum speeds of 3000 to 4000 r/min. Accordingly, gearheads assembled with brushless motors must generate low noise at high speed and also ensure high permissible torque and long life to take advantage of the characteristics of these high power motors. Oriental Motor has an extensive lineup of brushless motor gearheads, including parallel shaft gearheads that have the same structure as AC motor gearheads, and hollow shaft flat gearheads that have a hollow shaft specification with the parallel shaft structure.

●Hollow Shaft Flat Gearheads

Hollow shaft flat gearheads are designed not only to reduce couplings and other connecting parts, but also prevent saturation of permissible torque even at high gear ratios. These products are also suitable for applications where high permissible torque is required.
In addition, hollow shaft flat gearheads can be combined with slim brushless motors, which makes it possible to reduce the installation footprint without adopting a right-angle shaft mechanism.
Structurally, hollow shaft flat gearheads have their gear shaft extended in the lengthwise direction to widen the space volume compared to conventional parallel shaft gearheads, thereby improving the gear case rigidity while increasing the gear and bearing diameters at the same time.
These benefits make it possible to design a hollow output shaft based on the parallel shaft structure, resulting in higher permissible torque and longer life of the product.
Another advantage of hollow shaft flat gearheads is that their parallel shaft structure leads to a higher gear transmission efficiency than when a right-angle mechanism is used.
Oriental Motor's brushless motors are combination types pre-assembled with a gearhead. Accordingly, they can be easily installed in equipment and also permit the gearhead to be changed when the gear ratios need to be changed.



Structural Drawing of the Hollow Shaft Flat Gearhead

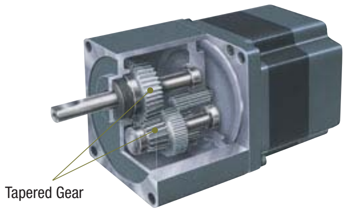
Stepping Motor, Servo Motor Gears

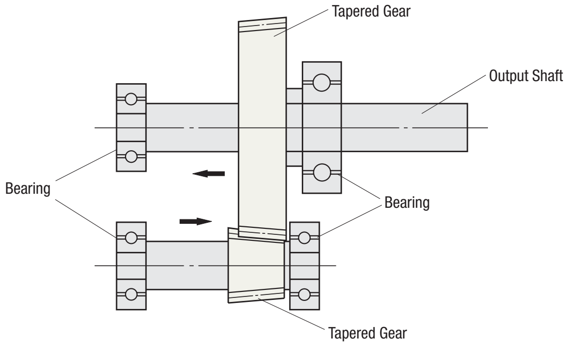
Control motors such as stepping motors and servo motors allow for high accuracy positioning, so gearheads assembled with these motors must be able to maintain this high accuracy. By focusing on the above point, Oriental Motor's stepping motor gears and servo motor gears adopt a newly developed mechanism designed to reduce backlash. Minimum backlash can also be guaranteed when a motor is combined with a gearhead.
Also, a stepping motor is generally associated with a larger output torque than an AC motor of the same frame size. A servo motor rotates at high speed. Accordingly, gearheads support higher torque or higher speed so as not to reduce the characteristics of stepping motors or servo motors.
The principle and structure of a representative control motor gear are shown below.

●**TH** Gears

◇Principle and Structure

In **TH** geared type, tapered gears are used in the final stage for the spur gear's gearhead and the meshing gear. The tapered gear is produced through continuous profile shifting toward the shaft. The tapered gears are finely adjusted in the direction of the arrows, as shown in the figure, to reduce backlash.



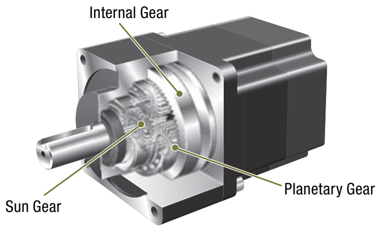


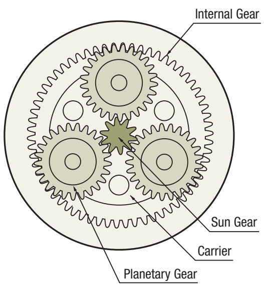
Structure of **TH** Gear's Final Stage

PS Gears

◇Principle and Structure

The **PS** gear employs a planetary gear mechanism. The planetary gear mechanism is comprised of three key parts: a sun gear, planetary gears and an internal gear. The sun gear is installed on the central axis (in a single stage type, this is the motor shaft) surrounded by multiple planetary gears, and revolves centered on the central axis via an internal gear. The revolution of planetary gears is translated into rotation of the output shaft via carriers.





Cross Section of **PS** Gear

Sun Gear : The center gear integrated with the input shaft.
Planetary Gears: Several external gears revolving around the sun gear. Each planetary gear meshes with the carrier, which is fixed to the output gear shaft.
Internal Gear : A cylindrical gear fixed to the gear case having teeth on its inside diameter.

◇High Permissible Torque

With the conventional spur gear mechanism based on a one-to-one gear meshing relationship, the transmissible torque is determined by the strength of each gear. On the other hand, the planetary gear mechanism can transmit greater torque because it is distributed through dispersion using several gears. The torque applied to each planetary gear in the planetary gear mechanism is shown below.

$$T = k \frac{T'}{n}$$

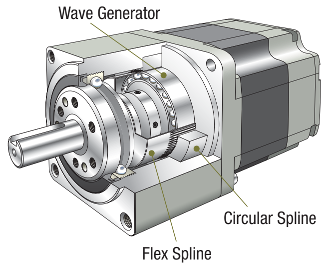
T : Torque applied to each planetary gear [N·m]
T': Total transmitted torque [N·m]
n : Number of planetary gears
k : Dispersion coefficient

Here, the dispersion coefficient indicates the degree of uniformity of torque dispersion among the respective planetary gears, where a coefficient value closer to 1 represents a more uniform dispersion and greater transmitted torque. To uniformly disperse transmitted torque, each part must be positioned in the correct relationship with other parts.

Harmonic Gears

◇Principle and Structure

The harmonic gear offers excellent precision in positioning for a gearhead and features a simple construction that utilizes the metal's elastodynamic property and one comprising of just three basic components (wave generator, flex spline and circular spline).



Wave Generator

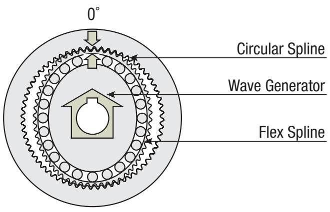
A thin ball bearing is fitted on the outer periphery of an oval cam, and the wave generator itself has an oval configuration. The inner wheel of the bearing is fixed to the oval cam, while the outer wheel deforms elastically through the balls. The wave generator is installed on the motor shaft.

Flex Spline

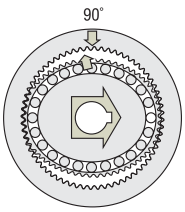
A metal elastic part that has the shape of a thin cup. Teeth are cut along the outer periphery of the cup opening. The output gear shaft is installed at the bottom of the flex spline.

Circular Spline

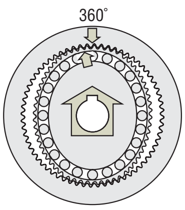
A rigid internal gear. The inner circumference has teeth of the same size as those on the flex spline, but the circular spline has two more teeth than the flex spline. The outer periphery is fixed to the gear case.



Combines three basic parts. The flex spline is bent into an oval shape by the wave generator. The teeth on the long axis of the oval mesh with the circular spline, while the teeth on the short axis of the oval are completely separate from it.



Rotating the wave generator (input) clockwise while keeping the circular spline fixed in position will subject the flex spline to elastic deformation, causing a gradual shift in the point of engagement between the circular spline and flex spline.



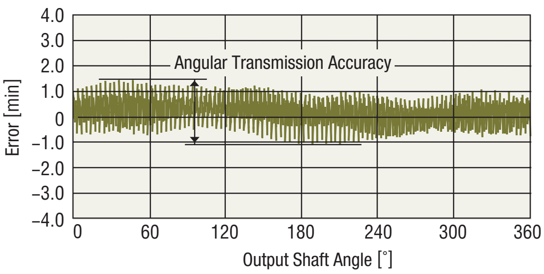
When the wave generator completes one revolution, the flex spline has rotated two fewer teeth than the circular spline has, resulting in the movement of flex spline for the difference in the tooth count (two teeth) in the opposite direction of the wave generator's rotation (i.e., counterclockwise). This movement translates into output, thereby decelerating the speed.

◇Accuracy

Unlike conventional spur gears, the harmonic gear has no backlash. The harmonic gear has many teeth in meshing engagement, and is designed to average out the effects of tooth pitch errors and accumulated pitch errors to the rotational accuracy to achieve high positioning accuracy. Also, harmonic gears have high gear ratio, so that the torsion when the load torque is applied to the output shaft is much smaller compared to that of a single motor and other geared motor, and the rigidity is high. High rigidity is less subject to load fluctuation and enables stable positioning. When the high positioning accuracy and rigidity are required, refer to the following characteristics.

◇Angular Transmission Accuracy

Angular transmission error is the difference between the theoretical rotation angle of the output shaft, as calculated from the input pulse count, and actual rotation angle. It is indicated by the range between the minimum and maximum values of the measurement error of a single rotation of the output shaft from an arbitrary point.

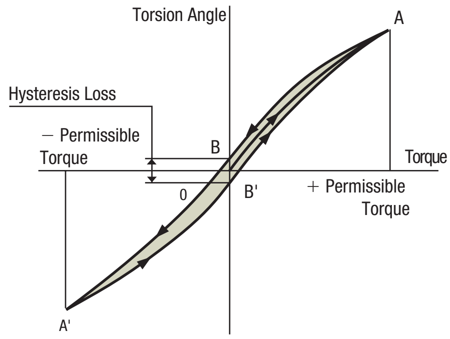


Product Name	Angular Transmission Accuracy [arc minute]
CRK513-H□	3 (0.05˚)
AR24-H□, **CRK523-H□**	2 (0.034˚)
AR46-H□ **RK543-H□**, **CRK543-H□**	1.5 (0.025˚)
AR66-H□ **RK564-H□**, **CRK564-H□**	

These are values under under no load (reference values of gear unit). In actual applications, frictional load always exists and displacement occurs according to the frictional load. If the frictional load is constant, the displacement is also constant for uni-directional operations. If an operation is performed from forward and reverse direction, however, the total displacement generated in each reciprocating cycle is doubled. The displacement can be presumed from the following torque – torsion angle characteristics.

Torque – Torsion Angle Characteristics

The torque – torsion angle characteristics in the graph shows the measurement of displacement (torsion) when the motor shaft is fixed and the load (torque) is gradually increased or decreased in the forward and reverse directions of the output shaft. When a load is applied to the output shaft in this way, displacement occurs due to the spring constant of the gear.



Torsion Angle – Torque Characteristics

The dispalcement occurs when an external force is applied when the gear is stopped, or when the gear is driven under a frictional load. The slope of the graph can be approximated with the spring constant in the following three classes depending on the size of load torque and inferred through calculation.

1. Load torque T_L is T_1 or less

$$\theta = \frac{T_L}{K_1} \text{ [min]}$$

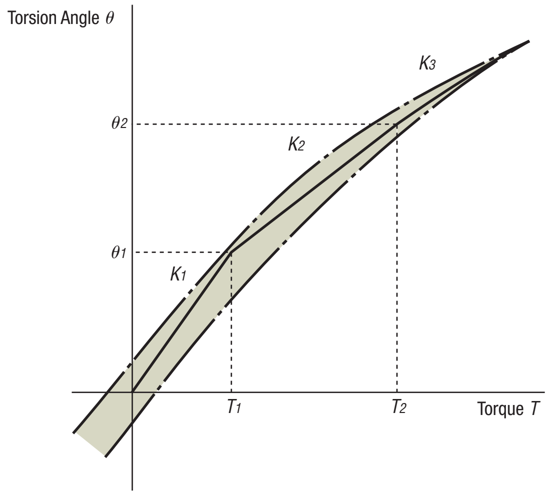
2. Load torque T_L exceeds T_1 and T_2 or less

$$\theta = \theta_1 + \frac{T_L - T_1}{K_2} \text{ [min]}$$

3. Load torque T_L exceeds T_2

$$\theta = \theta_2 + \frac{T_L - T_2}{K_3} \text{ [min]}$$

The torsion angle of the harmonic gear alone is calculated according to the size of the load torque.



Torsion Angle – Torque Characteristics

Values for Determining Torsion Angle

Product Name / Item	Gear Ratio	T_1 N·m	K_1 N·m/min	θ_1 min	T_2 N·m	K_2 N·m/min	θ_2 min	K_3 N·m/min
CRK513-H50	50	0.075	0.03	2.3	0.22	0.04	5.9	0.05
CRK513-H100	100	0.075	0.04	1.7	0.22	0.05	4.5	0.06
AR24-H50	50	0.29	0.08	3.7	–	0.12	–	–
CRK523-H50		0.29	0.12	2.6	0.75	0.17	5.4	0.2
AR24-H100	100	0.29	0.1	2.9	1.5	0.15	11	0.21
CRK523-H100		0.29	0.21	1.4	0.75	0.24	3.4	0.26
ARL46-H50 **AR46-H50** **RK543-H50** **CRK543-H50**	50	0.8	0.64	1.25	2	0.87	2.6	0.93
ARL46-H100 **AR46-H100** **RK543-H100** **CRK543-H100**	100	0.8	0.79	1.02	2	0.99	2.2	1.28
ARL66-H50 **AR66-H50** **RK564-H50** **CRK564-H50**	50	2	0.99	2	6.9	1.37	5.6	1.66
ARL66-H100 **AR66-H100** **RK564-H100** **CRK564-H100**	100	2	1.37	1.46	6.9	1.77	4.2	2.1
ARL98-H50 **AR98-H50** **RK596-H50**	50	7	3.8	1.85	25	5.2	5.3	6.7
ARL98-H100 **AR98-H100** **RK596-H100**	100	7	4.7	1.5	25	7.3	4	8.4

Hysteresis Loss

As shown in the torque – torsion angle characteristics, the torsion angle will not become 0 and a slight torsion remains even when the torque is removed after applying up to the permissible torque in the forward and reverse directions. (Figure B-B')

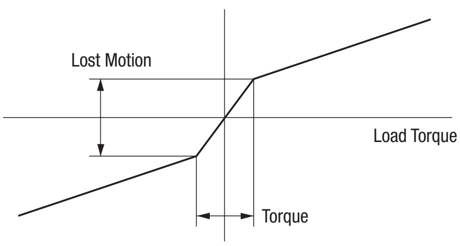
This is called a hysteresis loss. The harmonic gear is designed to have a hysteresis loss of two arc minutes or less.

When the external force is applied during stopping, when the acceleration/deceleration torque is applied in the inertial drive, when the frictional load is applied while driving, etc., a slight torsion remains because of the hysteresis loss even if there is no load.

Lost Motion

Since the harmonic gear has no backlash, lost motion is used as a reference for gear accuracy.

Lost motion represents the total displacement that occurs when a torque corresponding to approximately 5% of the permissible torque is applied to the output gear shaft.

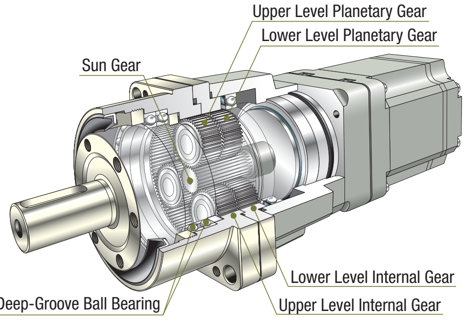


●PJ Gears

The **PJ** gear is the high strength, high accuracy planetary gear developed for Servo Motor and Driver Packages **NX** Series.

◇Principle and Structure

The **PJ** gear improves the accuracy of components and adopts the backlash eliminator which twists the upper- and lower-level internal gear teeth to achieve the specified backlash of 3 arc minutes or less.

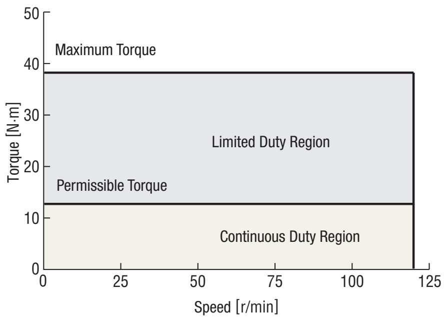


◇High Permissible Torque

Because the **PJ** gear adopts the same planetary gear mechanism employed by the **PS** gear, a higher permissible torque can be transmitted since torque is distributed through dispersion using several gears. For details, refer to "High Permissible Torque" in the sections explaining the **PS** gear.

Furthermore, by integrating the internal gear teeth and case, the **PJ** gear widened the space volume compared to conventional planetary gear and increased the gear diameter. It is stronger as a result, and achieves the strength that supports the maximum instantaneous torque of **NX** servo motor.

Speed – Torque Characteristics **NX820AC-J25-**◇

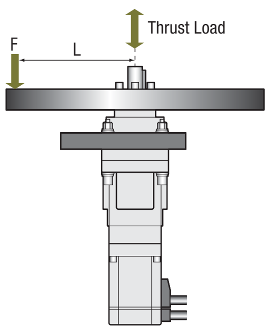


◇Calculate the Permissible Thrust Load and Moment Load

The **PJ** gear adopts the output shaft configuration which can install the load directly, so the output shaft is required to receive the thrust load and moment load created by the load. By adopting the double row deep-goove ball bearing to the output shaft, the **PJ** gear achieves high permissible thrust load and moment load.

The moment load is calculated with the following formula.

M [N·m] = F [N] × L [m]



Permissible Thrust Load and Moment Load of **PJ** Gear (Example: Frame Size 80 mm)

Gear Ratio	Permissible Thrust Load [N]	Permissible Moment Load [N·m]
5	300	16
10	400	33
25	600	60

◇Angular Transmission Accuracy

Angular transmission error is the difference between the theoretical rotation angle of the output shaft, as calculated from the input pulse count, and actual rotation angle. It is indicated by the range between the minimum and maximum values of the measurement error of a single rotation of output shaft from the arbitrary point.

Angular Transmission Accuracy by Frame Size

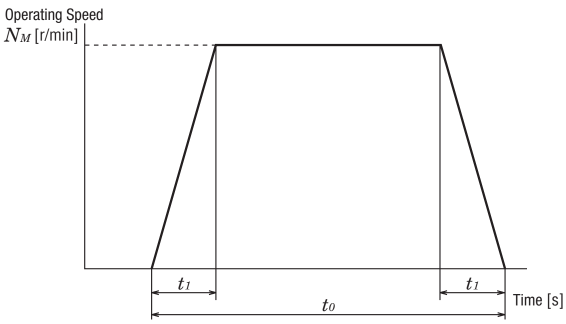
Frame Size [mm]	Angular Transmission Accuracy [arc minute]
80, 104	4 (0.07°)

Utilizing the Maximum Torque

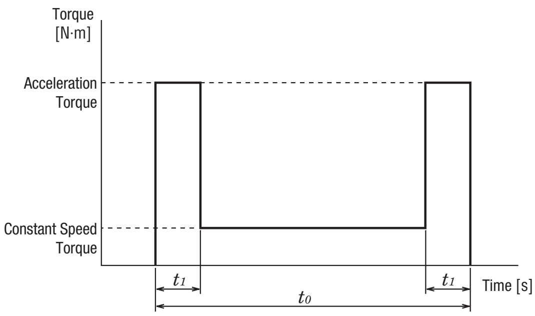
The following explains how to utilize the maximum torque of the **PS** gear and harmonic gears.
The maximum torque is the maximum value of torque which can be applied to the output gear shaft.
The permissible torque is the value of torque which can be applied continuously to the output gear shaft.
During acceleration and deceleration, a larger amount of torque than during operation at constant speed is applied to the output gear shaft as acceleration torque, due to load inertia. The following formula shows that the larger the load inertia or the shorter the acceleration/deceleration time, the larger the acceleration torque becomes. Therefore, the larger the torque applied to the output gear shaft, the shorter the positioning time becomes.

$$T_a\,[\text{N·m}] = \frac{(J_0 + J_L)}{9.55} \cdot \frac{N_M}{t_1}$$

T_a : Acceleration torque [N·m]
J_0 : Rotor inertia [kg·m^2]
J_L : Total load inertia [kg·m^2]
N_M : Motor operating speed [r/min]
t_1 : Acceleration (deceleration) time [s]
t_0 : Positioning time [s]



Operating Pattern

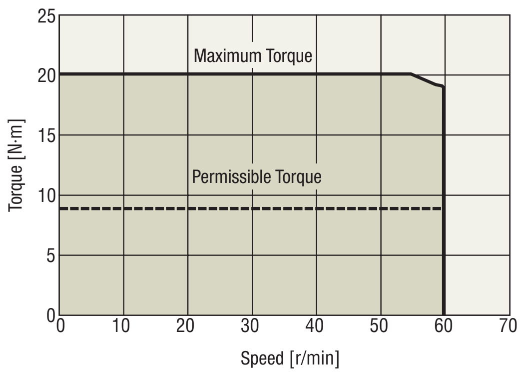


Torque Pattern

As an example of utilizing the maximum torque, the positioning times when driving the same sized inertial loads are compared. The speed – torque characteristics are shown below using **AR66AC-PS50-◇**.

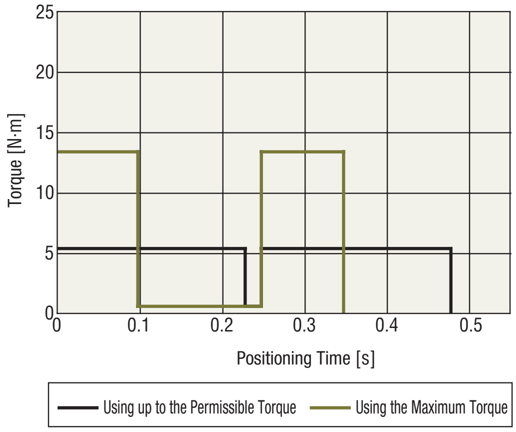
Condition ① When utilizing the maximum torque
② When estimating only the permissible torque
Driving Condition Safety Factor: 1.5
Diameter of Load Inertia: 300 mm (15 mm thick, iron)
Load Inertia: 942×10^{-4} [kg·m^2]
Traveling amount: 90 degrees

Item	**AR66AC-PS50-◇**
Frame Size	60 mm
Gear Ratio	50
Maximum Holding Torque	8 N·m
Permissible Torque	8 N·m
Maximum Torque	20 N·m
Mass	0.75 kg

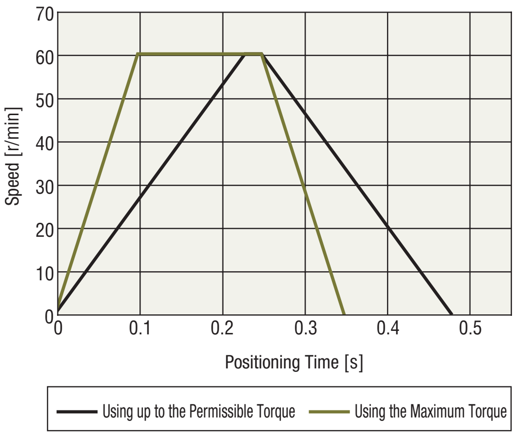


Speed – Torque Characteristics

The following graphs are the comparisons of torque patterns and positioning times. The graphs show that positioning time is faster at 0.1 [s] or more when maximum torque is utilized.
As mentioned above, positioning time is faster when maximum torque is utilized, which can lead to increased productivity.



Torque Pattern Comparison



Positioning Time Comparison