Gearheads

■Gearheads for AC Motors

Since AC motor gearheads are used continuously, primarily for transmitting power, they are designed with priority on ensuring high permissible torque, long life, noise reduction with an extensive gear ratio product line.
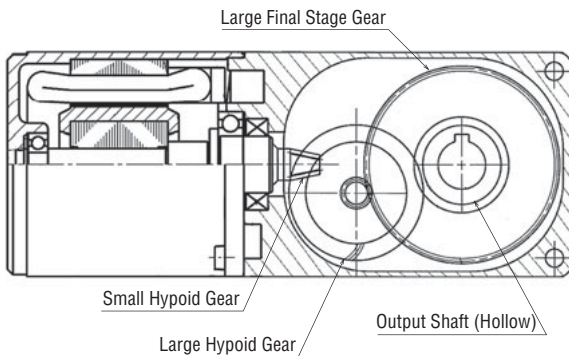
●Right-Angle Gearhead

The right-angle gearhead is designed to facilitate the efficient use of limited mounting space and the elimination of couplings and other power-transmission components (in the case of the hollow shaft gearhead). Oriental Motor offers right-angle hollow shaft gearheads, including and right-angle hollow shaft gearheads as well as right-angle solid shaft gearheads that use hypoid gears, and right-angle solid shaft gearheads as well as right-angle hollow shaft gearheads that use worm gears or crossed helical gears.
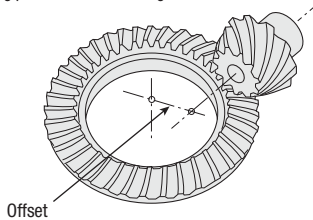
◇Hypoid Gears

By using hypoid gears on the motor shaft, a larger gear can be installed on the output shaft, which increases the output torque. Also, depending on the gear ratio, the number of gear stages can be reduced.

Because the gear meshing of hypoid gears is complicated, the backlash between gears and the gear meshing placement must be accurately adjusted. Because of this, the gearheads have been structured so that once a gearhead motor has been assembled, neither the motor nor the speed reduction mechanism can be detached.

Large Final Stage Gear
Small Hypoid Gear
Large Hypoid Gear
Output Shaft (Hollow)

Structural Drawing of a Right-Angle Gearhead

● Hypoid Gears
The hypoid gear is a conical gear with curved tooth trace for transmitting power between skew gear shaft.
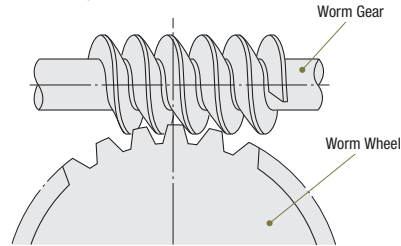

Offset

Structure of a Hypoid Gear

◇Worm Gears

The worm gear has a history as long as the spur gear, but its applications have been limited compared to the spur gear due to its relatively low efficiency and difficulty in fabrication. Oriental Motor has successfully incorporated the worm gear based on its right-angle property and capacity for large gear ratios, and has improved its efficiency over conventional types by increasing the lead.
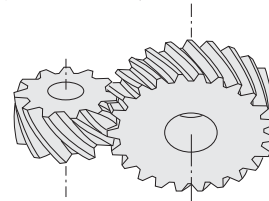
● Worm Gears
The worm gear transmits power from a single or multiple threaded worm to a mating worm wheel.

Worm Gear
Worm Wheel

◇Crossed Helical Gears

The crossed helical gear is a standard helical gear on its own. While mating parallel shaft helical gears have equal torsion angle and contact with the helixes running in opposite directions, the crossed helical gears are designed to contact with their shafts crossing perpendicularly. 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.
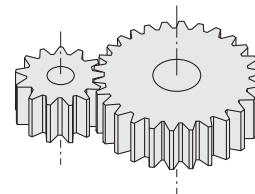
● Crossed Helical Gears
Helical gears are used for skew gear shafts (neither crosses each other nor are parallel to each other).
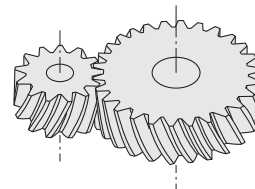

●Parallel Shaft Gearhead

Oriental Motor's parallel shaft gearheads use spur gears and helical gears. In particular, helical gears are used to reduce noise and improve strength.

● Spur Gears
A spur gear is a cylindrical gear in which the tooth trace consists of parallel straight lines.

● Helical Gears
A helical gear is a cylindrical gear whose tooth trace consists of a helical curve. Its high rate of contact compared to the spur gear has the advantages of low noise and higher strength, but its axial load calls for careful consideration in design.
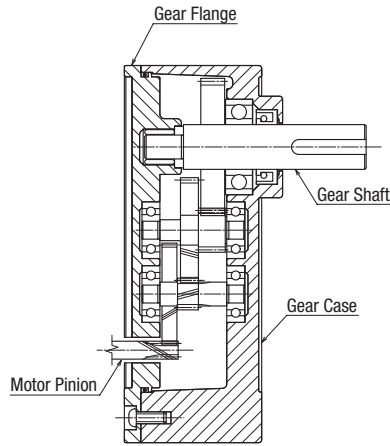
◇**GV** Gearhead

The **GV** gearhead achieves noise reduction through improving gear case rigidity, further improvement of gear machining technology, and higher accuracy in assembly technology. By using high-strength carburized gears and larger diameter bearings, the **GV** Series achieves 2 to 3 times more torque than the conventional **GN-K** gearheads, and have a rated life of 10,000 hours.

GV Gearhead

■Gearheads for Brushless Motors

Brushless motors used for speed control have high max. speeds in a range of 3000 to 4000 r/min. Accordingly, gearheads to be combined with these motors must keep the noise level low even at high speeds while also ensuring high permissible torque and long life to fully utilize the characteristics of the high output motors. Oriental Motor has an extensive product line 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.
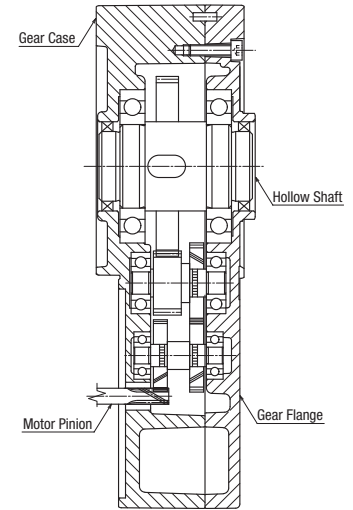
●Hollow Shaft Flat Gearhead

Hollow shaft flat gearheads are designed to prevent saturation of permissible torque even at high gear ratios. Accordingly, these products are also suitable for applications where high permissible torque is required. In addition, they allow effective installation in a limited space and enable a reduction in the number of power transmission components such as couplings.

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.

Hollow shaft flat gearheads are structured to increase the space volume beyond the levels of conventional parallel shaft gearheads by extending the gear shaft layout in the longitudinal direction. At the same time, the gear case has been made more rigid while the gear and bearing outer diameters have been increased.

These features make it possible to provide a hollow output shaft without changing the parallel shaft structure, which helps increase the permissible torque and life of the product.

In addition, the parallel shaft structure ensures higher gear transmission efficiency compared to conventional right-angle shaft mechanisms.

Structural Drawing of the Hollow Shaft Flat Gearhead

Gears for Stepper Motors and Servo Motors

Since stepper motors, servo motors and other control motors are designed to allow accurate positioning, the gearheads used for these motors are designed with emphasis on high accuracy, high permissible torque, and 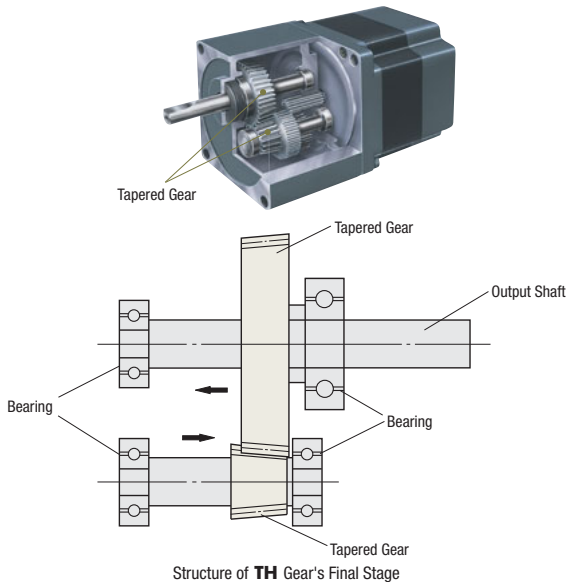high speed (for servo motors). Accordingly, Oriental Motor has developed a mechanism to minimize backlash in gears used with stepper motors and servo motors in order to ensure low backlash properties.

Generally, a stepper motor is associated with a larger output torque than an AC motor with the same frame size, and servo motors rotate at high speeds. Accordingly, gears for stepper motors and servo motors support high torque and high speed so as to not lose the characteristics of their respective motors. The basic principles and structures of typical control motor gears are explained below.

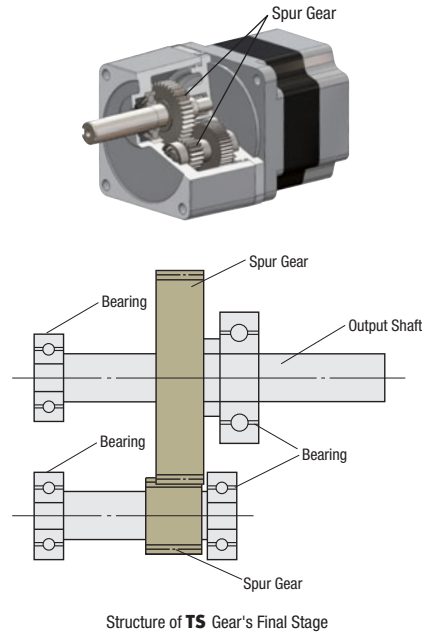### ●TH Gears
◇Principle and Structure

In **TH** gears, tapered gears are used in the final stage of the spur gear's speed-reduction mechanism 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

●TS Gears
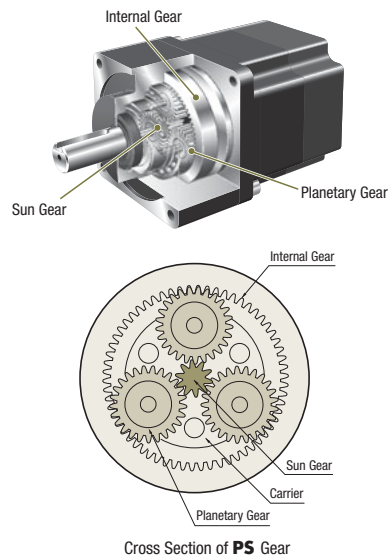#### ◇Principle and Structure

Through the use of high accuracy gear processing and heat treatment to reduce dimensional variation, **TS** gears reduces their effects on backlash. In addition, because the gear on the output shaft undergoes a high accuracy finishing process after the heat treatment, there are no dimensional variation effects from the heat treatment. Because of this, **TS** gears allow for simple structures that do not require a special adjustment mechanism.

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

●PS Gears
◇Principle and Structure

PS gears employ a planetary gear mechanism. The planetary gear mechanism is comprised of 3 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 around 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 : A gear located in the center, functioning as an input shaft.
Planetary Gears : Several external gears revolving around the sun gear. Each planetary gear is attached to the carrier, onto which the output gear shaft is fixed.
Internal Gear : A cylindrical gear affixed to the gearbox, having teeth on its inside diameter.

Selection Calculations

Motors

Linear & Rotary Actuators

Cooling Fans

Service Life

Stepper Motors

Servo Motors

Standard AC Motors
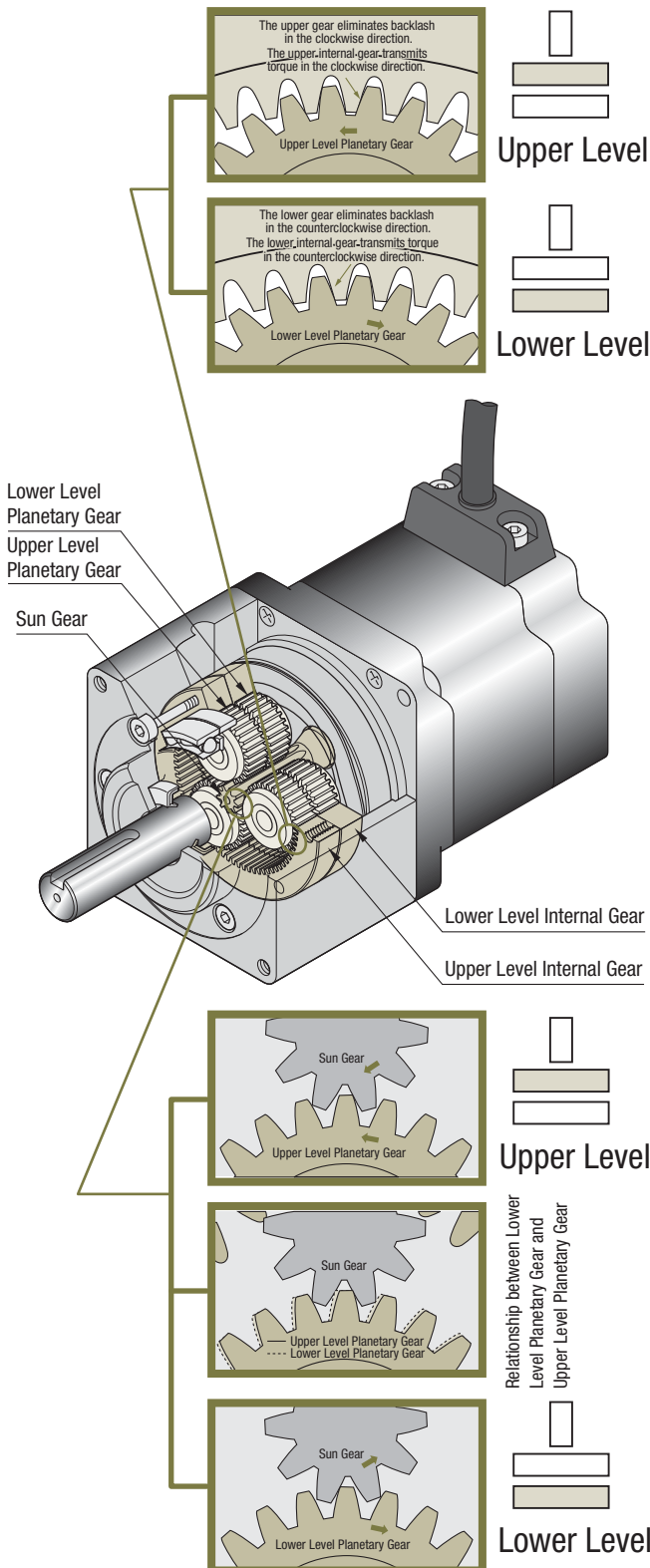
Brushless Motors/AC Speed Control Motors

Gearheads

Linear & Rotary Actuators

Cooling Fans

● PN Gears

◇ Principle and Structure

PN gears employs a planetary gear mechanism just like the **PS** gear. The **PN** gear achieves the specified backlash of less than 3 arcminutes through the improved finishing accuracy of its components and the backlash elimination mechanism. That mechanism is comprised of 2 sets of internal and planetary gears on the upper and lower levels with the internal gear teeth twisted in the circumferential direction. The upper internal gears and planetary gears reduce backlash in the CW direction, and the lower internal gears and planetary gears reduce backlash in the CCW direction.

The upper gear eliminates backlash in the clockwise direction. The upper internal gear transmits torque in the clockwise direction.

Upper Level Planetary Gear

Upper Level

The lower gear eliminates backlash in the counterclockwise direction. The lower internal gear transmits torque in the counterclockwise direction.

Lower Level Planetary Gear

Lower Level

Lower Level Planetary Gear
Upper Level Planetary Gear
Sun Gear

Lower Level Internal Gear
Upper Level Internal Gear

Sun Gear
Upper Level Planetary Gear

Upper Level

Sun Gear
Upper Level Planetary Gear
---- Lower Level Planetary Gear

Relationship between Lower Level Planetary Gear and Upper Level Planetary Gear

Sun Gear
Lower Level Planetary Gear

Lower Level

◇ Angular Transmission Accuracy

Angular transmission accuracy is the difference between the theoretical rotation angle of the output shaft, as calculated from the input pulse count, and the actual rotation angle. Represented as the difference between the min. value and max. value in the set of measurements taken for a single rotation of the output shaft, starting from an arbitrary position.

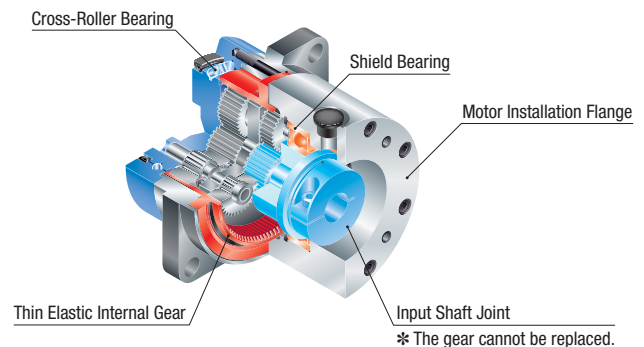Angular Transmission Accuracy by Frame Size

Frame Size [mm]	Angular Transmission Accuracy [arcminute]
28, 42	6 (0.1°)
60	5 (0.09°)
90	4 (0.07°)

● HPG Gear

◇ Principle and Structure

The HPG gear is a planetary gear that applies a thin elastic gear to an internal gear of the planetary gear mechanism. This provides low backlash without an adjustment mechanism, using the elastic deformation of the internal gear.

The planetary gear has a structure where the sun gear and the planetary gear, and the planetary gear and the internal gear are interlock at the same time. Minimizing the backlash with accurately sized parts only causes uneven rotation torque and the generation of noise, due to interference between the interlocking parts caused by size error. To solve this problem, a "thin elastic gear" with a function to reduce interference between the interlocking parts and sufficient strength was developed, and Harmonic Planetary, the planetary gear with a ground-breaking structure was born. There is little change in the amount of backlash generated by Harmonic Planetary throughout the gear life.

Cross-Roller Bearing
Shield Bearing
Motor Installation Flange
Thin Elastic Internal Gear
Input Shaft Joint
✱ The gear cannot be replaced.

(Copyright © 1999 HARMONIC DRIVE SYSTEMS INC. All Rights Reserved.)
● Harmonic Planetary is a registered trademark of Harmonic Drive Systems Inc.

◇ Angular Transmission Accuracy

Angular transmission accuracy is the difference between the theoretical rotation angle of the output shaft, as calculated from the input pulse count, and actual rotation angle. Represented as the difference between the min. value and max. value in the set of measurements taken for a single rotation of the output shaft, starting from an arbitrary position.
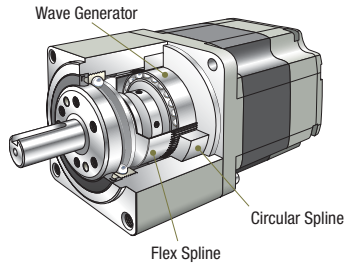
Angular Transmission Accuracy by Frame Size

Frame Size [mm]	Angular Transmission Accuracy [arcmin]
40	5 (0.09°)
60	4 (0.07°)
90	4 (0.07°)

● **Harmonic Gears**

◇ **Principle and Structure**

The harmonic gear offers excellent positioning accuracy for a gearhead and features a simple construction that utilizes the metal's elastodynamic property. It is comprised of 3 basic components: a wave generator, a flex spline and a circular spline.

Wave Generator

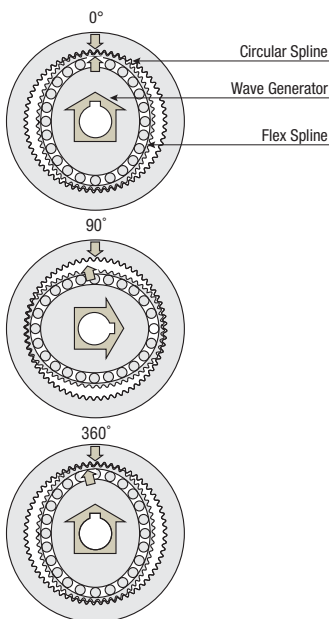Circular Spline

Flex Spline

Wave Generator

The wave generator is an oval-shaped component with a thin ball bearing placed around the outer circumference of the oval cam. The bearing's inner ring is fixed to the oval cam, while the outer ring is subjected to elastic deformation via the balls. The wave generator is installed onto the motor shaft.

Flex Spline

The flex spline is a thin, cup-shaped component made of elastic metal, with teeth formed along the outer circumference of the cup's opening. The output gear shaft is attached at the bottom of the flex spline.

Circular Spline

The circular spline is a rigid internal gear with teeth formed along its inner circumference. These teeth are the same size as those of the flex spline, but the circular spline has 2 more teeth than the flex spline. The circular spline is attached to the gear case along its outer circumference.

0°

Circular Spline

Wave Generator

Flex Spline

Combines 3 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.

90˚

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.
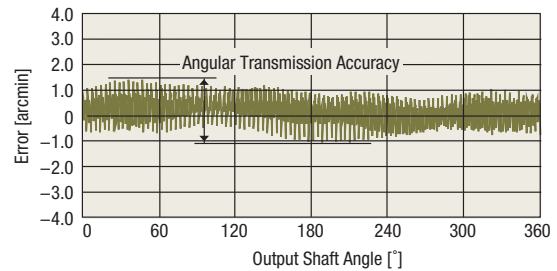
360˚

When the wave generator completes a revolution, the flex spline has rotated 2 fewer teeth than the circular spline has, resulting in the movement of flex spline for the difference in the number of teeth (2 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 the conventional spur gear gearhead, the harmonic gear has no backlash. The harmonic gear has many teeth in simultaneous meshing engagement, and is designed to average out the effects of tooth pitch error and cumulative pitch error on rotation accuracy to ensure 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 than 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. Represented as the difference between the min. value and max. value in the set of measurements taken for a single rotation of the output shaft, starting from an arbitrary position.
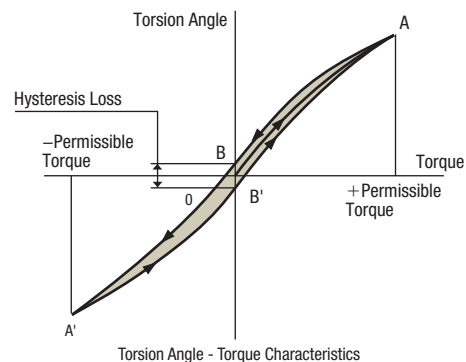
Angular Transmission Accuracy

Error [arcmin]

Output Shaft Angle [˚]

Product Name	Angular Transmission Accuracy [arcminute]
CRK513-H□	3 (0.05˚)
AR24-H□, CRK523-H□	2 (0.034˚)
AR46-H□, AZM46-HS□	
RKS543-HS□, CRK543-H□	
AR66-H□, AZM66-HS□	1.5 (0.025˚)
RKS564-HS□, CRK564-H□	
PKP262-H□	
AR98-H□, AZM98-HS□	1 (0.017˚)
RKS596-HS□	

These are the values under no load (gear reference value). In actual applications, there is always frictional load, and displacement is produced as a result of this frictional load. If the frictional load is constant, the displacement will be constant for unidirectional operation. However, in bidirectional operation, double the displacement is produced over a round trip. This displacement can be estimated from the following torque – torsion characteristics.

Torque – Torsion Angle Characteristics

The torque – torsion angle characteristics in the graph measure displacement (torsion) when the motor shaft is fixed and the load (torque) is gradually increased and 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 gear's spring constant.

Torsion Angle

A

Hysteresis Loss

−Permissible Torque

B

0   B'

Torque

+Permissible Torque

A'

Torsion Angle - Torque Characteristics

This displacement occurs when an external force is applied as the gear is stopped, or when the gear is driven under a frictional load. The slope can be approximated with the spring constant in the following 3 classes, depending on the size of the torque, and can be estimated through calculation.

1. Load torque T_L is T_1 max.
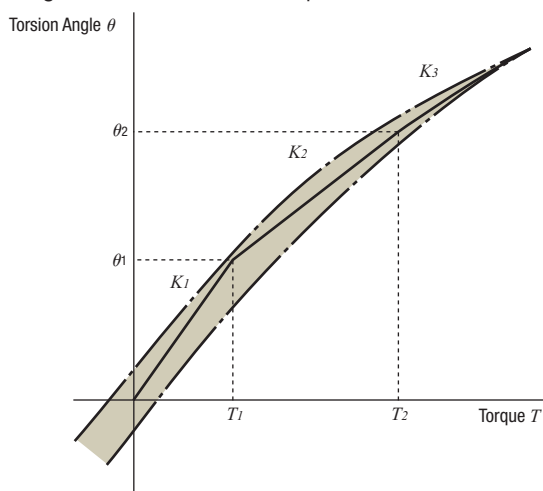
$$\theta = \frac{T_L}{K_1} \ [\text{min}]$$

2. Load torque T_L exceeds T_1 but is less than T_2

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

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

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 bidirectionally. (Figure B-B')
This is referred to as a hysteresis loss. The harmonic gear is designed to have a hysteresis loss of 2 arcminutes or less.
When the external force is applied during stopping, or when the acceleration/deceleration torque is applied in the inertial drive, or 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.

Values for Determining Torsion Angle

Product Name	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 CRK523-H50	50	0.29	0.08	3.7	–	0.12	–	–
		0.29	0.12	2.6	0.75	0.17	5.4	0.2
AR24-H100 CRK523-H100	100	0.29	0.1	2.9	1.5	0.15	11	0.21
		0.29	0.21	1.4	0.75	0.24	3.4	0.26
AR46-H50 AZM46-HS50 RKS543-HS50 CRK543-H50	50	0.8	0.64	1.25	2	0.87	2.6	0.93
AR46-H100 AZM46-HS100 RKS543-HS100 CRK543-H100	100	0.8	0.79	1.02	2	0.99	2.2	1.28
AR66-H50 AZM66-HS50 RKS564-HS50 CRK564-H50	50	2	0.99	2	6.9	1.37	5.6	1.66
PKP262-H50	50	2	0.84	2.37	6.9	1.08	6.53	1.37
AR66-H100 AZM66-HS100 RKS564-HS100 CRK564-H100	100	2	1.37	1.46	6.9	1.77	4.2	2.1
PKP262-H100	100	2	1.16	1.72	6.9	1.28	5.50	1.77
AR98-H50 AZM98-HS50 RKS596-HS50	50	7	3.8	1.85	25	5.2	5.3	6.7
AR98-H100 AZM98-HS100 RKS596-HS100	100	7	4.7	1.5	25	7.3	4	8.4