Harmonic Planetary®

HPG Series
Planetary Gearhead

Harmonic Planetary®

Precision Gearing & Motion Control

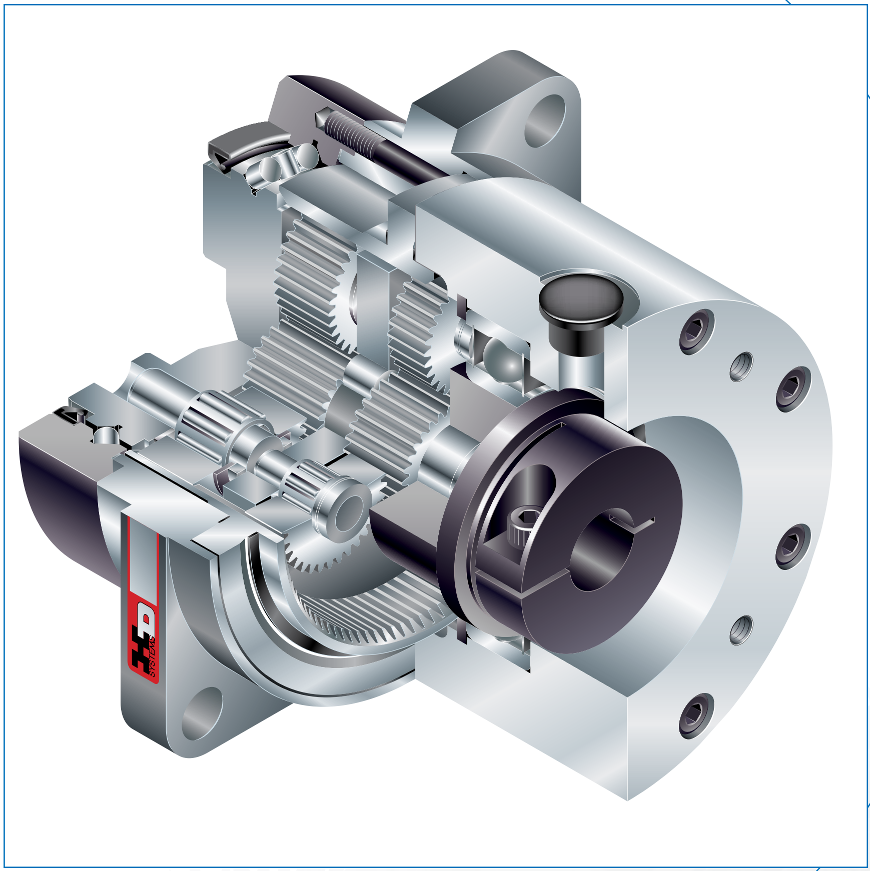
Harmonic Drive LLC

is the world's largest manufacturer of strain wave gearing and motion control systems, with an installed base of over 4 million products worldwide. Known for its high precision, zero backlash Harmonic Drive™ products, Harmonic Drive LLC was a pioneer in developing high precision mechanical drive products to complement the growing use of high accuracy servo and stepper motors in motion control. With its new, unique Harmonic Planetary® gearhead, Harmonic Drive LLC continues to lead the way in innovative, precision motion products.

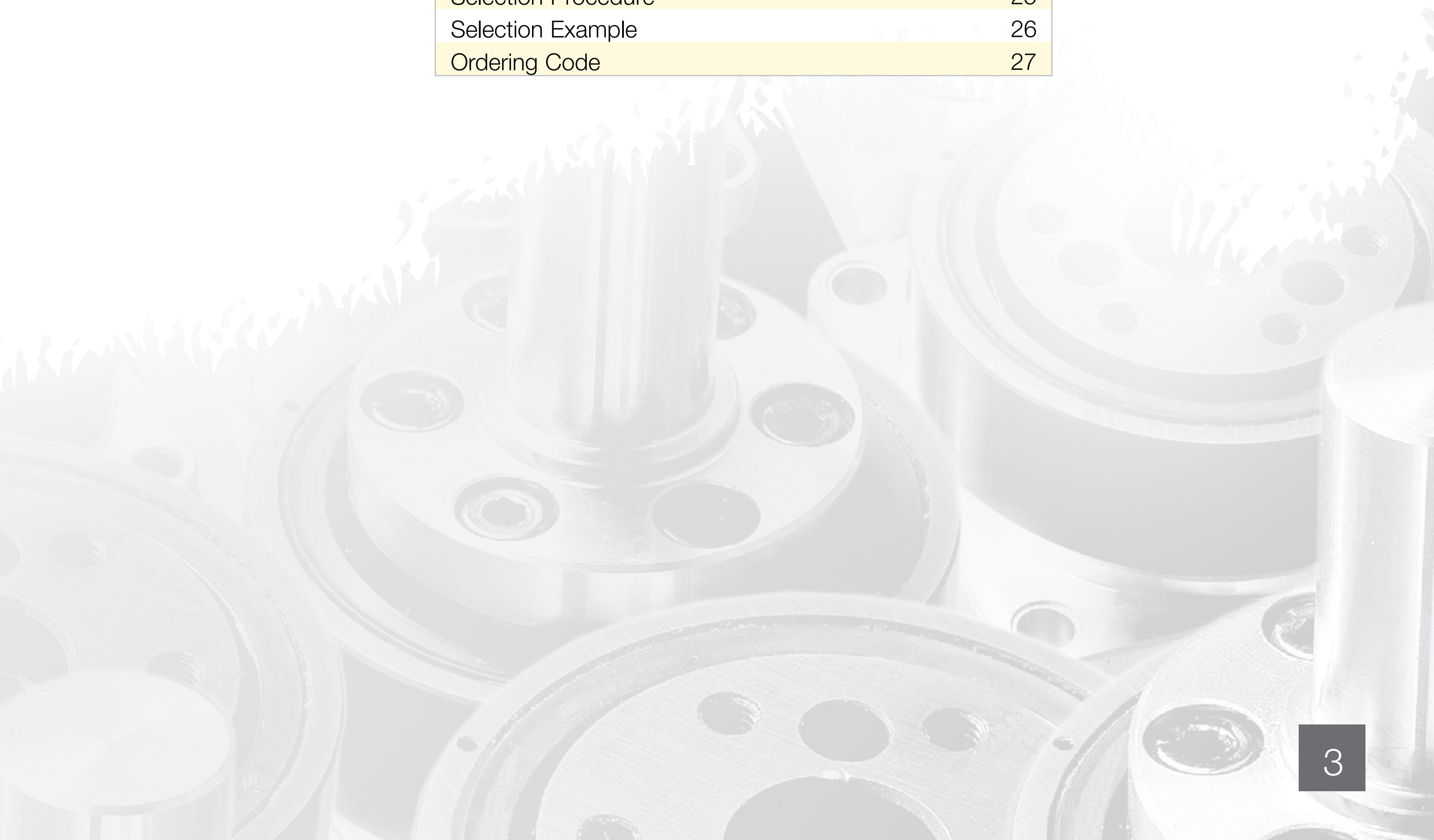
Harmonic Drive LLC products are used everywhere precision motion is needed, including semiconductor equipment, robotics, and even space applications. HPG is manufactured in the company's 150,000 square foot, ultra-modern facility in Nagano, Japan, and then assembled to exact customer specifications in the US headquarters located in Peabody, MA. Both facilities are ISO 9001certified. Complete application engineering, custom design, customer service, and technical support are provided in the United States.

The NEW Harmonic Planetary®
Low Backlash For Life

The new **Harmonic Planetary®** gearhead is a revolutionary new design in planetary gearheads. The innovative Ring Gear automatically adjusts for backlash, ensuring consistent, low backlash for the life of the gearhead. Harmonic Drive LLC's experience in designing and producing precision strain wave gearing was used to design a unique ring gear. This ring gear acts as a "backlash buffer," as it automatically provides the optimum backlash in the planetary gear train. As compared to other planetary designs, where gear wear increases backlash over time, the Harmonic Planetary® maintains the same low backlash for the life of the gearhead. The design engineer is ensured of consistently low backlash, without the annoying "backlash creep" of other designs.



Contents



The outstanding feature of the new HPG series precision planetary gears is the innovative ring-gear. This is the result of Harmonic Drive LLC's engineering and manufacturing know-how. By using a new ring-gear design, the planetary gears achieve a backlash level of less than 3 arc-min without requiring an additional backlash adjustment mechanism. In addition, a backlash level of less than 1 arc-min is available as an option.

Until now highly accurate gears and an additional adjustment mechanism were necessary to minimize backlash. Tight gear engagement for conventional planetary gears leads to torque ripple and an increase in of noise and wear. To avoid this problem the new HPG series features a unique internally toothed ring-gear, thereby exploiting many years of Harmonic Drive LLC experience. The ring-gear ensures that backlash is minimized and that all planet gears share the load equally.

Backlash less than 1 arc-min

By using an innovative ring-gear, backlash of less than 1 arc-min can be achieved without requiring an additional backlash adjustment mechanism.

High moment stiffness

The very compact and very stiff cross-roller output bearing provides the planetary gears with a high moment stiffness and excellent running tolerances at the output flange.

High efficiency

As a result of the optimized tooth profile efficiencies of more than 90 % can be achieved.

Repeatability better than 20 arc-sec

The highly precise components and the automatic backlash compensation mechanism afforded by the ring gear design provide a repeatability better than ±20 arc-sec.

Easy motor assembly

The supported motor shaft coupling and the variable adapter flange guarantee an extremely rapid and easy motor assembly.

Reduction ratios between 3:1 and 45:1

A selection of reduction ratios (3:1, 11:1, 21:1, 33:1 and 45:1) allows a wide range of output torque and speed.

Flange or Shaft Output Configuration

The HPG is available in either configuration to provide convenient methods to attach the output load.

System Components

- Input coupling
- Ring gear
- One piece: Inner ring of cross-roller bearing, carrier of the second stage, and output flange.

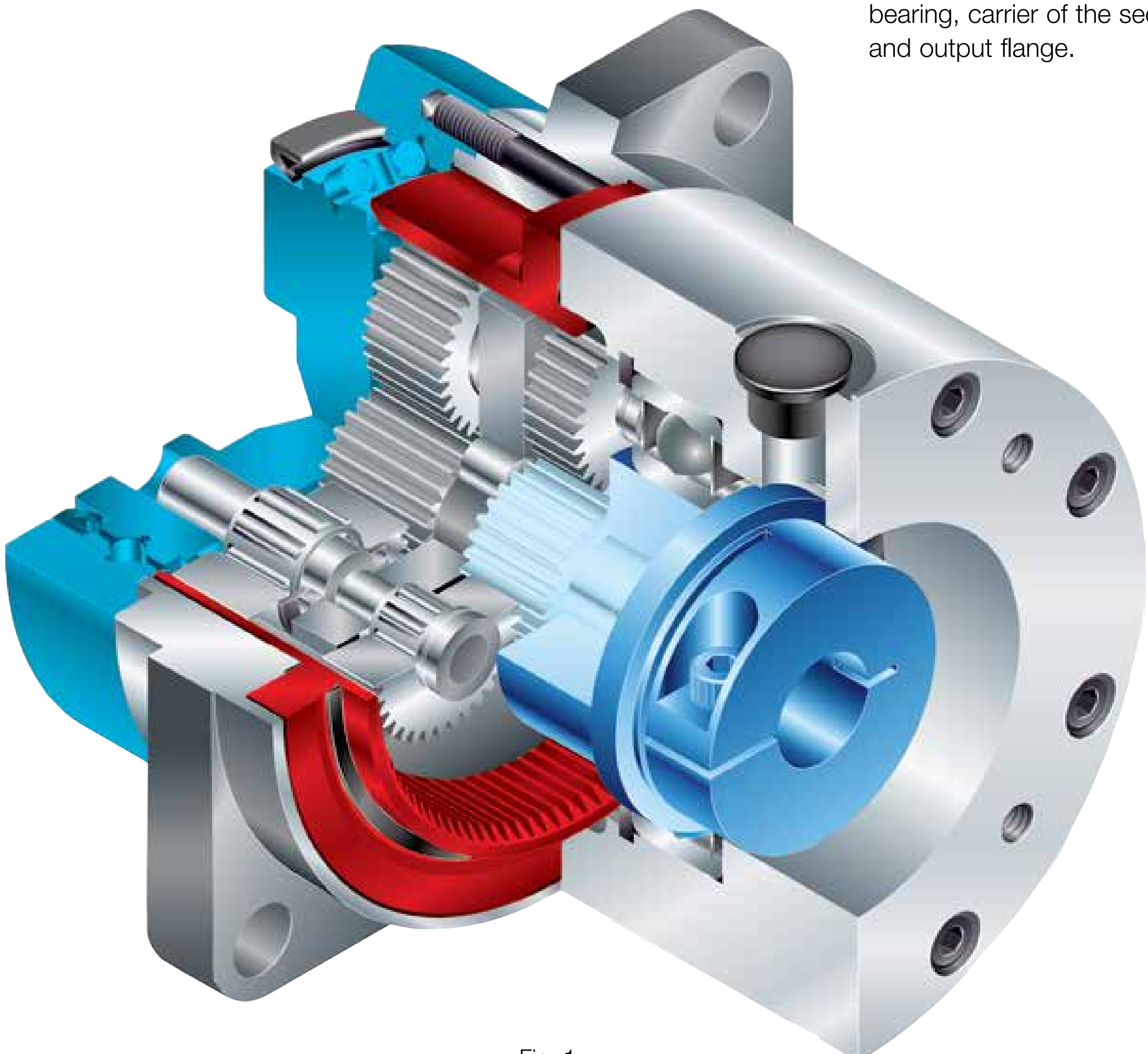
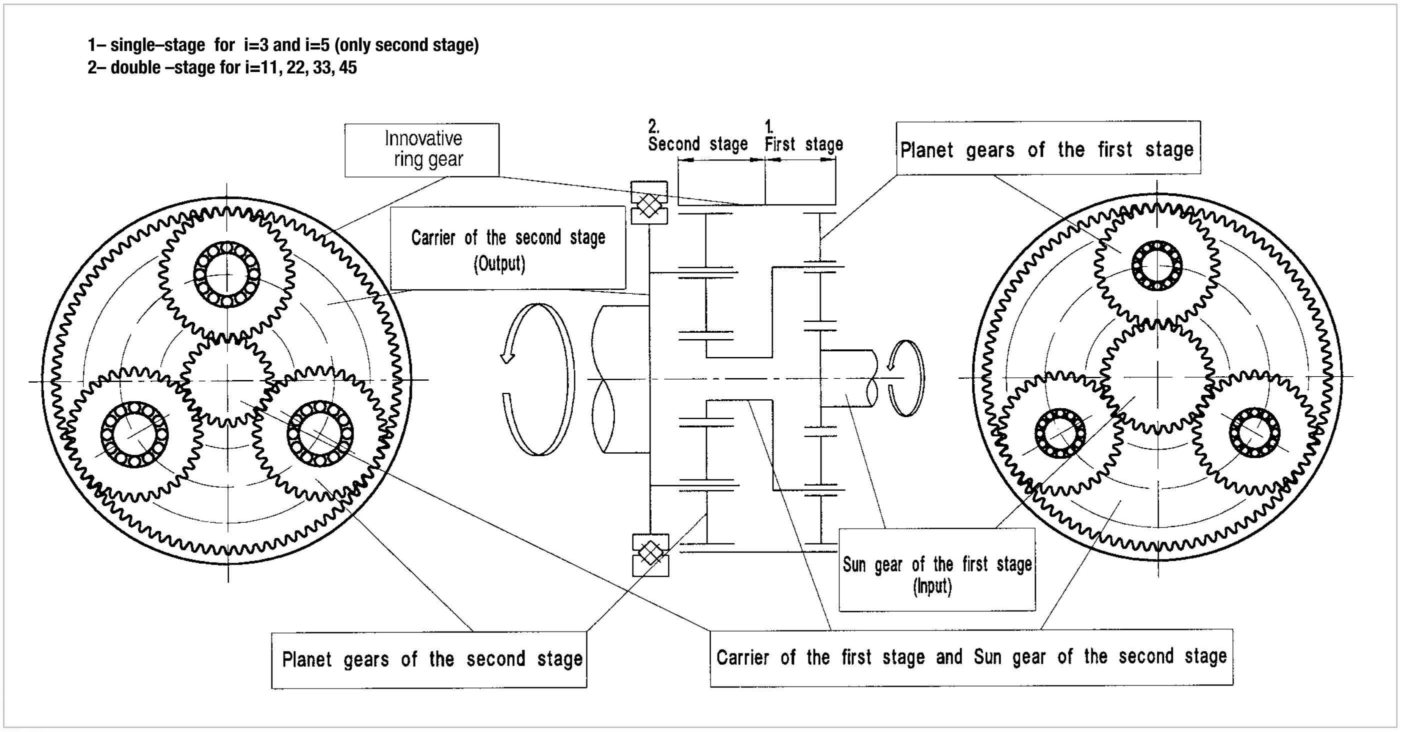


Fig. 1

Principle of Operation

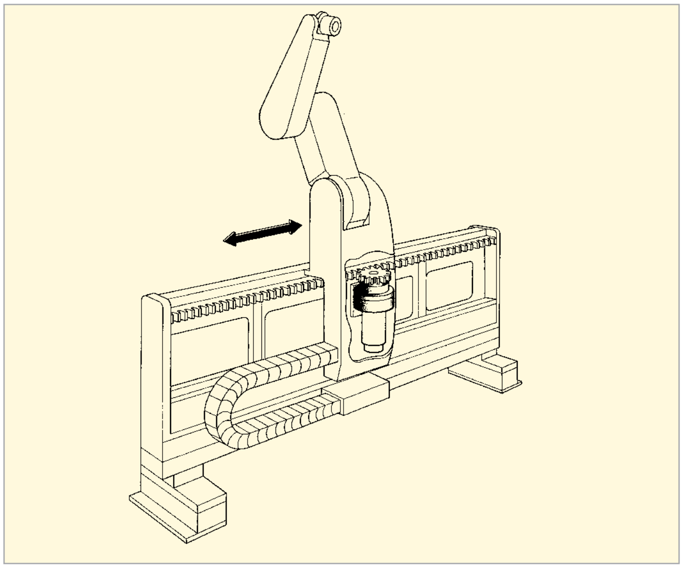
Fig. 2



For double-stage HPG gears the sun gear of the first-stage planetary gear is connected to the motor shaft. The input torque from the motor is transmitted to three equally spaced planet gears. The ring gear is common to both gear stages. The carrier of the first stage is connected to the fully floating sun gear of the second planetary stage. This also features three equally spaced planet gears, which engage with the deformable region of the ring gear. The carrier of the second stage, which acts as output element, is integrated with the flange and inner ring of the output-side cross roller bearing. The direction of rotation of the input shaft and output flange/shaft are the same. For single-stage HPG gears the complete first stage as described above is absent and the sun gear of the second stage is connected directly to the motor shaft.

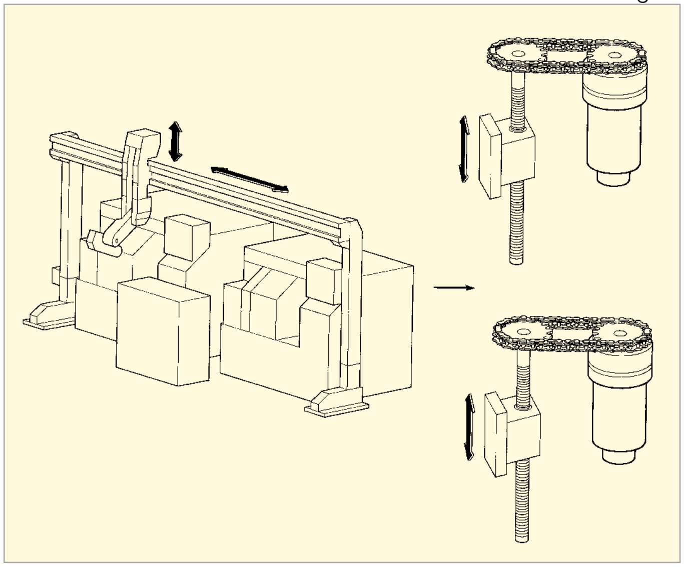
Linear axis for robots

Fig. 3



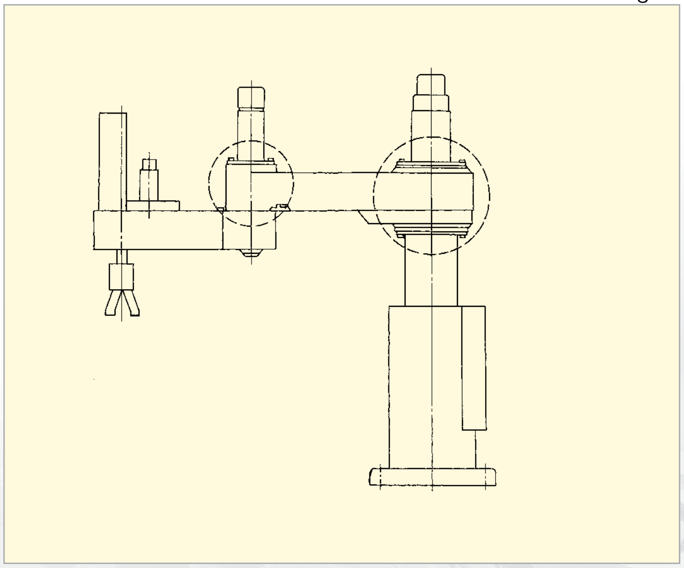
Loading and unloading equipment

Fig. 4



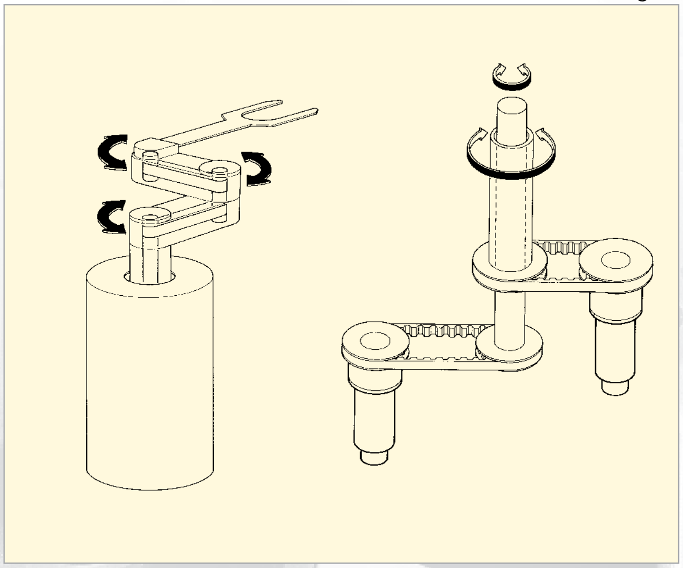
Primary axes of scara robots

Fig. 5



Wafer handling robots

Fig. 6



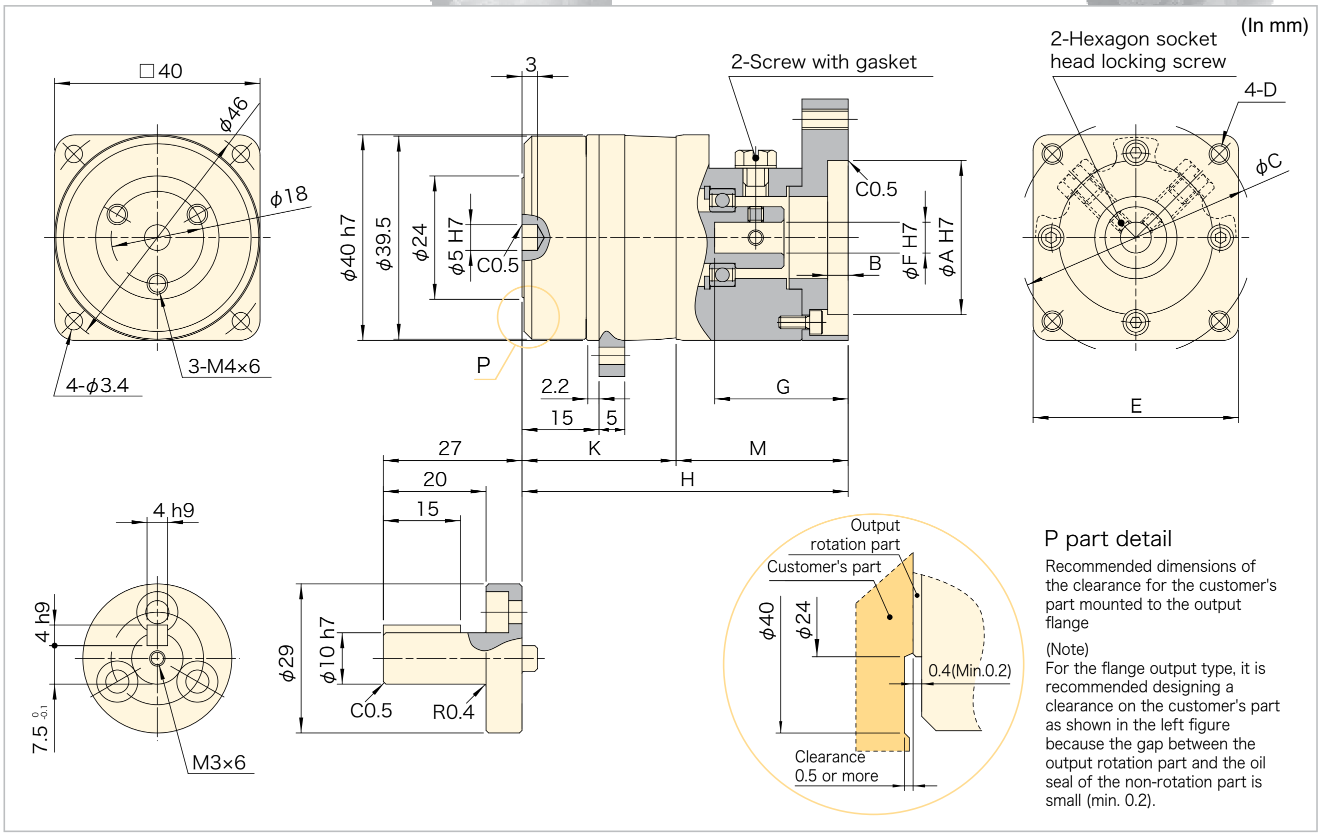
Rating Table

Size	Gear Ratio	Rated Torque at 3000rpm *1		Limit for Average Torque *2		Limit for Repeated Peak Torque*3		Limit for Momentary Torque *4		Max. Average Input Speed *5	Max. Input Speed *6 (grease)	Moment of Inertia *7				Weight *8			
												Gear heads w/Output		Input Shaft Type w/ Output		Gear heads w/ Output		Input Shaft Type w/ Output	
		Nm	lb-in	Nm	lb-in	Nm	lb-in	Nm	lb-in	r/min	r/min	Shaft X 10 -4 kg.m2	Flange X 10 -4 kg.m2	Shaft X 10 -4 kg.m2	Flange X 10 -4 kg.m2	Shaft kgf	Flange kgf	Shaft kgf	Flange kgf
	5	2.5	22	5	44	7.8	69					0.0036	0.0021			0.18	0.14	–	–
	9	2.5	22	3.9	35	3.9	35					0.0012	0.0007						
11	21	3.4	30					20	177	3,000	10,000	0.0019	0.0018	–	–				
	37	3.4	30	6	53	9.8	87					0.00068	0.00066			0.24	0.20	–	–
	45	3.4	30									0.00049	0.00048						
	3	2.9	26	6.4	57	15	133	37	327		5,000	0.077	0.059	0.120	0.110	0.50	0.40	0.80	0.70
	5	5.9	52	13	115							0.026	0.020	0.073	0.067				
	11	7.8	69									0.019	0.018	0.059	0.058				
14	15	9	80			23	204	56	496	3,000	6,000	0.017	0.016	0.057	0.056				
	21	8.8	78	15	133							0.0092	0.0089	0.049	0.049	0.60	0.50	0.90	0.80
	33	10	89									0.0030	0.0029	0.043	0.043				
	45	10	89									0.0028	0.0027	0.043	0.043				
	3	8.8	78	19	168	64	566	124	1,097		4,000	0.57	0.46	0.80	0.69	1.6	1.2	2.4	2.0
	5	16	142	35	310							0.21	0.17	0.44	0.40				
	11	20	177	45	398							0.16	0.15	0.32	0.31				
20	15	24	212	53	469	100	885	217	1,920	3,000	6,000	0.14	0.14	0.30	0.30				
	21	25	221	55	487							0.071	0.069	0.23	0.23	1.8	1.4	2.7	2.1
	33	29	257	60	531							0.024	0.023	0.19	0.19				
	45	29	257	60	531							0.022	0.022	0.18	0.18				
	3	31	274	71	628	225	1,991	507	4,487		3,600	2.8	2.0	4.2	3.4	4.3	2.9	6.3	4.9
	5	66	584	150	1,328							1.0	0.73	2.4	2.2				
	11	88	779									0.84	0.78	2.0	1.9				
32	15	92	814	170	1,505	300	2,655	650	5,753	3,000	6,000	0.65	0.62	1.8	1.8				
	21	98	867									0.36	0.34	1.5	1.5	4.9	3.5	6.9	5.3
	33	108	956	200	1,770							0.13	0.12	1.3	1.3				
	45	108	956	200	1,770							0.12	0.11	1.3	1.3				
	3	97	858	195	1,726	657	5,814				3,000	17	13	21	18	13	10	17	14
	5	170	1,505	340	3,009							6.1	4.8	11	9.2				
	11	200	1,770	400	3,540							3.6	3.3	7.4	7.1				
50	15	230	2,036	450	3,983	850	7,523	1,850	16,373	2,000	4,500	3.1	2.9	6.8	6.7				
	21	260	2,301									1.7	1.6	5.5	5.4	15	12	19	16
	33	270	2,390	500	4,425							0.63	0.6	4.4	4.3				
	45	270	2,390									0.59	0.6	4.3	4.3				
	4	500	4,425	900	7,965						2,500	(42) *9	28			(32) *9	22	–	–
	5	530	4,691	1,000	8,850							(27) *9	18						
	12	600	5,310	1,100	9,735	2,200	19,470					(18) *9	17						
	15	730	6,461	1,300	11,505			4,500	39,825	2,000		(17) *9	16						
65	20	800	7,080	1,500	13,275						3,000	(7.1) *9	6.5	–	–	(47) *9	37	–	–
	25	850	7,523	1,500	13,275							(6.5) *9	6.1						
	40	640	5,664	1,300	11,506	1,900	16,816					(1.5) *9	1.3						
	50	750	6,638	1,500	13,276	2,200	19,472					(1.3) *9	1.2						

*1: Rated torque is based on an L10 life of 20,000 hours with an input speed of 3,000 rpm, which is the typical rated speed of servo motors. Rated input speed for sizes 50 Keyence and 65 are 2,000 rpm.
*2: The limit for average toruque is calculated based on the load torque pattern.
*3: The limit for torque seen during start and stop cycles.
*4: The limit for torque resulting from an emergency stop or from external shock loads. Always operate below this value. Calculate the permissible number of events to assure it meets the required operating conditions (see equation 22, page 21).
*5: Maximum instantaneous input speed.
*6: Maximum average input speed depends on the operating environment, but it is the limiting value for the continuous operating speed or the average input speed of a motion profile. Average input speed is limited due to heat generated in the reducer.
*7: Inertia value is for the gearhead only.
*8: The weight is for th gearhead only (without input shaft coupling & motor flange).
*9: Flange output is standard for the size 65 gearhead. Shaft type (J2 & J6) is available by special order only.

HPG-11B

Fig. 7



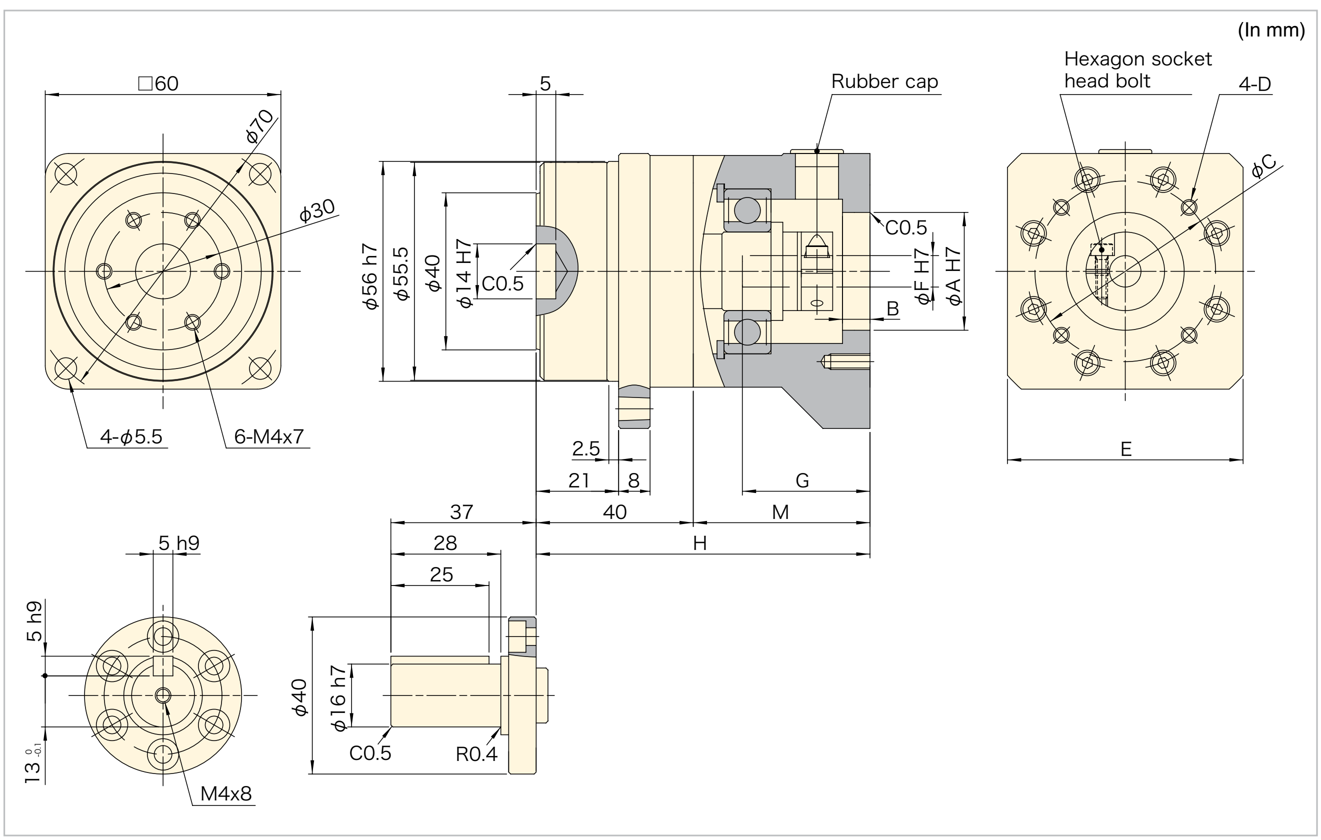
P part detail

Recommended dimensions of the clearance for the customer's part mounted to the output flange

(Note)
For the flange output type, it is recommended designing a clearance on the customer's part as shown in the left figure because the gap between the output rotation part and the oil seal of the non-rotation part is small (min. 0.2).

HPG-14A

Fig. 8

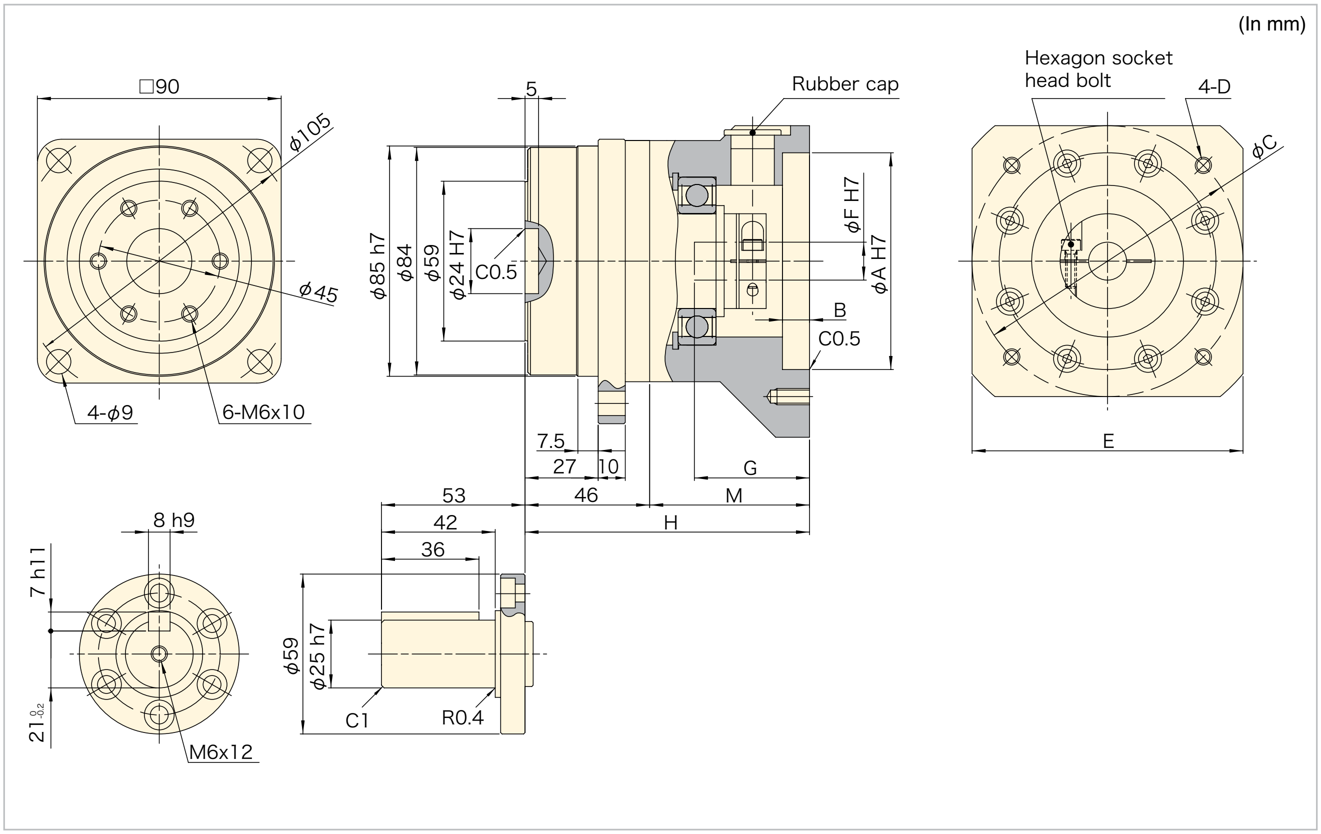


Dimensions A, B, C, D, E, F, G, H depend on the chosen motor/adapter flange combination. Contact Harmonic Drive LLC for details.

Dimensions

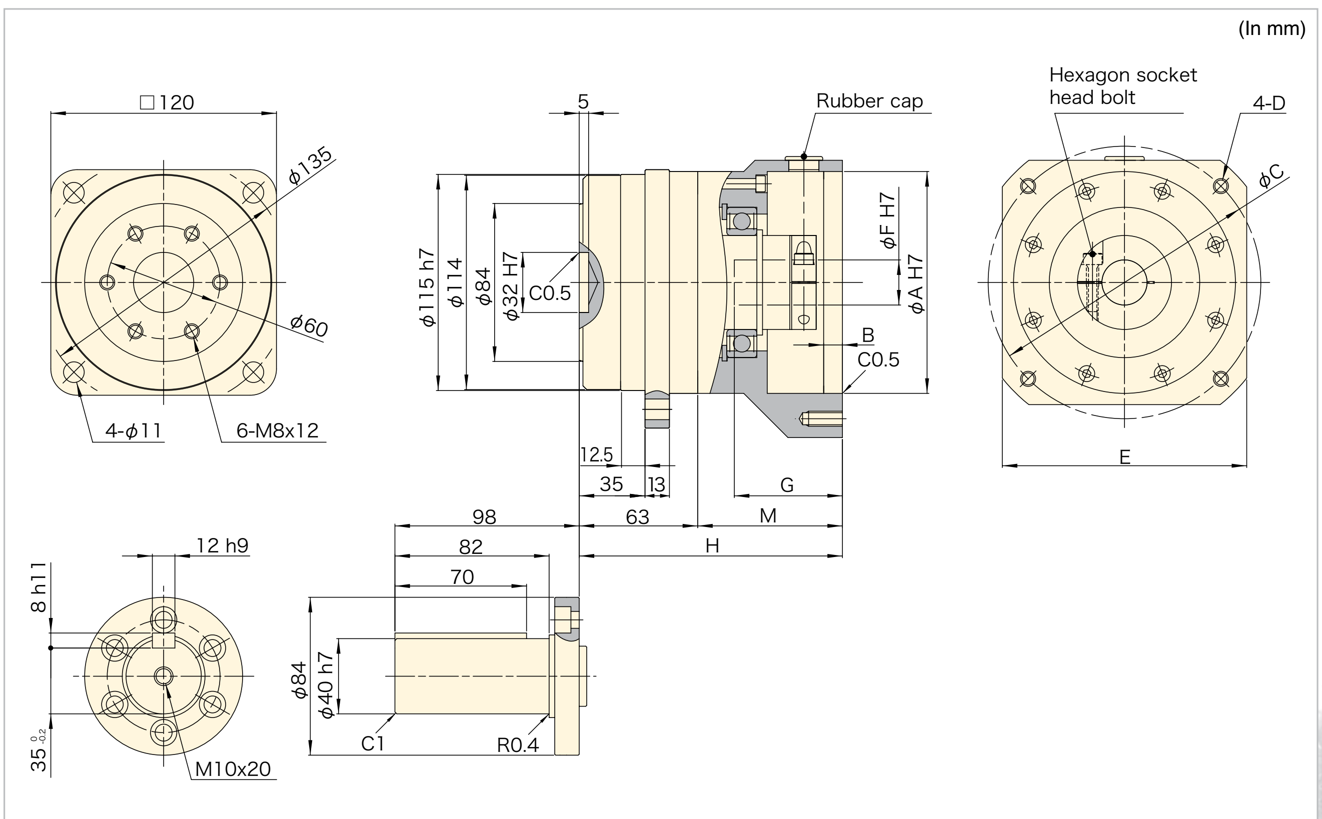
HPG-20A

Fig. 9



HPG-32A

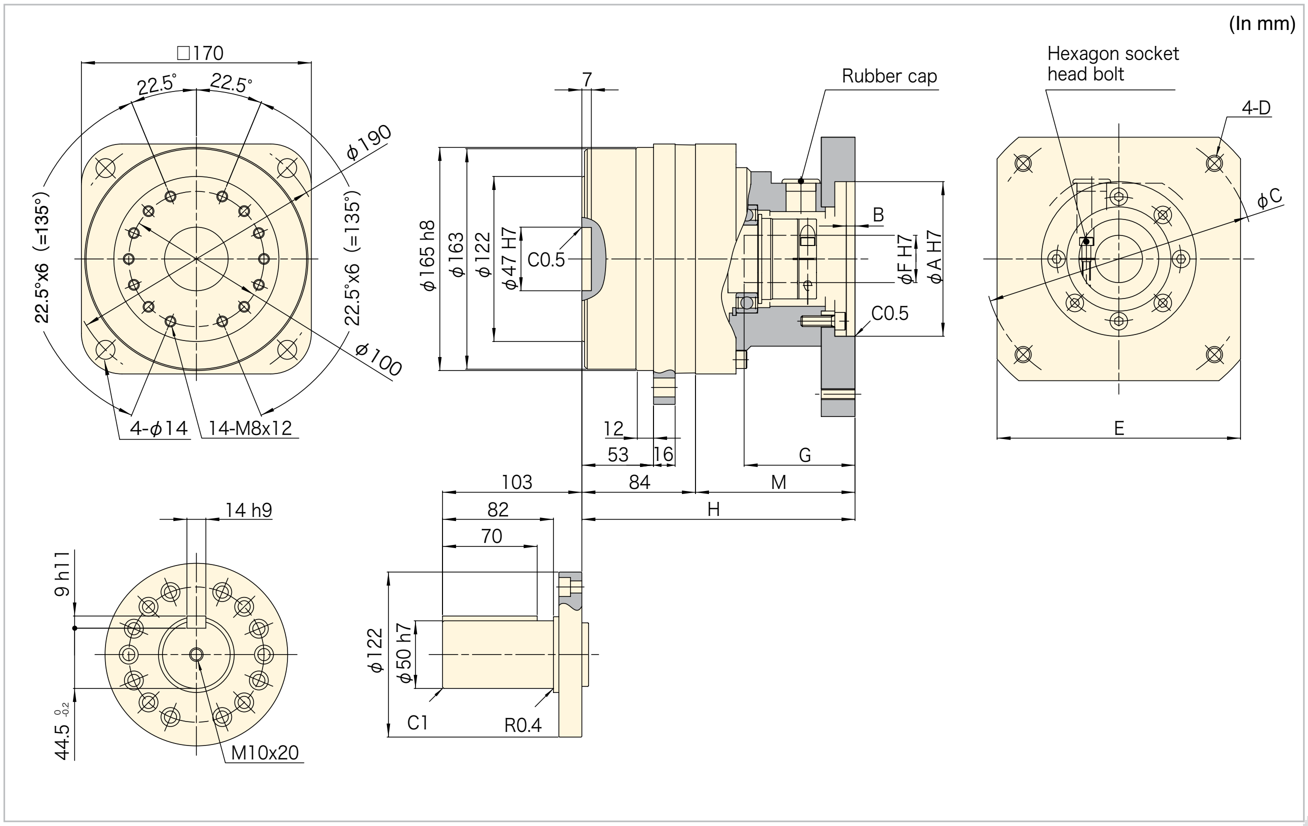
Fig. 10



Dimensions A, B, C, D, E, F, G, H depend on the chosen motor/adapter flange combination. Contact Harmonic Drive LLC for details.

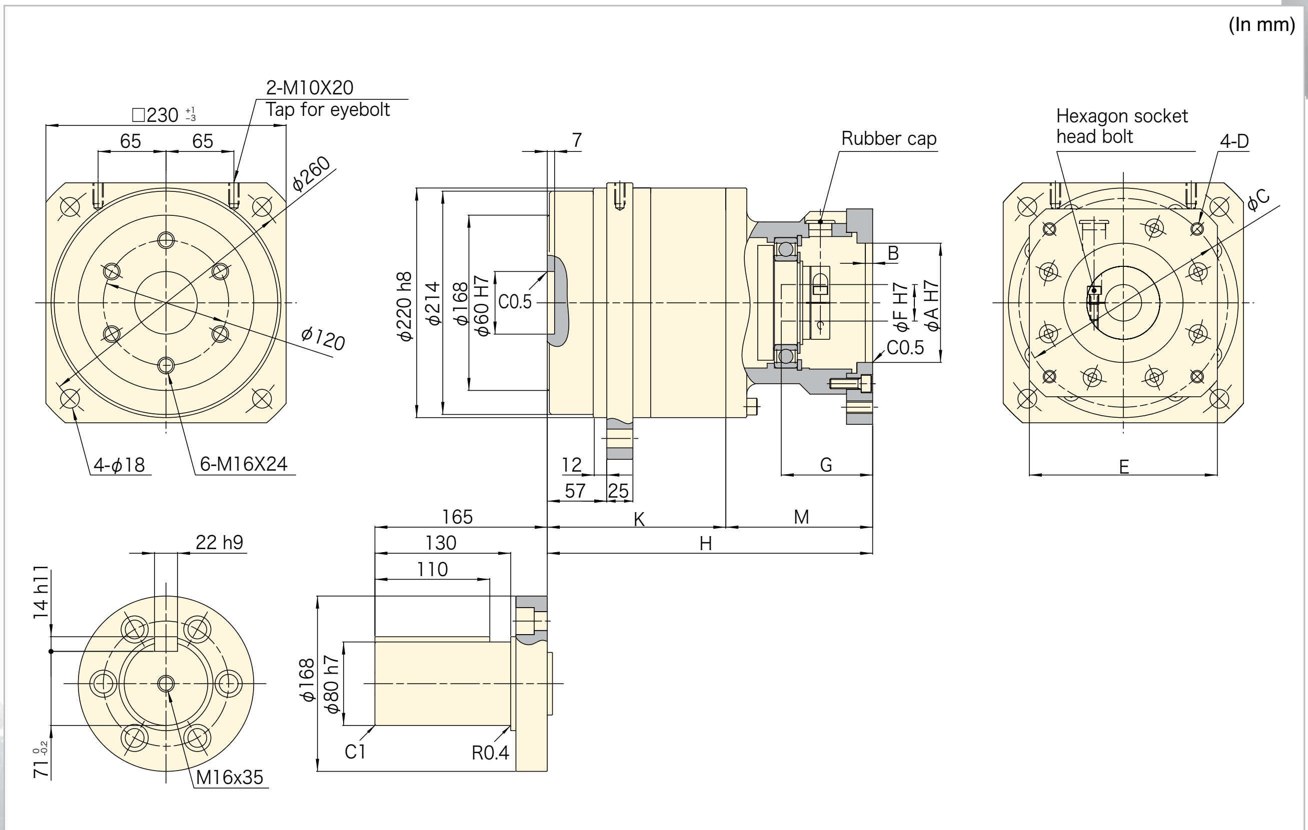
HPG-50A

Fig. 11



HPG-65A

Fig. 12

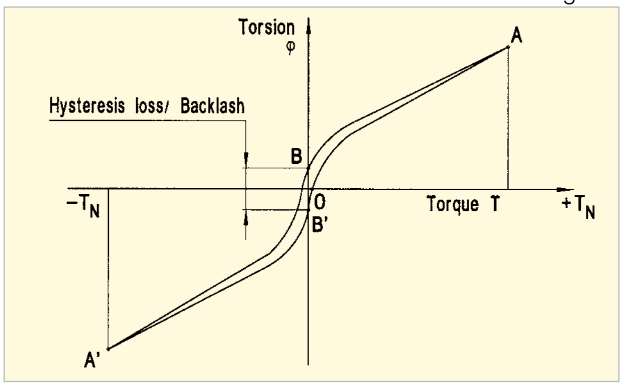


* While the flange output is for standard, the shaft output is for special specification.

Dimensions A, B, C, D, E, F, G, H depend on the chosen motor/adapter flange combination. Contact Harmonic Drive LLC for details.

Hysteresis Loss/Backlash (description via hysteresis curve)

Fig. 11



T_N : Rated output torque
φ : Output rotation angle

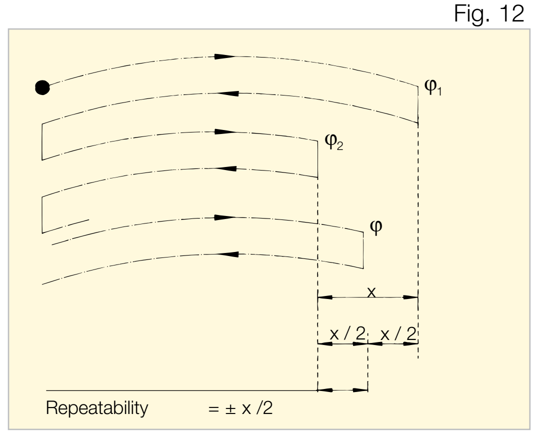
When a torque is applied to the output of a Harmonic Planetary® Gear HPG with the input rotationally locked, the torque-torsion relationship measured at the output typically follows the hysteresis curve 0-A-B-A'-B'-A, as shown in Fig. 11.

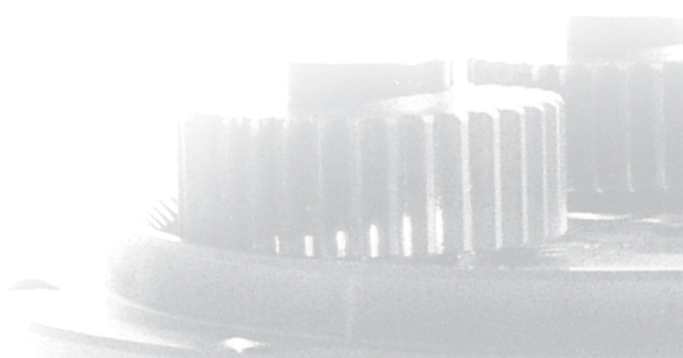
The value of the displacement B-B' is defined as the hysteresis loss or backlash.

Repeatability (linear representation)

The repeatability of the gear describes the position difference measured during repeated movement to the same desired position from the same direction. The repeatability is defined as half the value of the maximum difference measured, preceded by a ± sign, as shown in Fig. 12.

Fig. 12

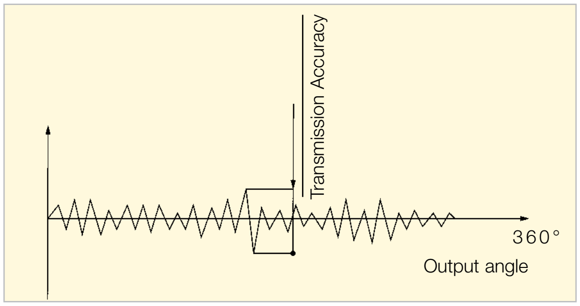




Accuracy Definitions

Transmission Accuracy (linear representation)

Fig. 13



The transmission accuracy of the gear represents a linearity error between input and output angle. The transmission accuracy is measured for one complete output revolution using a high resolution measurement system. The measurements are carried out without direction reversal. The transmission accuracy is defined as the sum of the maximum positive and negative differences between theoretical and actual output rotation angle, as shown in Fig. 13.

Accuracy Data

Accuracy of HPG Harmonic Planetary® Gears

Size	Hysteresis Loss Backlash [arc min]		Repeatability [arc sec]	Transmission Accuracy [arc min]
	Standard BL3	Optional BL1		
11	3	-	< ± 30	< 5
14	3	1	< ± 20	< 4
20	3	1	< ± 15	< 4
32	3	1	< ± 15	< 4
50	3	1	< ± 15	< 3
65	3	1	< ± 15	< 3

Torsional Stiffness

The torsional stiffness may be evaluated by means of the torque-torsion curve shown in Fig. 14.
The values quoted in table 3 are the average of measurements made during numerous tests.

Fig. 14

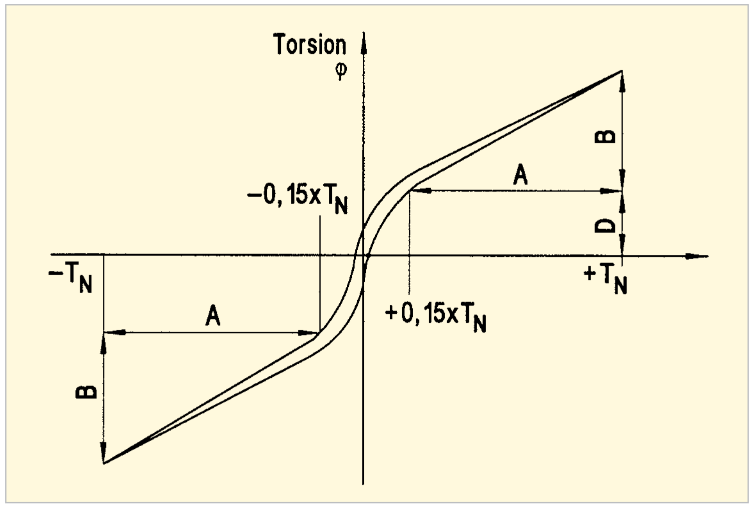


Table 3

Size	Torsional Stiffness = $\frac{A}{B}$ [Nm/min]	Torsional Stiffness = $\frac{A}{B}$ [Nm/rad]	D [arc-min] Backlash Class BL3 i = 5	BL3 i > 5	BL1 i = 5	BL1 i > 5
11	0.68	2,200	2.5	3.0	-	-
14	1.4	4,700	2.2	2.7	1.1	1.7
20	5.4	18,500	1.5	2.0	0.6	1.1
32	22.0	74,100	1.3	1.7	0.5	1.0
50	140	470,000	1.3	1.7	0.5	1.0
65	380	1,300,000	1.3	1.7	0.5	1.0

$\frac{A}{B}$: Torsional stiffness
T_N: Rated Torque; Tab.1
D: Average torsion angle at 0.15 x T_N
φ: Output rotation angle

Calculation of the torsion angle φ at load torque T

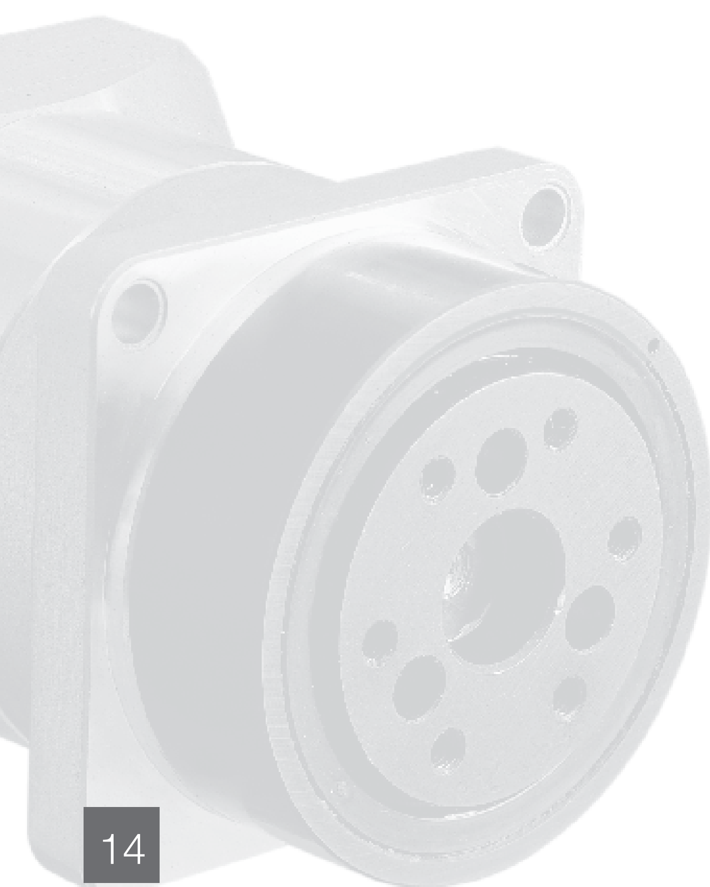
$$\varphi = D + \frac{(T - T_L)}{\left(\frac{A}{B}\right)}$$

D : [min] (Fig. 14)

T : Load torque -[Nm]

T_L : T_N x 0,15 [Nm]

$\frac{A}{B}$: Torsional stiffness [Nm/min] ; Tab. 3



No-load Starting Torque, Back Driving Torque, Running Torque

Table 4

Size	Ratio	No-load starting torque	No-load* running torque at 3000 rpm	No-load back driving torque
		Ncm	Ncm	Nm
11	5	4.0	5.0	0.20
	9	3.7	2.5	0.33
	21	2.9	1.3	0.60
	37	1.6	0.90	0.60
	45	1.4	0.80	0.64
14	3	14	21	0.43
	5	8.6	10	0.43
	11	8.0	5	0.90
	15	7.4	3	1.1
	21	5.2	3	1.1
	33	3.3	2	1.1
	45	2.4	2	1.1
20	3	31	50	0.93
	5	18.6	28	0.93
	11	15.1	15	1.7
	15	12	11	1.8
	21	9.3	9	2.0
	33	6.4	6	2.1
	45	4.7	5	2.1
32	3	56	135	1.7
	5	33.3	73	1.7
	11	26.7	38	2.9
	15	25	29	3.7
	21	22.4	24	4.7
	33	15	14	4.8
	45	11	13	5.1
50	3	134	250	4.0
	5	80	130	4.0
	11	45	60	5.0
	15	40	47	6.0
	21	36	40	7.6
	35	24	24	7.8
	45	20	20	8.9
65	4	288	420	12
	5	240	360	12
	12	125	190	15
	15	110	160	17
	20	95	130	19
	25	84	110	21
	40	75	76	30
	50	70	64	35

No-load Starting Torque

The no-load starting torque is the torque required to start rotation of the input element (high speed side) with no load applied to the output element (low speed side), see Table 4.

No-load Running Torque

The no-load running torque is the torque required to maintain rotation the input element (high speed side) at a defined input speed with no load applied to the output.

No-load Back Driving Torque

The no-load back driving torque is the torque required to start rotation of the output element (low speed side) with no load applied to the input element (high speed side).
The approximate range for no-load back driving torque, based on tests of actual production gears, is shown in Table 4. In no case should the values given be regarded as a margin in a system that must hold an external load. A brake must be used where back driving is not permissible.

All values refer to a gear at an operating temperature of +25°C.
* For Backlash Class BL1 the values increased by 20%.

Efficiency

The efficiency curves are mean values, which are valid for the following conditions:

Input Speed:	n = 3000 rpm
Ambient Temperature:	25°C
Lubrication:	Size 14A~32A - Grease SK-2 Size 50A - EPNOC AP(N)2
Backlash Class:	BL3 (for BL1 efficiency approx. 2% lower)

In case of an ambient temperature below 25°C the efficiency η_T can be determined using equation 2, and figure 15. Efficiency η is found from figures 16~19.

$$\eta_T = \eta \cdot K$$

[Equation 2]

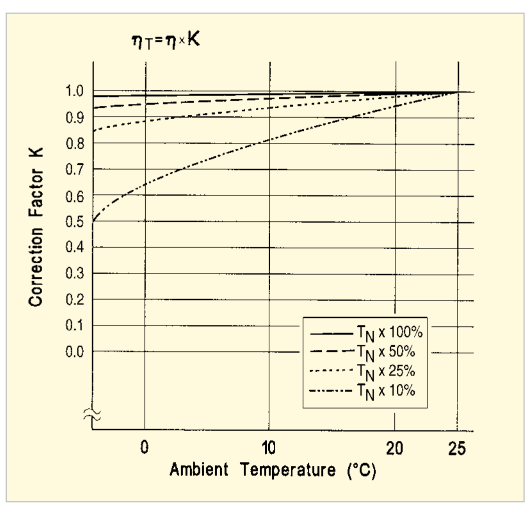
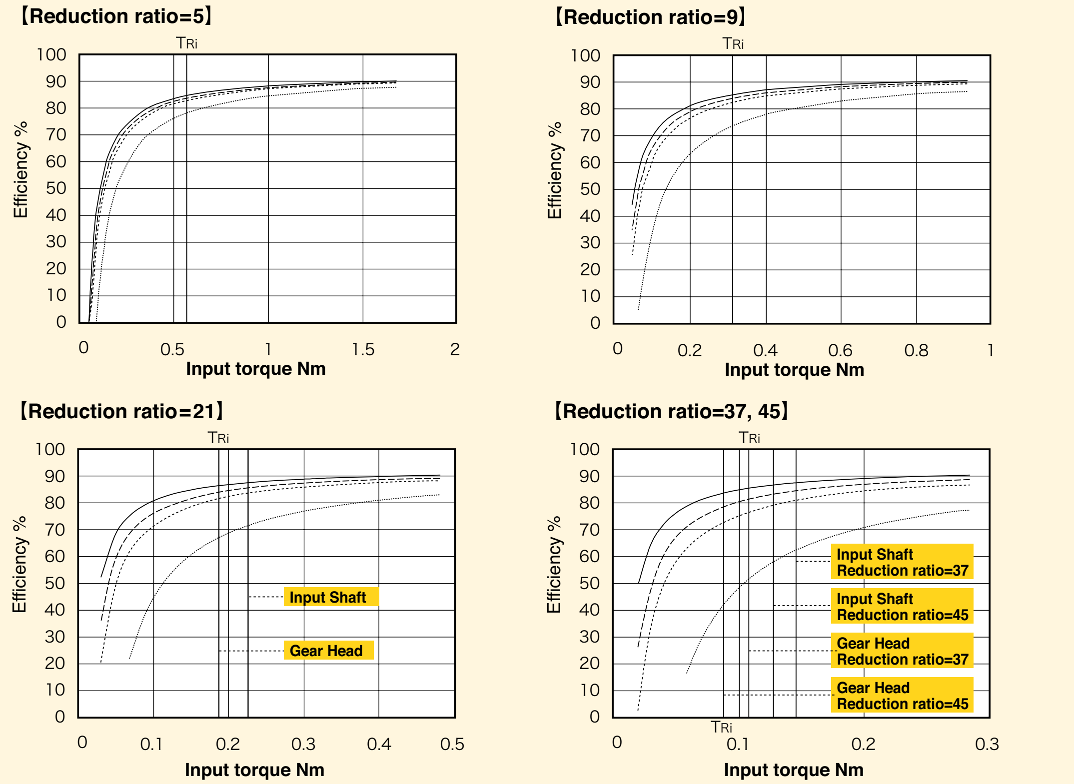


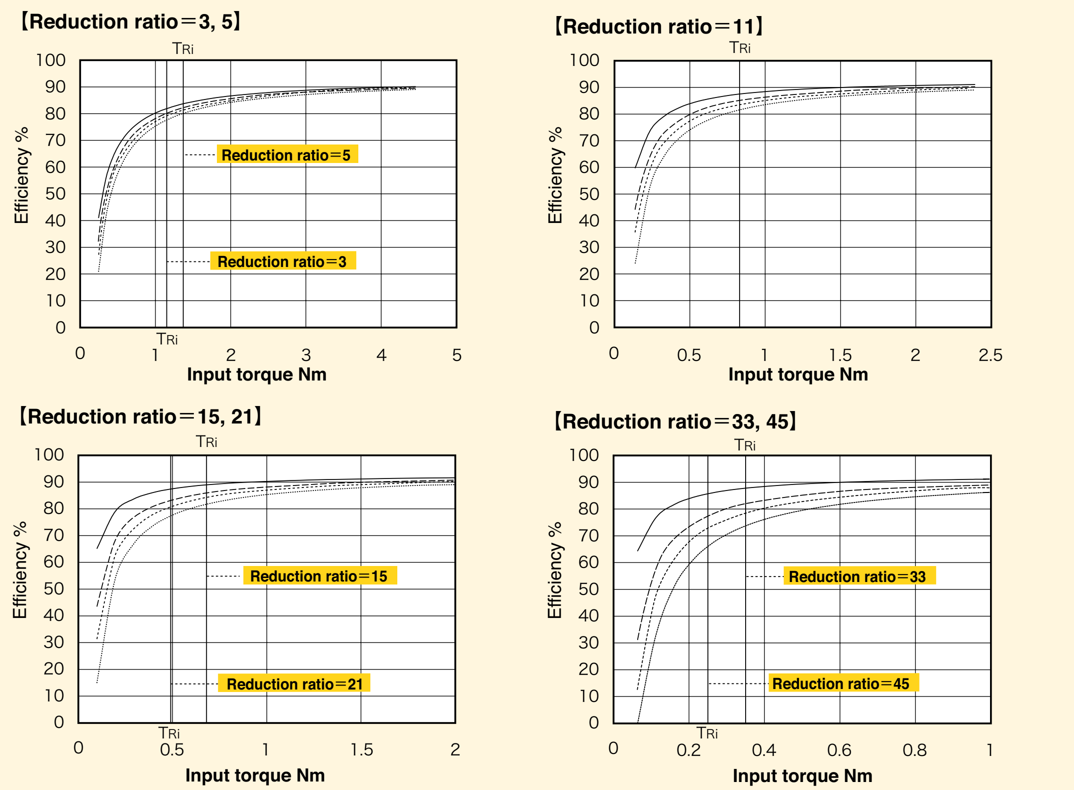
Fig. 15

Model No. 11 : **Gear Head Type** **Input Shaft Type**



—— Speed reducer only ‐‐‐ Gear head type (standard item) ...... DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item) ········ Input Shaft Type TRi Input torque corresponding to output torque

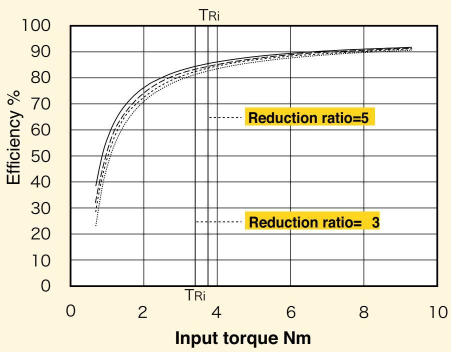
Model No. 14 : **Gear Head Type** **Input Shaft Type**



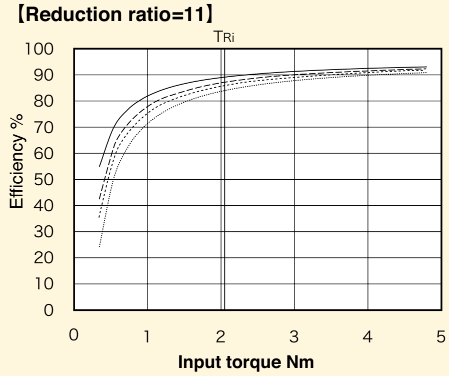
—— Speed reducer only ‐‐‐ Gear head type (standard item) ...... DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item) ········ Input Shaft Type TRi Input torque corresponding to output torque

Model No. 20 : Gear Head Type | Input Shaft Type

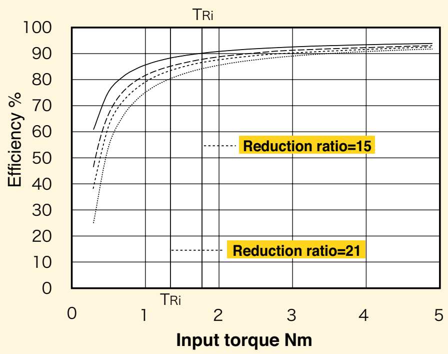
【Reduction ratio=3, 5】



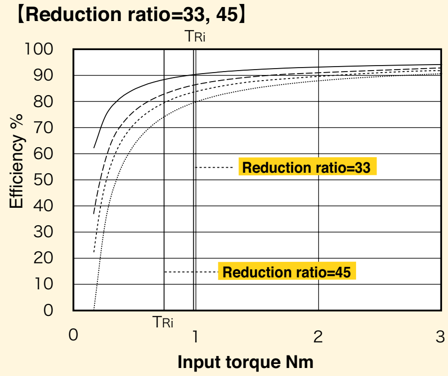
【Reduction ratio=11】



【Reduction ratio=15, 21】



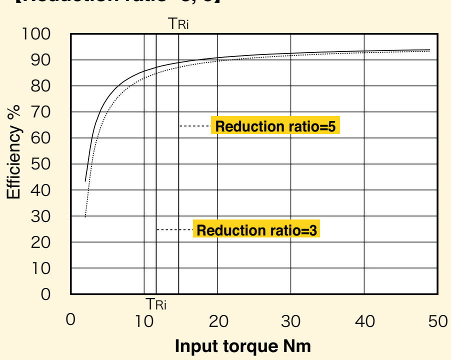
【Reduction ratio=33, 45】



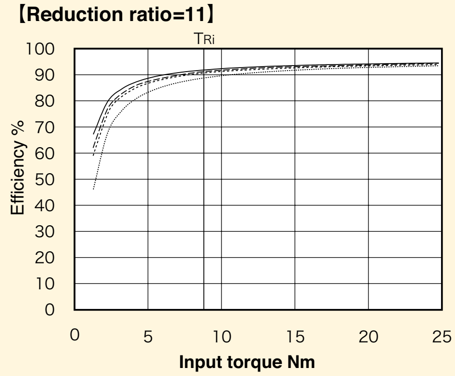
—— Speed reducer only - - - Gear head type (standard item) ...... DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item) —— Input Shaft Type TRi Input torque corresponding to output torque

Model No. 32 : Gear Head Type | Input Shaft Type

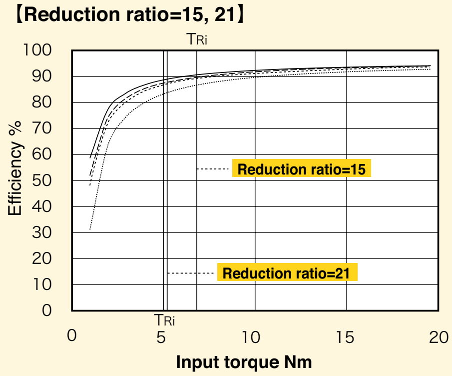
【Reduction ratio=3, 5】*1



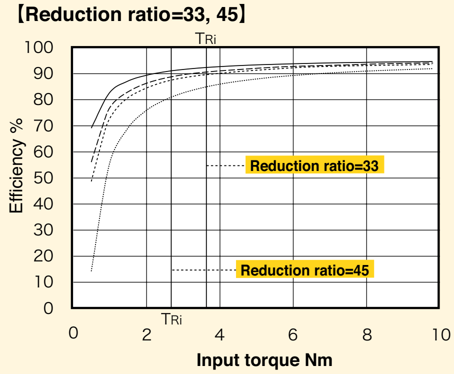
【Reduction ratio=11】



【Reduction ratio=15, 21】



【Reduction ratio=33, 45】

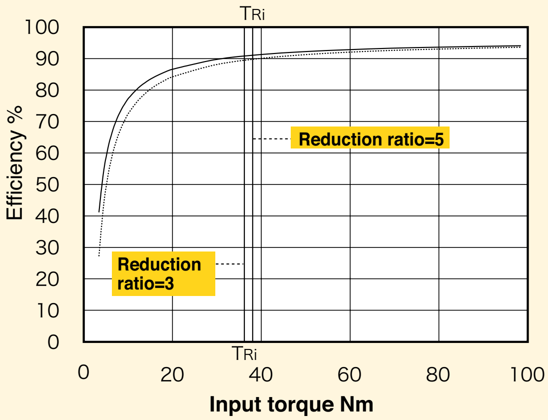


—— Speed reducer only - - - Gear head type (standard item) ...... DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item) —— Input Shaft Type TRi Input torque corresponding to output torque

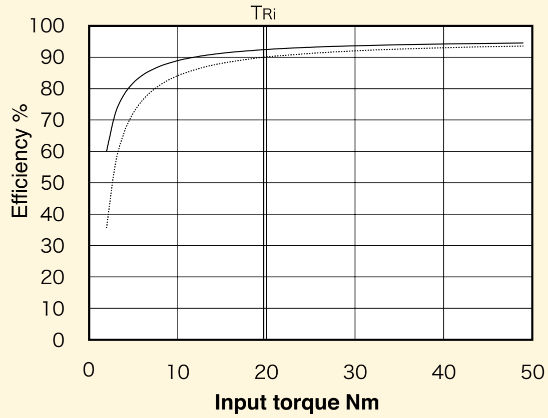
*1 Only one line is shown in graphs because the difference between the speed reducer and a bearing assembled on the input side is small.

Model No. 50 : **Gear Head Type** **Input Shaft Type**

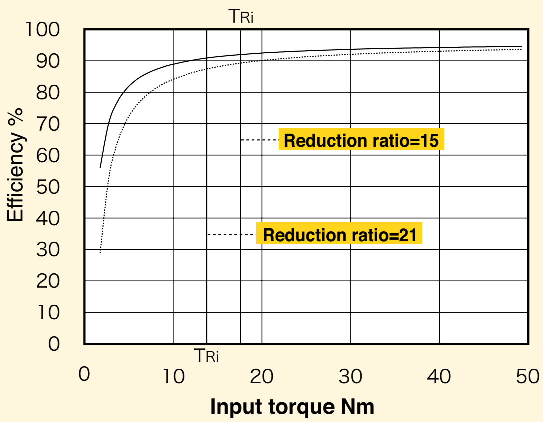
【Reduction ratio=3, 5】 ＊1



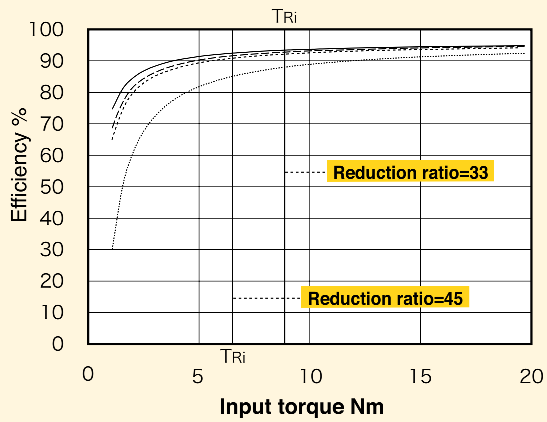
【Reduction ratio=11】 ＊1



【Reduction ratio=15, 21】 ＊1



【Reduction ratio=33, 45】

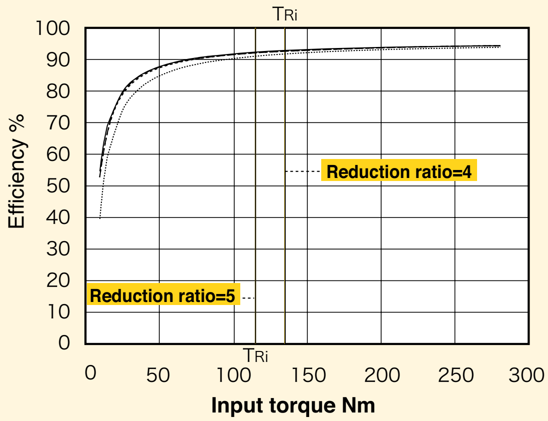


—— Speed reducer only   - - - Gear head type (standard item)   ...... DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item)   —— Input Shaft Type   TRi Input torque corresponding to output torque

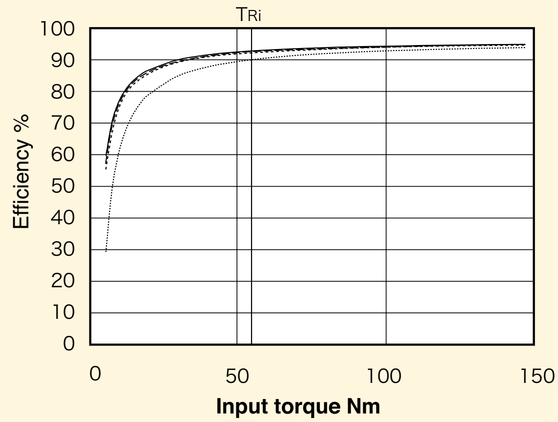
＊1 Only one line is shown in graphs because the difference between the speed reducer and a bearing assembled on the input side is small.

Model No. 65 : **Gear Head Type** **Input Shaft Type**

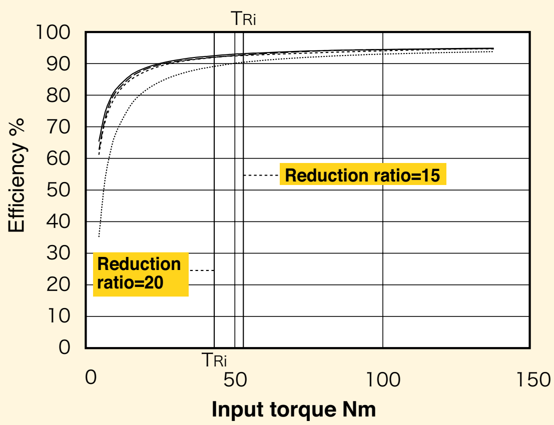
【Reduction ratio=4, 5】 ∗1



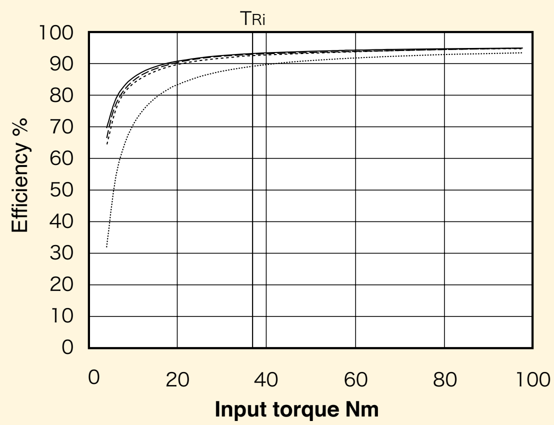
【Reduction ratio=12】 ∗1



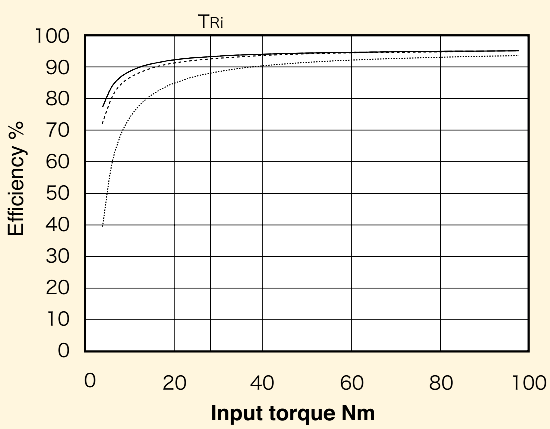
【Reduction ratio=15, 20】 ∗1



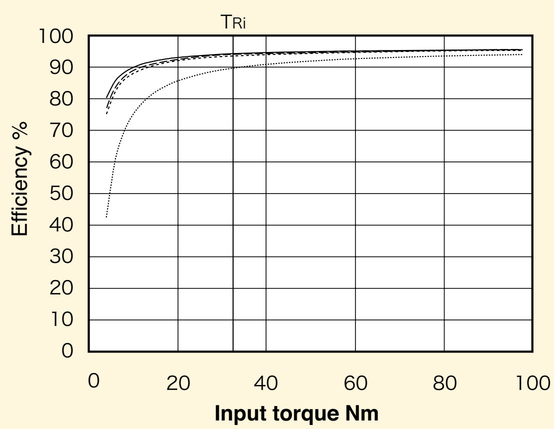
【Reduction ratio=25】 ∗1



【Reduction ratio=40】 ∗1



【Reduction ratio=50】 ∗1



—— Speed reducer only ‒ ‒ ‒ Gear head type (standard item) ...... DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item) ········ Input Shaft Type TRi Input torque corresponding to output torque

∗1 Only one line is shown in graphs because the difference between the speed reducer and a bearing assembled on the input side is small.

Motor Assembly

To connect a motor to a HPG Series gear please follow the following instructions:

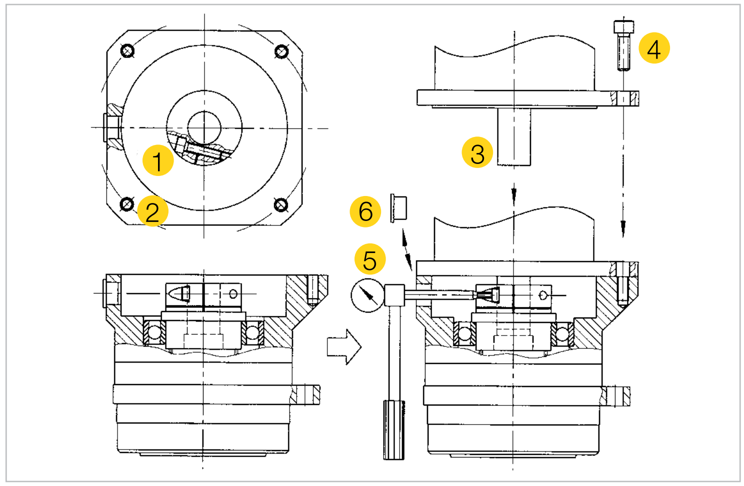
1. Turn the coupling on the input side so that the head of the bolt aligns with the bore for the rubber cap.
2. Apply Loctite® 515 (or equiv.) sealant on mating surface of Gearhead adapter.
3. Gently insert the motor into the gear.
4. Fix the motor and gear by tightening the bolts on the flange (see Table 5).
5. Fasten the bolt on the input coupling (see Table 6).
6. Finally, insert the rubber cap provided.

Table 5

Bolt Size	M2.5	M3	M4	M5	M6	M8	M10	M12
Tightening Torque [Nm]	0.59	1.4	3.2	6.3	10.7	26.1	51.5	89.9

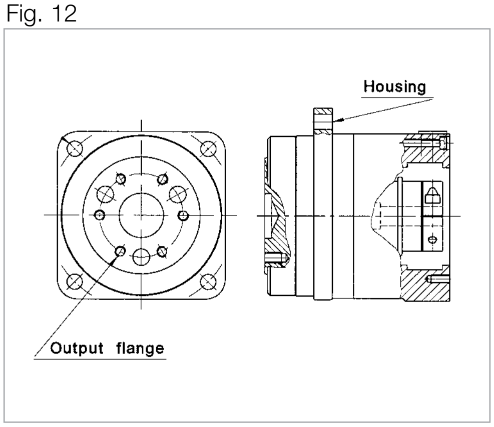
Bolt Size	M3	M4	M5	M6	M8	M10	M12
Tightening Torque [Nm]	2.0	4.5	9.0	15.3	37.2	73.5	128

Fig. 20



Assembly of the Housing and Output Flange

Fig. 12



Assembly of the Housing

When installing the HPG in a machine, please ensure that the assembly surfaces are flat and the tapped holes are free of burrs.

Table 7

Size	HPG-11A	HPG-14A	HPG-20A	HPG-32A	HPG-50A	HPG-65A
Number of Bolts	4	4	4	4	4	4
Bolt Size	M3	M5	M8	M10	M12	M16
Bolt pitch diameter [mm]	46	70	105	135	190	260
Tightening Torque [Nm]	1.4	6.3	26.1	51.5	103	255
Torque transmitting capacity [Nm]	26.3	110	428	868	2030	5180

Assembly of the Output Flange

When connecting the load to the output flange please observe the specifications for the output bearing given on page 17.

Table 8

Size	HPG-11A	HPG-14A	HPG-20A	HPG-32A	HPG-50A	HPG-65A
Number of Bolts	3	6	6	6	14	6
Bolt Size	M4	M4	M6	M8	M8	M16
Bolt pitch diameter [mm]	18	30	45	60	100	120
Tightening Torque [Nm]	4.5	4.5	15.3	37.2	37.2	319
Torque transmitting capacity [Nm]	19.0	63	215	524	2036	4480

Please note:
The flange is sealed against oil leakage. It is therefore not necessary to apply additional sealing liquid.

Lubrication

HPG Planetary Gears are delivered grease-packed. An additional grease lubrication is not necessary, either during assembly or during operation.
Applied lubricant: 14A~32A: Harmonic Drive™ Grease type SK-2.
50A: EPNOC AP(N)2 Nippon Oil Company
Ambient temperature range: -10°C up to +40°C.
Maximum operating temperature: + 80°C

Performance Data for the Output Bearing

HPG Planetary Gears incorporate a high stifness cross-roller bearing to support output loads. This specially developed bearing can withstand high axial and radial forces as well as high tilting moments. The reduction gear is thus protected from external loads, enabling a long service life and consistent performance. The integration of an output bearing also serves to reduce subsequent design and production costs, by removing the need for additional output bearings in most applications. Furthermore, installation and assembly of the reduction gear is greatly simplified.

Checking procedure

(1) Checking the maximum load moment load (M_{max})

Obtain the maximum load moment load (M_{max}). → Maximum load moment load (M_{max}) ≦ Permissible moment (Mc)

(2) Checking the life

Obtain the average radial load (F_{rav}) and the average axial load (F_{aav}). → Obtain the radial load coefficient (X) and the axial load coefficient (Y). → Calculate the life and check it.

(3) Checking the static safety coefficient

Obtain the static equivalent radial load coefficient (Po). → Check the static safety coefficient. (fs)

Specification of output-side main bearing

The specification of the crossed roller bearing is supplied in Table 1.

Table 1 Specification of HPG main bearing

Model	Circlar Pitch of roller	Offset Amount	Basic Rated Load		Permissible Moment Load Mc *3	Moment Stiffness Km
	dp	R	Basic dynamic rated load C *1	Basic static rated load Co *2	Nm	$\times 10^4$
	m	m	N	N		Nm/rad
11	0.0275	0.006	3116	4087	9.50	0.88
14	0.0405	0.011	5110	7060	32.3	3.0
20	0.064	0.0115	10600	17300	183	16.8
32	0.085	0.014	20500	32800	452	42.1
50	0.123	0.019	41600	76000	1076	100
65	0.170	0.023	90600	148000	3900	364

Model	Reduction Ratio	Permissible Radial Load *4	Permissible Axial Load *4
		N	N
11	5	280	430
	9	340	510
	21	440	660
	37	520	780
	45	550	830
14	3	400	600
	5	470	700
	11	600	890
	15	650	980
	21	720	1080
	33	830	1240
	45	910	1360
20	3	840	1250
	5	980	1460
	11	1240	1850
	15	1360	2030
	21	1510	2250
	33	1729	2580
	45	1890	2830

Model	Reduction Ratio	Permissible Radial Load *4	Permissible Axial Load *4
		N	N
32	3	1630	2430
	5	1900	2830
	11	2410	3590
	15	2640	3940
	21	2920	4360
	33	3340	4990
	45	3670	5480
50	3	3700	5570
	5	4350	6490
	11	5500	8220
	15	6050	9030
	21	6690	9980
	33	7660	11400
	45	8400	12500
65	4	8860	13200
	5	9470	14100
	12	12300	18300
	15	13100	19600
	20	14300	21400
	25	15300	22900
	40	17600	26300
	50	18900	28200

How to obtain the maximum load moment load

Maximum load moment load (M_{max}) is obtained as follows. Make sure that $M_{max} \leqq Mc$.

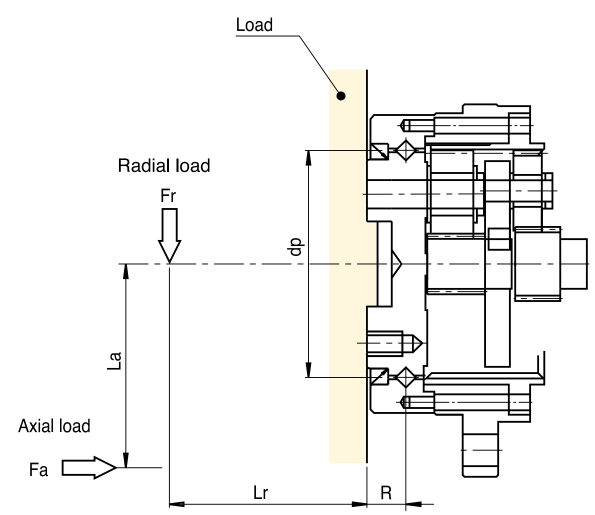
● Formula (1)

$$M_{max} = Fr_{max}\,(Lr+R) + Fa_{max} \cdot La$$

Symbol of formula (1)

Fr *max*	Max. radial load	N (kgf)	See Fig. 1.
Fa *max*	Max. axial load	N (kgf)	See Fig. 1.
Lr,La	————	m	See Fig. 1.
R	Offset amount	m	See Fig. 1 and Table 1.

Fig. 1 External load influence diagram



How to obtain the radial load coefficient and the axial load coefficient

Table 2 The radial load coefficient (X) and the axial load coefficient (Y)

● Formula (2)

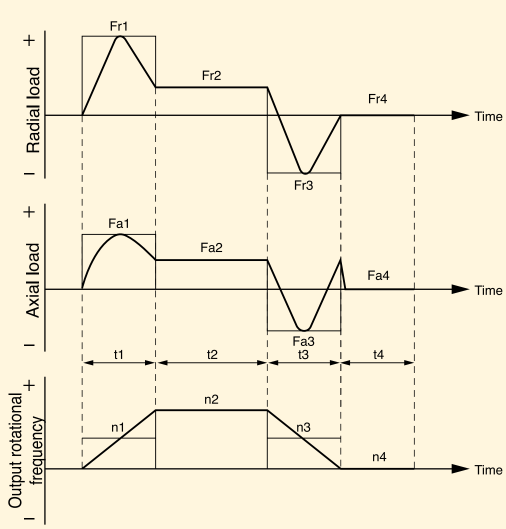
Formula	X	Y
$\frac{Fa_{av}}{Fr_{av}+2\,(Fr_{av}(Lr+R)+Fa_{av}\cdot La)/dp} \leqq 1.5$	1	0.45
$\frac{Fa_{av}}{Fr_{av}+2\,(Fr_{av}(Lr+R)+Fa_{av}\cdot La)/dp} > 1.5$	0.67	0.67

Symbol of formula (2)

Fr *av*	Avarage radial load	N (kgf)	See "How to obtain the ave. load."
Fa *av*	Avarage axial load	N (kgf)	See "How to obtain the ave. load."
Lr,La	————	m	See Fig. 1.
R	Offset amount	m	See Fig. 1 and Table 1.
dp	Pitch circle	m	See Fig. 1 and Table 1.

How to obtain the average load (Average radial load, average axial load, average output rotational frequency)

If the radial load and the axial load fluctuate, they should be converted into the average load to check the life of the crossed roller bearing.



● Formula (3) How to obtain the average radial load (Fr_{av})

$$Fr_{av} = \sqrt[10/3]{\frac{n_1t_1\,(|Fr_1|)^{10/3} + n_2t_2\,(|Fr_2|)^{10/3} \cdots n_nt_n\,(|Fr_n|)^{10/3}}{n_1t_1+n_2t_2+\cdots+n_nt_n}}$$

Note that the maximum radial load within the t1 section is Fr1 and the maximum radial load within the t3 section is Fr3.

● Formula (4) How to obtain the average axial load (Fa_{av})

$$Fa_{av} = \sqrt[10/3]{\frac{n_1t_1\,(|Fa_1|)^{10/3} + n_2t_2\,(|Fa_2|)^{10/3} \cdots n_nt_n\,(|Fa_n|)^{10/3}}{n_1t_1+n_2t_2+\cdots+n_nt_n}}$$

Note that the maximum axial load within the t1 section is Fa1 and the maximum axial load within the t3 section is Fa3.

● Formula (5) How to obtain the average output rotational frequency (N_{av})

$$N_{av} = \frac{n_1t_1+n_2t_2+\cdots+n_nt_n}{t_1+t_2+\cdots+t_n}$$

How to obtain the life

Obtain the life of the crossed roller bearing by Formula (6). You can obtain the dynamic equivalent radial load (Pc) by Formula (7).

●Formula (6)

$$L_{10}=\frac{10^6}{60\times Nav}\times\left(\frac{C}{fw\cdot Pc}\right)^{10/3}$$

Symbol of formula (6)

L_{10}	Life	hour	———
N*av*	Ave. output speed	r/min	See "How to obtain the ave. load."
C	Basic dynamic rated load	N (kgf)	See Table 1 on page 76.
Pc	Dynamic equivalent radial load	N (kgf)	See Formula (7).
fw	Load coefficient	———	See Table 3.

●Formula (7)

$$Pc=X\cdot\left(Frav+\frac{2(Frav\ (Lr+R)\ +Faav\cdot La)}{dp}\right)+Y\cdot Faav$$

Symbol of formula (7)

Fr*av*	Average radial load	N (kgf)	See "How to obtain the average load."
Fa*av*	Average axial load	N (kgf)	
dp	Circlar pitch of roller	m	See Table 1 on page 76.
X	Radial load coefficient	———	See Table 2 on page 77.
Y	Axial load coefficient	———	
Lr,La	———	m	See Fig. 1 on page 77.
R	Offset amount	m	See Fig. 1 on p.77 and Table 1 on p.76.

Table 3 Load coefficient

Load status	fw
During smooth operation without shock or vibration	1 to 1.2
During normal operation	1.2 to 1.5
During operation with shock and vibration	1.5 to 3

How to obtain the life under oscillating movement

Obtain the life of the crossed roller bearing under oscillating movement by Formula (8).

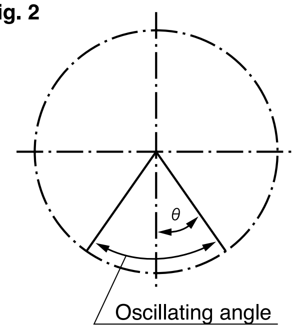
●Formula (8)

$$Loc=\frac{10^6}{60\times n1}\times\frac{90}{\theta}\times\left(\frac{C}{fw\cdot Pc}\right)^{10/3}$$

Symbol of formula (8)

Loc	Rated life under oscillating movement	hour	———
n1	No. of reciprocating oscillation per min.	cpm	———
C	basic dynamic rated load	N (kgf)	See Table 1 on page 76.
Pc	Dynamic equivalent radial load	N (kgf)	See Formula (7).
fw	Load coefficient	———	See Table 3.
θ	Oscillating angle /2	Deg.	See Fig. 2.

Fig. 2



When the oscillating angle is small (5° or less), it is difficult to generate an oil film on the contact surface of the orbit ring, and the rolling element and fretting may be generated. Contact us if this happens.

Note: When it is used for a long time while the rotation speed of the output shaft is in the ultra-low operation range (0.02r/min or less), the lubrication of the bearing becomes insufficient, resulting in deterioration of the bearing or increased load in the driving side. When using it in the ultra-low operation range, contact us.

How to obtain the static safety coefficient

In general, the basic static rated load (Co) is considered to be the permissible limit of the static equivalent load. However, obtain the limit based on the operating and required conditions. Obtain the static safety coefficient of the roller bearing by Formula (9). General values under the operating condition are shown in Table 4. You can obtain the static equivalent radial load (Po) by Formula (10).

●Formula (9)

$$fs = \frac{Co}{Po}$$

Symbol of formula (9)

Co	Basic static rated load	N (kgf)	See Table 1 on page 76.
Po	Static equivalent radial load	N (kgf)	See Formula (10).

●Formula (10)

$$Po = Fr_{max} + \frac{2M_{max}}{dp} + 0.44Fa_{max}$$

Symbol of formula (10)

Fr_{max}	Max. radial load	N (kgf)	See "How to obtain the max. load moment load".
Fa_{max}	Max. axial load	N (kgf)	
M_{max}	Max. load moment load	Nm (kgfm)	
dp	Circlar pitch of roller	m	See Table 1 on p.76.

Table 4 Static safety coefficient

Operating condition of the roller bearing	fs
When high rotation precision is required	≧3
When shock and vibration are expected	≧2
Under normal operating condition	≧1.5

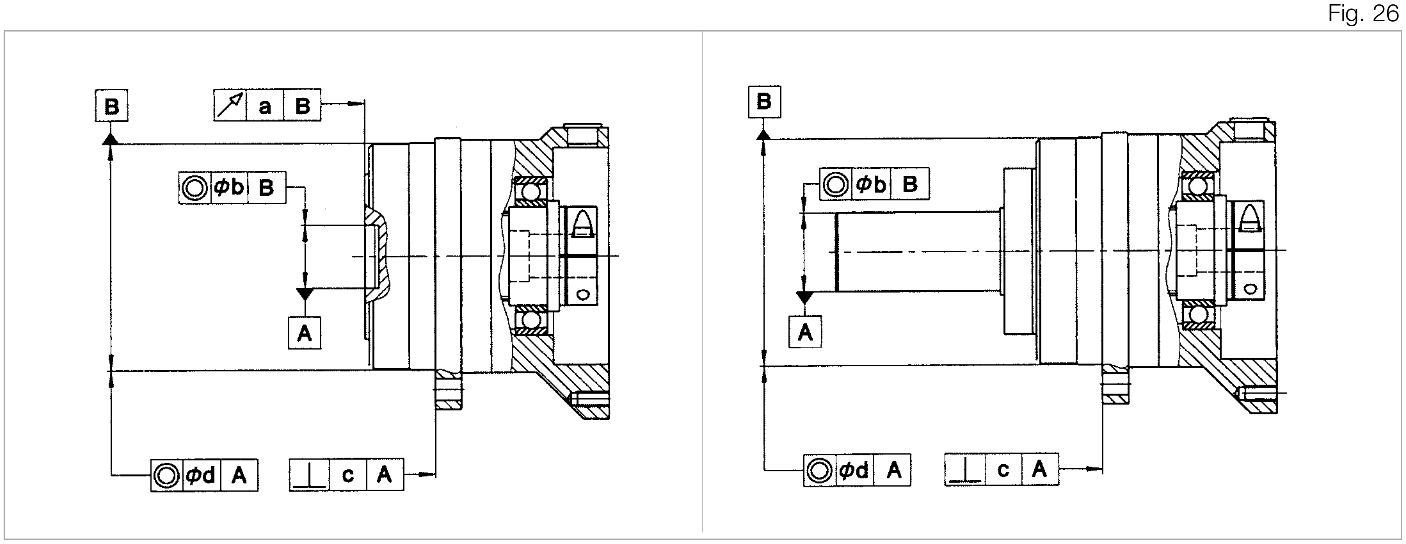
Table 13

Output Bearing Tolerances

[mm]

Size	Run-out a	Run-out b	Perpendicularity c	Concentricity d
11	0.020	0.030	0.050	0.040
14	0.020	0.040	0.060	0.050
20	0.020	0.040	0.060	0.050
32	0.020	0.040	0.060	0.050
50	0.020	0.040	0.060	0.040
65	0.040	0.060	0.090	0.080

Fig. 26



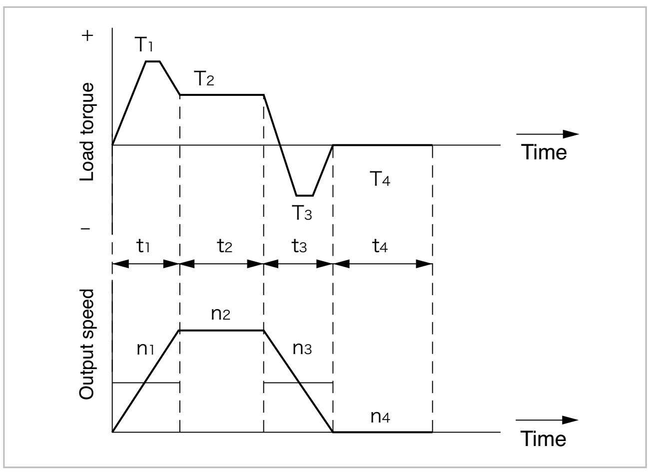
Check your operating conditions and select suitable model Nos. based on the flowchart to fully demonstrate the excellent performance of the Harmonic Planetary® HPG series.

Selection Procedure

In general, a servo system is rarely in a continuous constant load state. The input speed, load torque change and a comparatively large torque is applied during start and stop. Unexpected impact torques may also be applied.
Check your operating conditions against the following load torque pattern and select suitable model Nos. based on the flowchart shown on the right. Also check the life and static safety factor of the crossed roller bearing and input-side main bearing (input shaft type only). (See the specification of the input-side main bearing and the output-side main bearing on pages 76 to 81.)

Checking the load torque pattern

First, you need to look at the picture of the load torque pattern. Check the specifications shown in the figure below.



Obtain the value of each load torque pattern.

Load torque	T_1 to T_n (Nm)
Time	t_1 to t_n (sec)
Output speed	n_1 to n_n (r/min)

<Normal operation pattern>

Starting time	T_1, t_1 n_1
Steady operation time	T_2, t_2, n_2
Stopping (slowing) time	T_3, t_3, n_3
Break time	T_4, t_4 n_4

<Maximum rotational speed>

Max. output speed	$n_o\ max \geqq n_1$ to n_n
Max. input speed	$n_i\ max \geqq n_1 xR$ to $n_n xR$
(Restricted by motors)	R: Reduction ratio

<Impact torque>

When impact torque is applied T_s

<Required lifespan>

L_{10} = L (hours)

Flowchart of model number selection

Select a model number according to the following flowchart.
If you find a value exceeding that from the ratings, you should review it with the upper-level model number or consider reduction of conditions including the load torque.

Calculate the average load torque applied to the output side from the load torque pattern: *Tav* (Nm).

$$Tav = \sqrt[10/3]{\frac{|n_1|\cdot t_1\cdot|T_1|^{10/3}+|n_2|\cdot t_2\cdot|T_2|^{10/3}+\cdots+|n_n|\cdot t_n\cdot|T_n|^{10/3}}{n_1\cdot t_1+n_2\cdot t_2+\cdots+n_n\cdot t_n}}$$

Calculate the average output speed based on the load torque pattern: no av (r/min)

$$n_o\,av = \frac{|n_1|\cdot t_1+|n_2|\cdot t_2+\cdots+|n_n|\cdot t_n}{t_1+t_2+\cdots+t_n}$$

↓

Tentatively select a model No. under the following condition:
Tav ≦ Average load torque (See the rating table on page 10, 40, 54) — NG

OK ↓

Determine the reduction ratio (R) based on the maximum output speed (no *max*) and maximum input speed (ni *max*).

$$\frac{n_i\ max}{n_o\ max} \geqq R$$

(ni *max* is limited by the motor and other factors)
Calculate the maximum input speed (ni *max*) from the maximum output speed (no *max*) and reduction ratio (R).

$$n_i\ max = n_o\ max \cdot R$$

↓

Calculate the average input speed (ni *av*) based on the average output speed (no *av*) and reduction ratio (R): ni *av* = no *av*·R ≦ Permissible average input speed (nr). — NG

Check the description in Caution below.

OK ↓

Check if the maximum input speed is within the values in the rating table.
ni *max* ≦ maximum input speed (r/min) — NG

OK ↓

Check that T_1 and T_3 are within peak torques (Nm) on start and stop in the rating table. — NG

OK ↓

Check that T_s is within instantaneous max. torques (Nm) in the rating table. — NG

OK ↓

Calculate the tolerable count (Ns) based on impressed shock torque (Ts) and check if the operating conditions can be met.
Definition range of shock torque: $T_s > T_P$
T_s: Shock torque T_P: Peak torque on start and stop

$$\chi = 8.5 - 1.5 \times \frac{TS}{TP} \qquad NS = 1.0 \times 10^{\chi}\ \text{(cycle)}$$

— NG

OK ↓

Calculate the life (hours) and check if it meets the specification requirement.
Tr: Output torque
n_r: Permissible average input speed

$$L_{10} = 20000 \cdot \left(\frac{T_r}{Tav}\right)^{10/3} \cdot \left(\frac{n_r}{n_i\ av}\right) \quad \text{(Hour)}$$

— NG

Review of the operation conditions, model No and reduction ratio.

OK ↓

The model number is determined.

Caution

Check impacts by speed reducer temperature rise, vibration during acceleration and deceleration and other factors if the operating conditions are as specified below. Study to "increase the speed reducer size", "review the operating conditions" and other means if it becomes necessary to study safety. Exercise reasonable caution especially when operating conditions are close to continuous operation.
Average load torque (*Tav*) > Permissible maximum value of average load torque.

Selection Example

Value of each load torque pattern.

Load torque	T_n (Nm)
Time	t_n (sec)
Output speed	n_n (r/min)

<Regular operation pattern>

Starting time	T_1 = 70 Nm,	t_1 = 0.3 sec,	n_1 = 60 r/min
Steady operation time	T_2 = 18 Nm,	t_2 = 3 sec,	n_2 = 120 r/min
Stopping (slowing) time	T_3 = 35 Nm,	t_3 = 0.4 sec,	n_3 = 60 r/min
Break time	T_4 = 0 Nm,	t_4 = 5 sec,	n_4 = 0 r/min

<Maximum speed>

Max. output speed	no *max* = 120 r/min
Max. input speed	ni *max* = 5,000 r/min (Restricted by motors)

<Impact torque>

When impact torque is applied	T_s = 180 Nm N_s = 1,000 (cycle)

<Required lifespan>

L_{10} = 30,000 (hours)

Calculate average load torque applied to the output side based on the load torque pattern: T*av* (Nm).

$$Tav = \sqrt[10/3]{\frac{|60\ r/min| \cdot 0.3sec \cdot |70Nm|^{10/3} + |120\ r/min| \cdot 3sec \cdot |18Nm|^{10/3} + |60\ r/min| \cdot 0.4sec \cdot |35Nm|^{10/3}}{|60\ r/min| \cdot 0.3sec + |120\ r/min| \cdot 3sec + |60\ r/min| \cdot 0.4sec}}$$

Calculate average output speed based on the load torque pattern: no *av* (r/min)

$$no\ av = \frac{|60\ r/min| \cdot 0.3sec + |120\ r/min| \cdot 3sec + |60\ r/min| \cdot 0.4sec + |0\ r/min| \cdot 5sec}{0.3sec + 3sec + 0.4sec + 5sec}$$

Tentatively select a model No. under the following condition. T*av* = 30.2Nm ≦ 60Nm. (**HPG-20A-33** is tentatively selected based on the average load torque (see the rating table on page 10, 40, 54) of model No. 20 and reduction ratio of 33.) — NG / OK

Determine a reduction ratio (R) based on the maximum output speed (no *max*) and maximum input speed (ni *max*).

$$\frac{5{,}000\ r/min}{120\ r/min} = 41.7 \geqq 33$$

Calculate the maximum input speed (ni *max*) based on the maximum output speed (no *max*) and reduction ratio (R):
ni *max* = 120 r/min·33=3,960 r/min

Calculate the average input speed (ni *av*) based on the average output speed (no *av*) and reduction ratio (R):
ni *av* = 46.2 r/min·33=1,525 r/min≦ Permissible average input speed of model No. 20 3000 (r/min) — NG / OK

Check the description in Caution at the bottom of page 82

Check if the maximum input speed is within the values specified in the rating table.
ni *max* = 3960 r/min ≦ 6000 r/min (maximum input speed of model No. 20) — NG / OK

Check if T_1 and T_3 are smaller than peak torques (Nm) on start and stop in the rating table.
T_1=70Nm≦100Nm (Peak torques on start and stop of model No. 20)
T_3=35Nm≦100Nm (Peak torques on start and stop of model No. 20) — NG / OK

Check if Ts is within the values of the instantaneous max. torque (Nm) in the rating table.
T_s=180Nm≦217Nm (instantaneous max. torque of model No. 20) — NG / OK

Calculate tolerable count based on applied shock torque (Ts) and check if it meets the operating condition.

$$\chi = 5.8 = 8.5 - 1.5X\frac{180}{100} \qquad N_s = 1.0X10^{5.8}\ (cycle) = 631{,}000\ (cycle) \geqq 1{,}000\ (cycle)$$

— NG / OK

Calculate life hours and check if they meet the specification requirement.

$$L_{10} = 20{,}000 \cdot \left(\frac{29Nm}{30.2Nm}\right)^{10/3} \cdot \left(\frac{3{,}000\ r/min}{1{,}525\ r/min}\right) = 34{,}543\ (hours) \geqq 30{,}000\ (hours)$$

— NG / OK

Review of the operation conditions, model No and reduction ratio.

As a result of the preceding steps, HPG-20A-33 is determined.

ORDERING INFORMATION

HPG -	20 -	A -	5 -	J2	XXXX -	BL 1
Model Name	**Model No.**	**Design Order**	**Reduction Ratio**	**Output Configurations**	**Input Configuratin Code**	**Additional Code**
HPG (Harmonic Planetary®)	11	**B:** Version	5, 9, 21, 37, 45	**FO =** Flange output **J2 =** Shaft output (No keyway) **J6 =** Shaft output (Key and tapped hole) * The shaft output of model No.65 is customized specification	Please provide the model number of the motor being coupled to this gearhead so we can specify a unique Harmonic Drive LLC P/N for a ready-to-mount gearhead.	**BL3 =** Backlash less than 3 arc-min. **BL1 =** Backlash of less than 1 arc-min. special specification (Size No.14 through 65) **NR6 =** Noise reduction Backlash of less than 6 arc-min (Size No.14 through 50) **Z =** Input side bearing with double non-contact shields **D =** Input side bearing with double contact seals
	14	**A:** Version	3. 5. 11, 15, 21, 33, 45			
	20		3, 5, 11, 15, 21, 33, 45			
	32		3, 5, 11, 15, 21, 33, 45			
	50		3, 5, 11, 15, 21, 33, 45			
	65		4, 5, 12, 15, 20, 25, 40, 50