

Harmonic Planetary®

HPG Series
Planetary Gearhead



Harmonic Planetary®

Precision Gearing & Motion Control

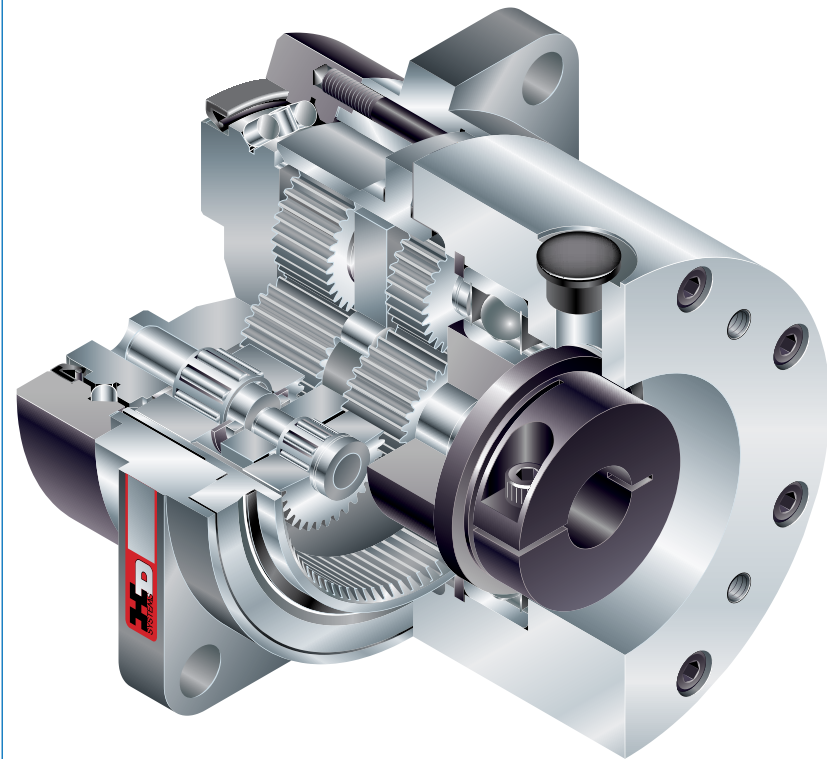
Harmonic Drive LLC

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 9001 certified. 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.



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HPG Series Harmonic Planetary® Gears



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 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

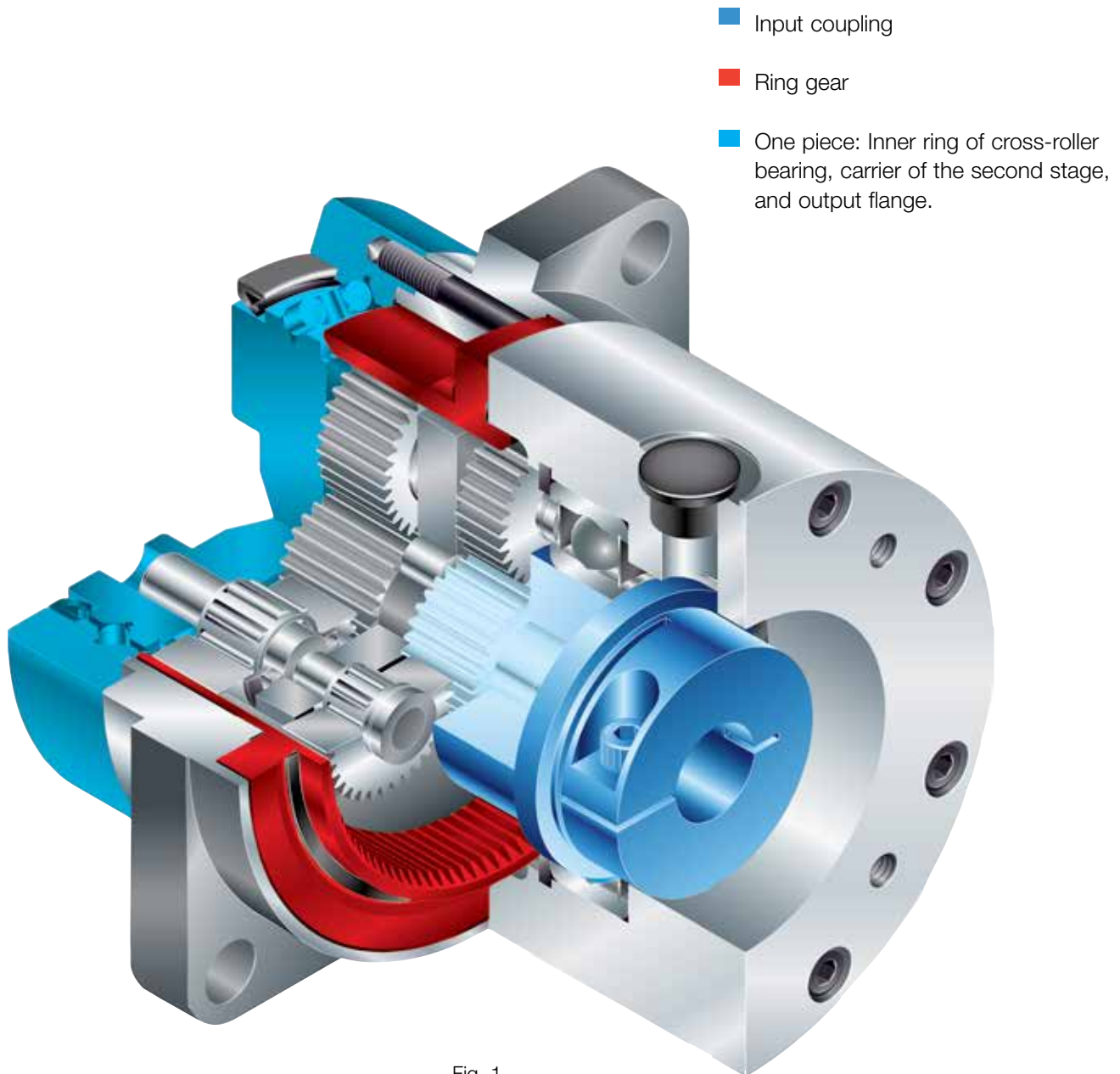
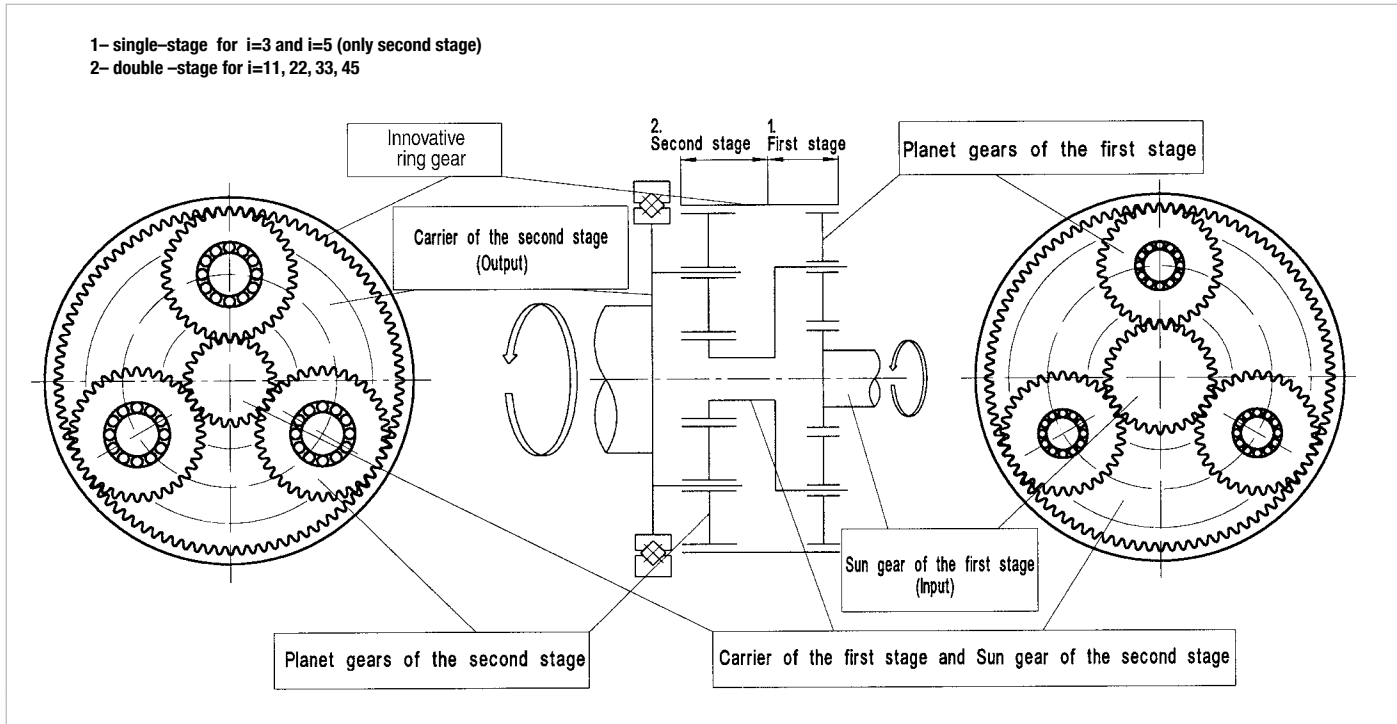


Fig. 1

Principle of Operation

Fig. 2

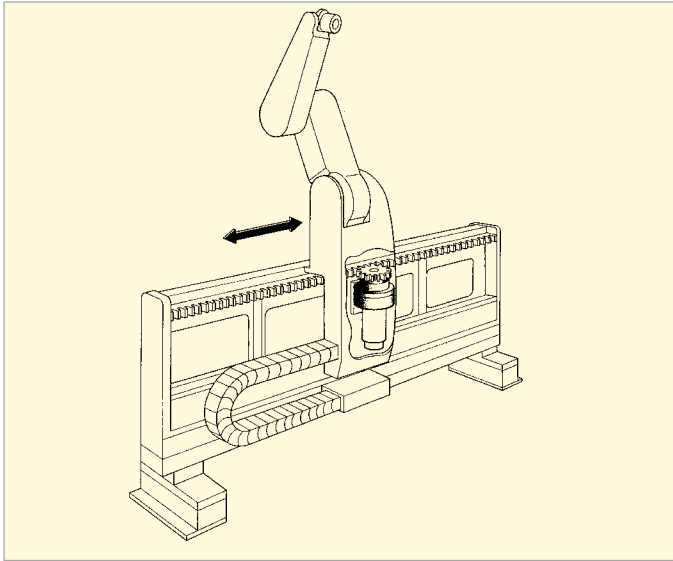


For double-stage HPG gears the sun gear of the first-stage planetary gear is connected to the motor shaft. The input torque from the motor is transmitted to three equally spaced planet gears. The ring gear is common to both gear stages. The carrier of the first stage is connected to the fully floating 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.

Application Examples

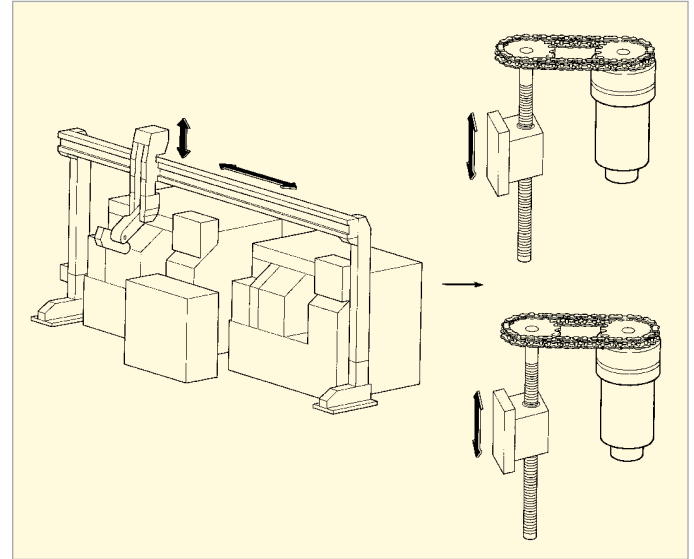
Linear axis for robots

Fig. 3



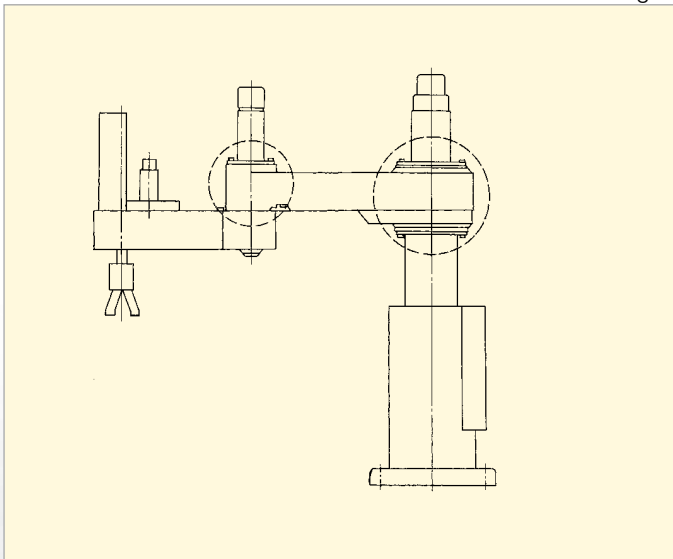
Loading and unloading equipment

Fig. 4



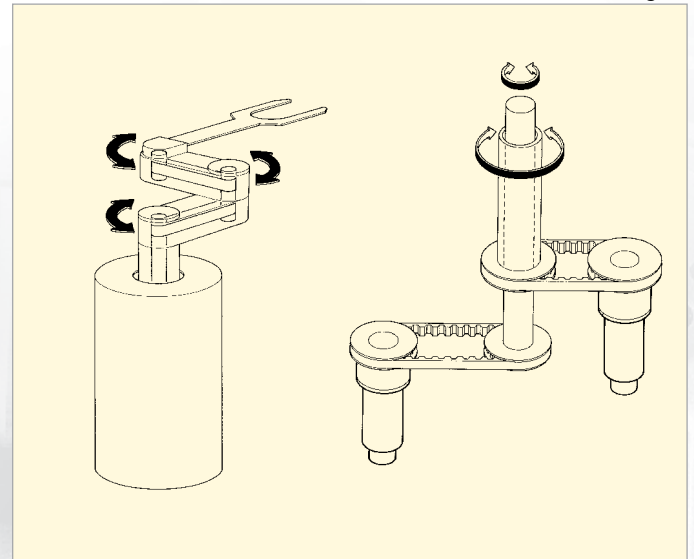
Primary axes of scara robots

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

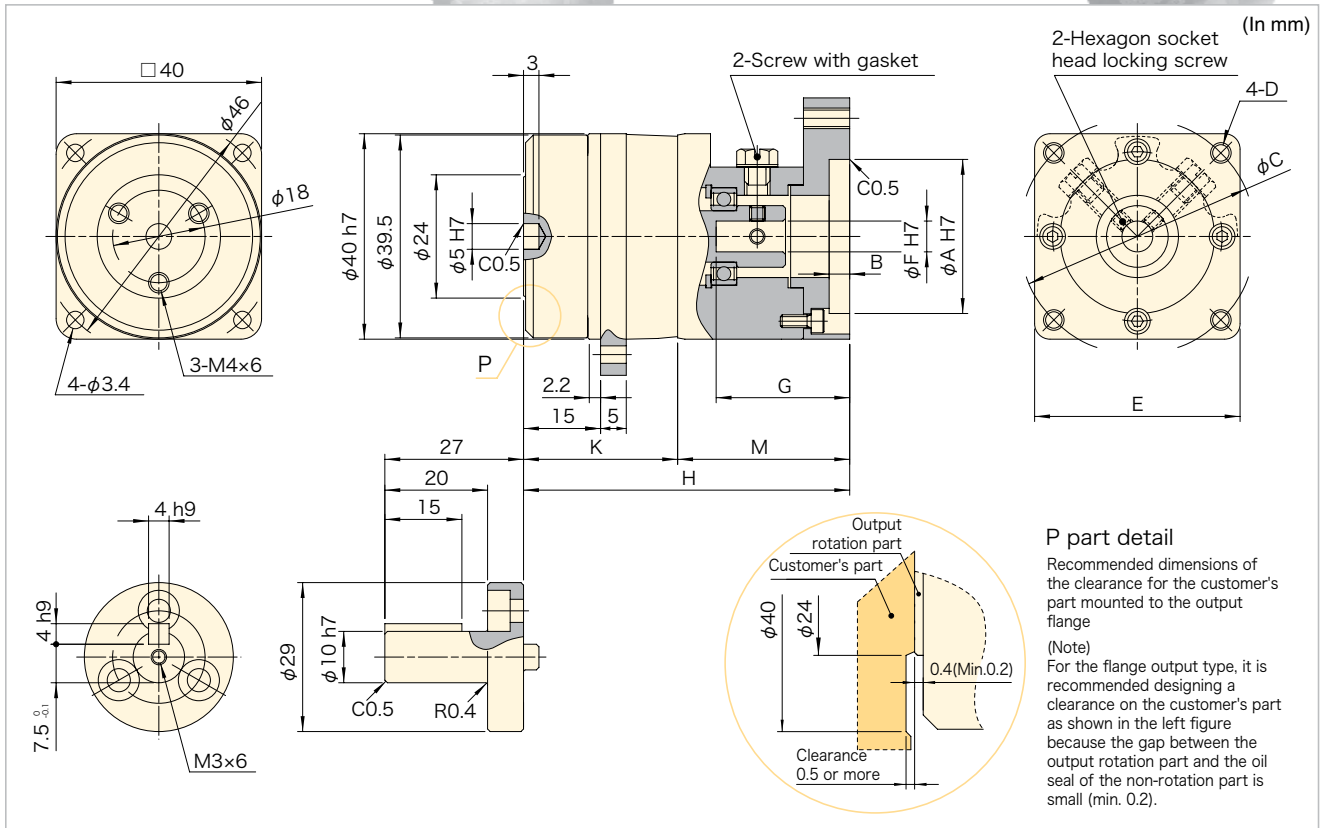
*6: Maximum average input speed depends on the operating environment, but it is the limiting value for the continuous operating speed or the average input speed of a motion profile. Average input speed is limited due to heat generated in the reducer.

*7: Inertia value is for the gearhead only.

*8: The weight is for the gearhead only (without input shaft coupling & motor flange).

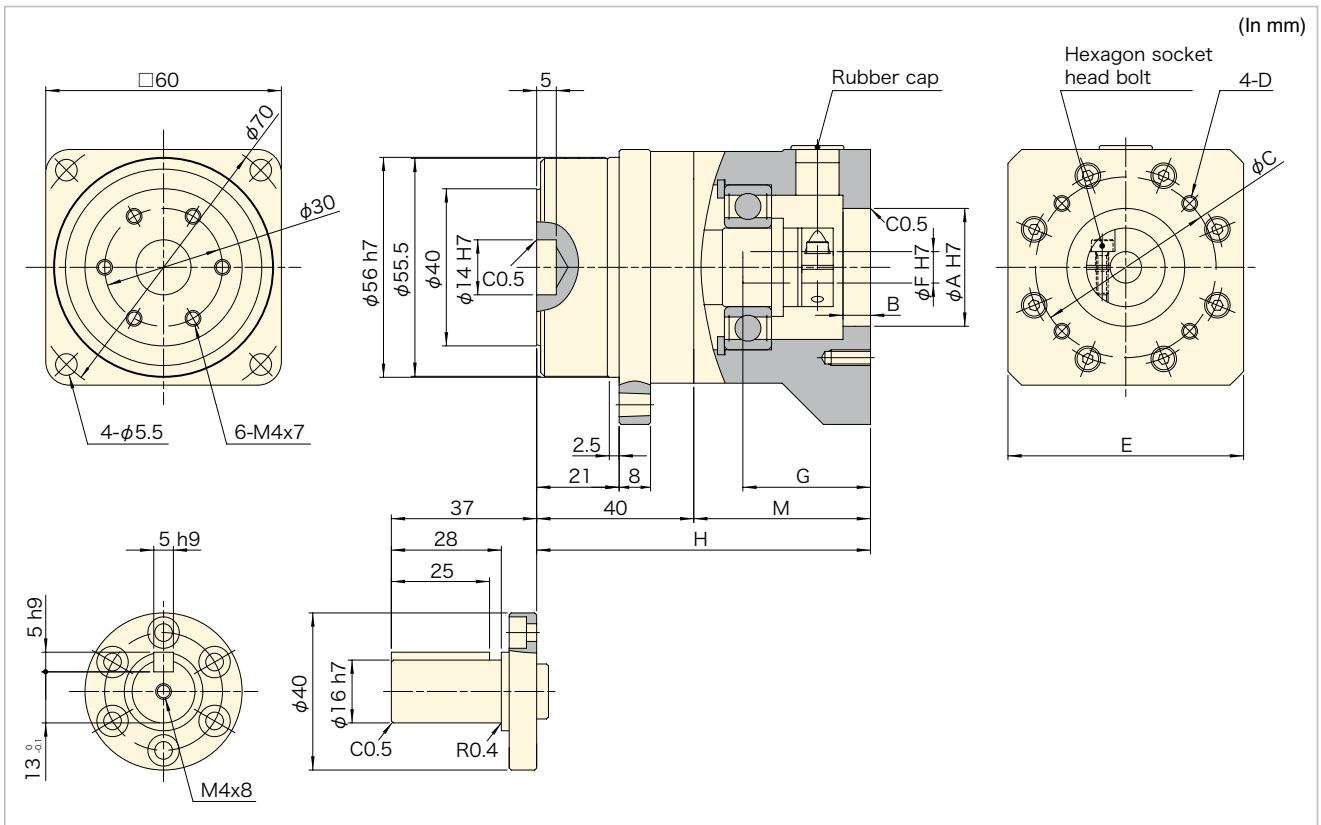
*9: Flange output is standard for the size 65 gearhead. Shaft type (J2 & J6) is available by special order only.

Fig. 7



HPG-14A

Fig. 8



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

Dimensions

HPG-20A

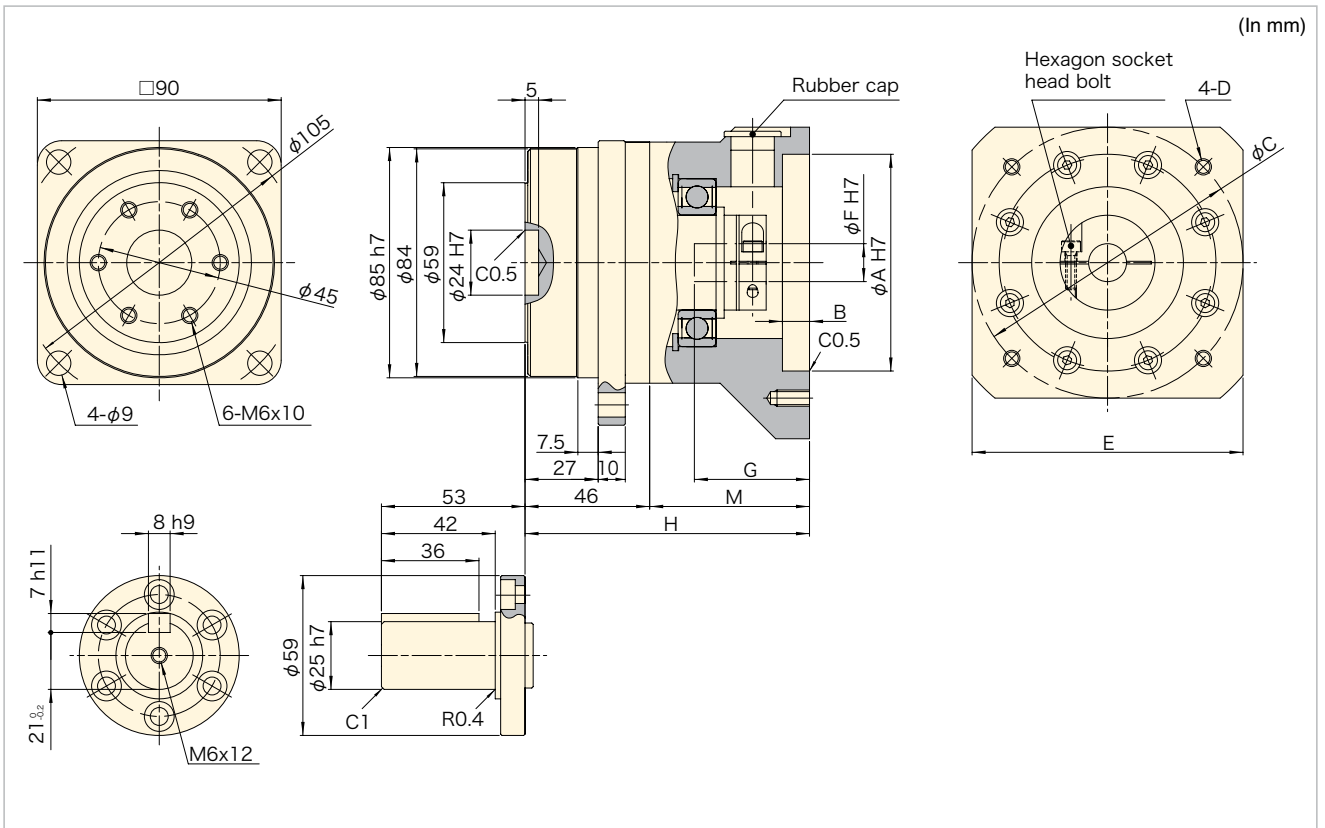


Fig. 9

HPG-32A

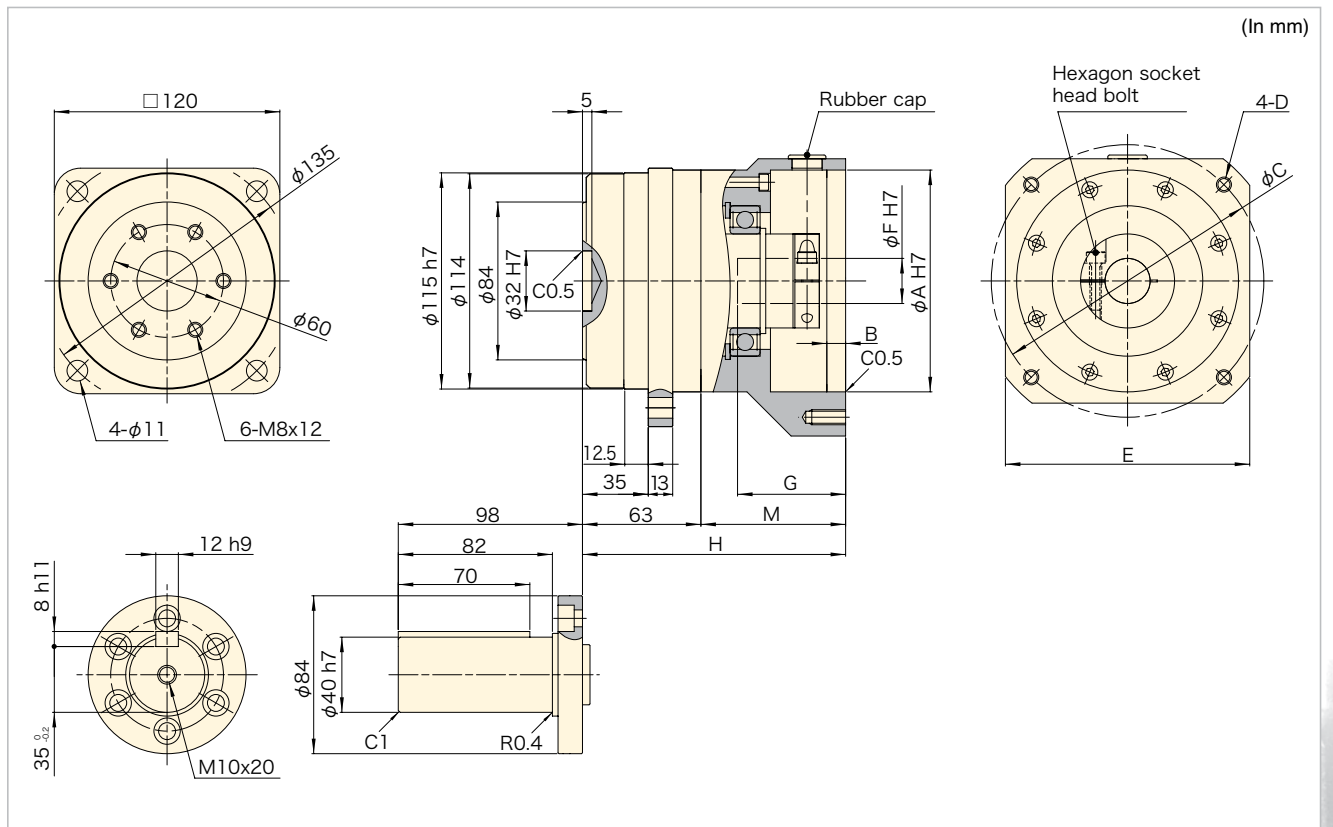
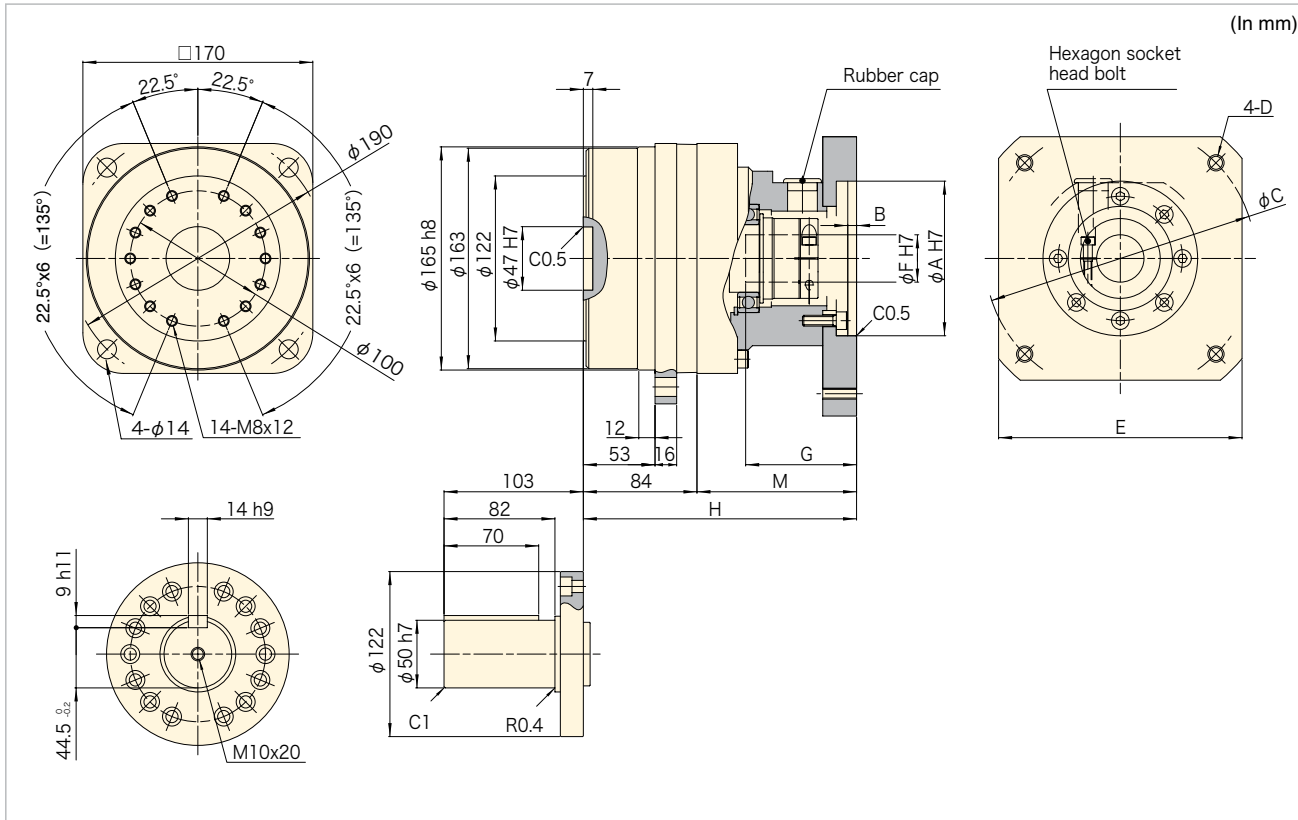


Fig. 10

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

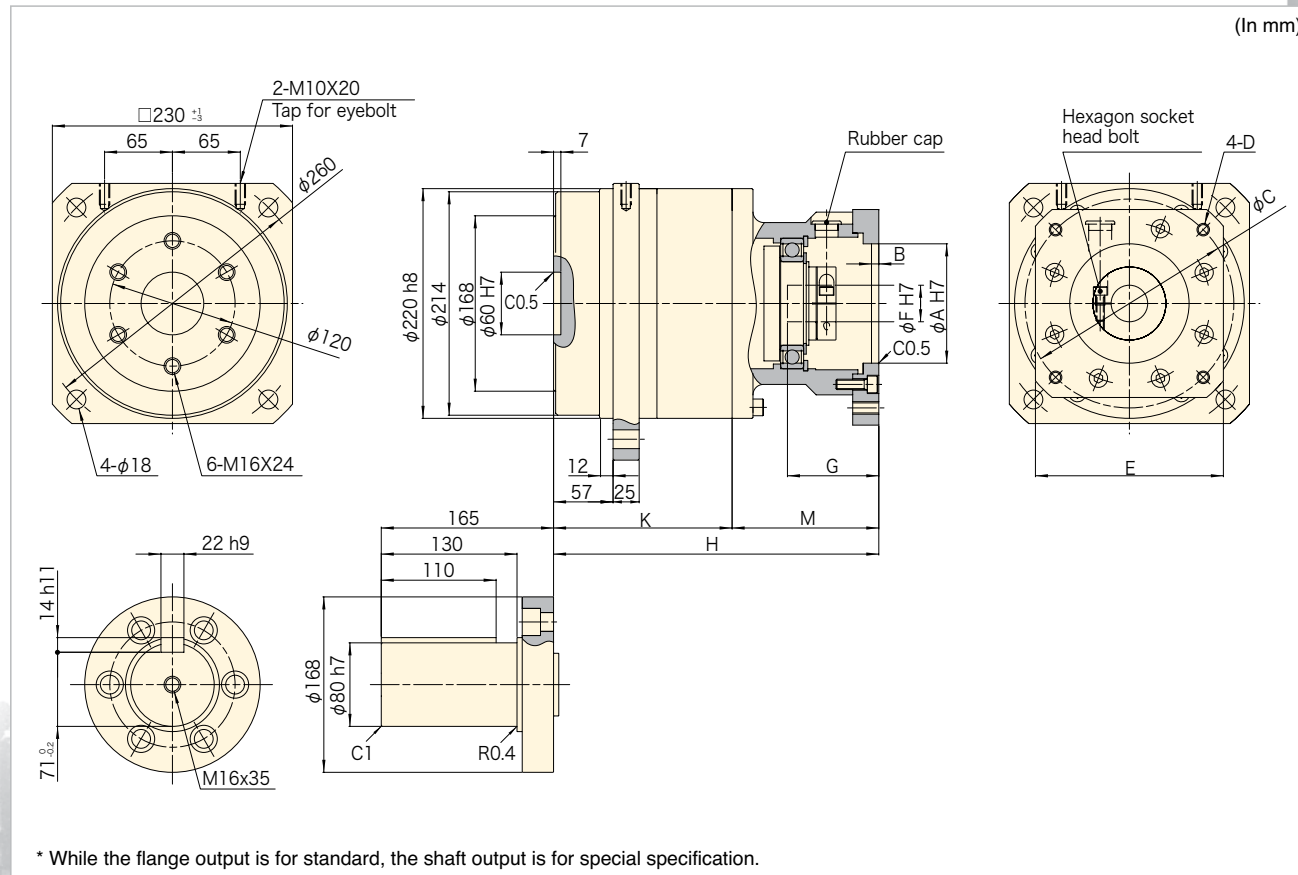
HPG-50A

Fig. 11



HPG-65A

Fig. 12



Hysteresis Loss/Backlash (description via hysteresis curve)

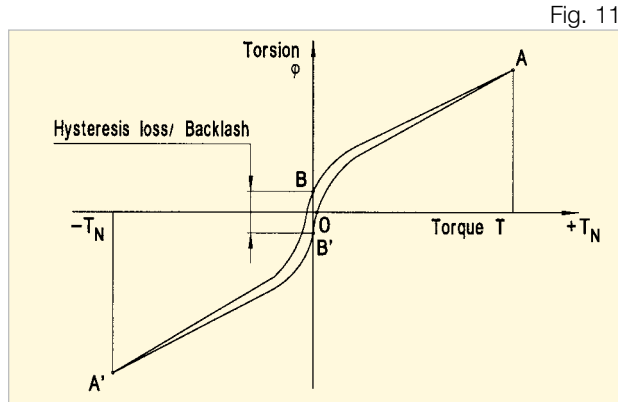


Fig. 11

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.

T_N : Rated output torque
 ϕ : Output rotation angle

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 \pm sign, as shown in Fig. 12.

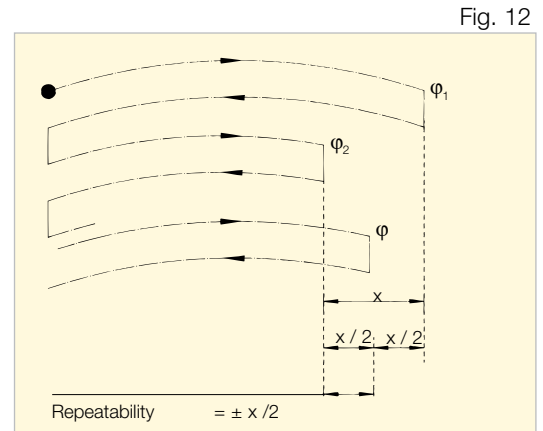
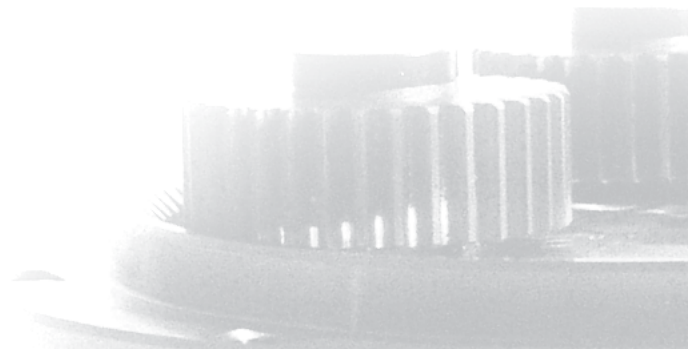
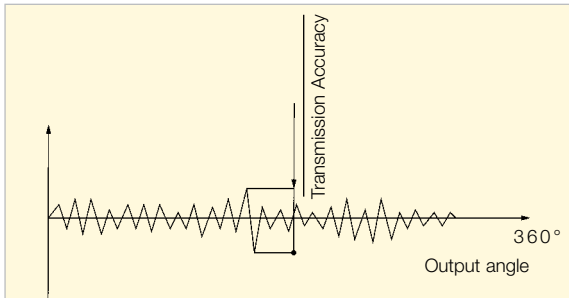


Fig. 12



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

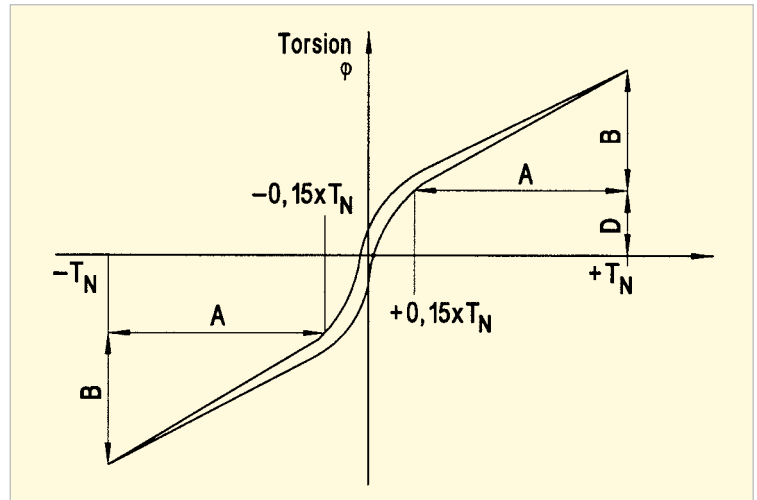


Table 3

Size	Torsional Stiffness = $\frac{A}{B}$		D [arc-min]			
			Backlash Class			
	[Nm/min]	[Nm/rad]	BL3		BL1	
			i = 5	i > 5	i = 5	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 $0.15 \times T_N$

ϕ : Output rotation angle

Calculation of the torsion angle ϕ at load torque T

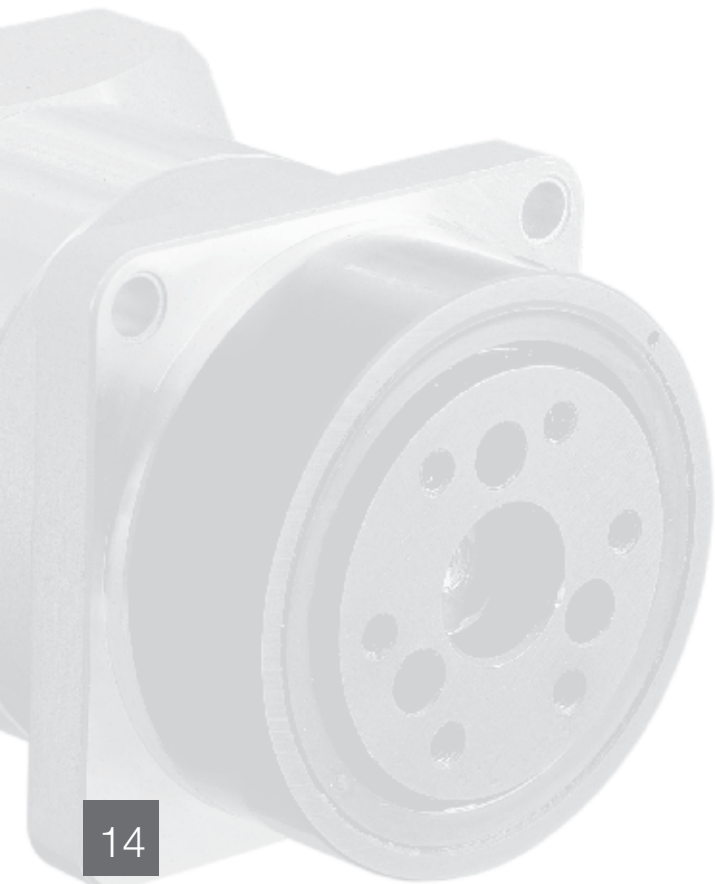
$$\phi = D + \left(\frac{T - T_L}{\frac{A}{B}} \right)$$

D : [min] (Fig. 14)

T : Load torque -[Nm]

T_L : $T_N \times 0,15$ [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
20	45	2.4	2	1.1
	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
32	33	6.4	6	2.1
	45	4.7	5	2.1
	3	56	135	1.7
	5	33.3	73	1.7
	11	26.7	38	2.9
	15	25	29	3.7
50	21	22.4	24	4.7
	33	15	14	4.8
	45	11	13	5.1
	3	134	250	4.0
	5	80	130	4.0
	11	45	60	5.0
65	15	40	47	6.0
	21	36	40	7.6
	35	24	24	7.8
	45	20	20	8.9
	4	288	420	12
	5	240	360	12
65	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]

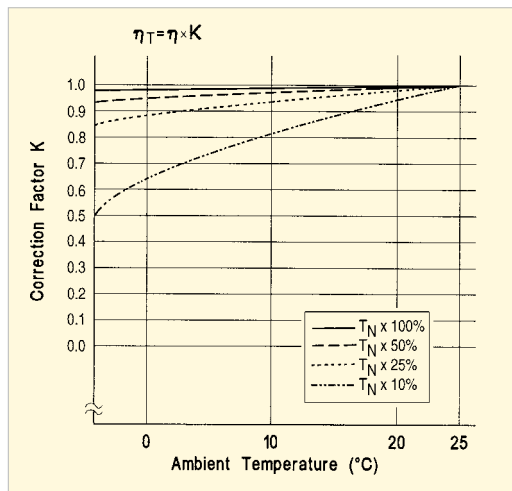
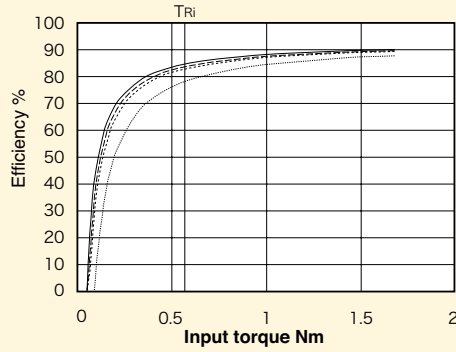


Fig. 15

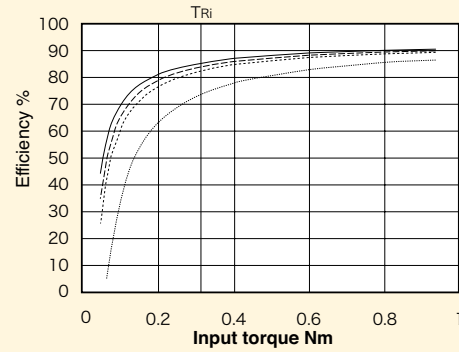
Efficiency

Model No. 11 : Gear Head Type Input Shaft Type

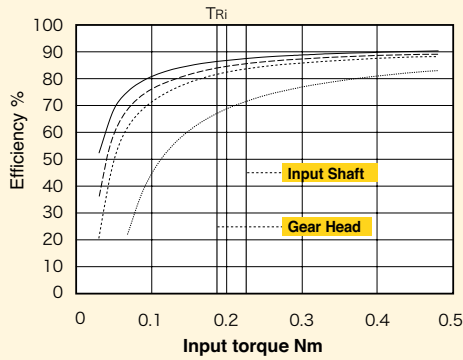
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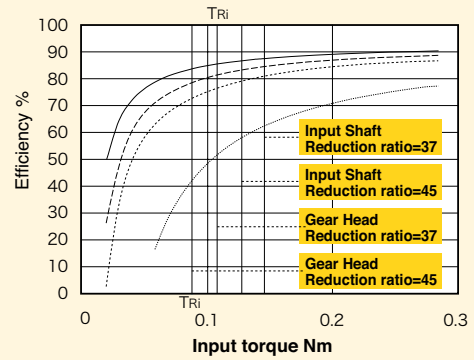
[Reduction ratio=9]



[Reduction ratio=21]



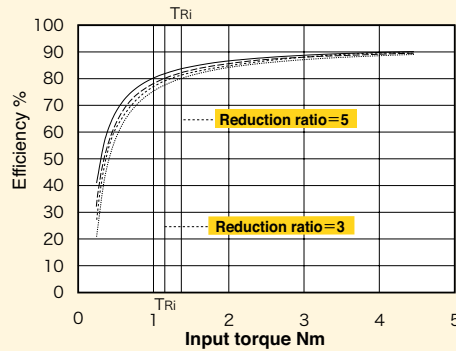
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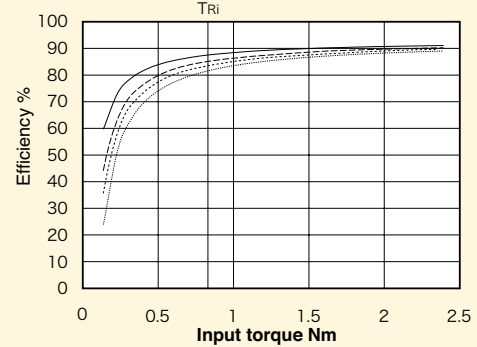
— Speed reducer only - - - Gear head type (standard item) DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item) — Input Shaft Type TRi Input torque corresponding to output torque

Model No. 14 : Gear Head Type Input Shaft Type

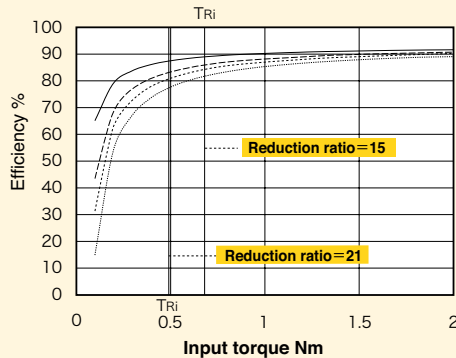
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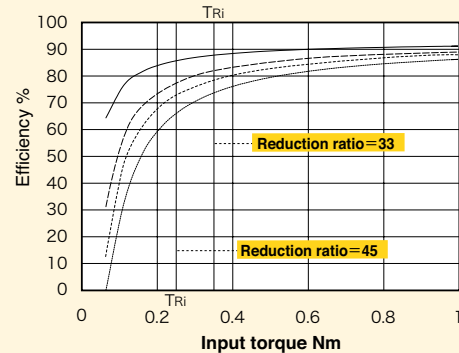
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[Reduction ratio=15, 21]



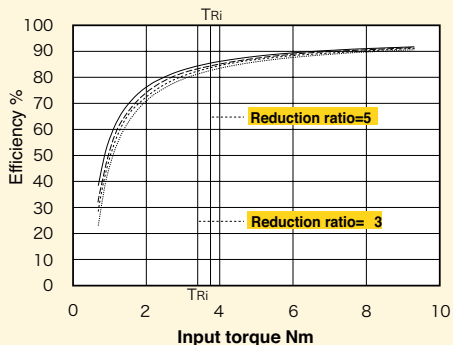
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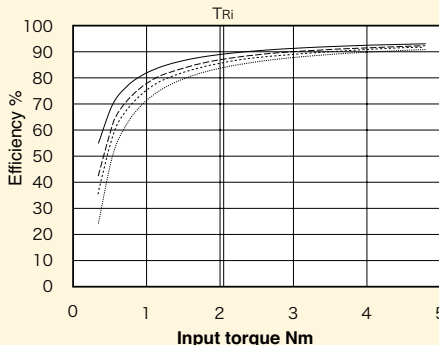
— Speed reducer only - - - Gear head type (standard item) DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item) — Input Shaft Type TRi Input torque corresponding to output torque

Model No. 20 : Gear Head Type Input Shaft Type

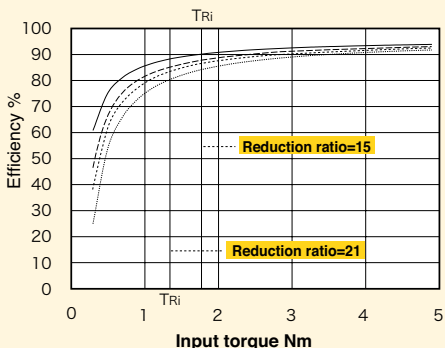
[Reduction ratio=3, 5]



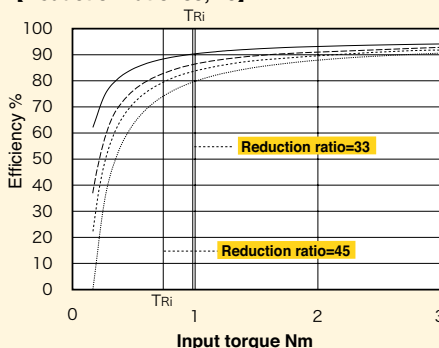
[Reduction ratio=11]



[Reduction ratio=15, 21]



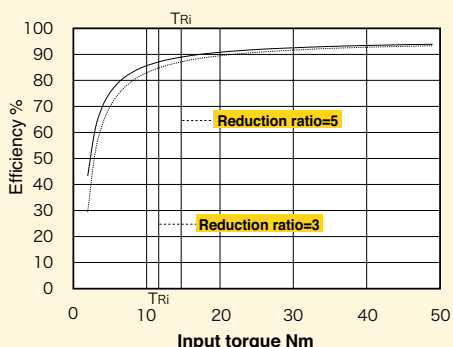
[Reduction ratio=33, 45]



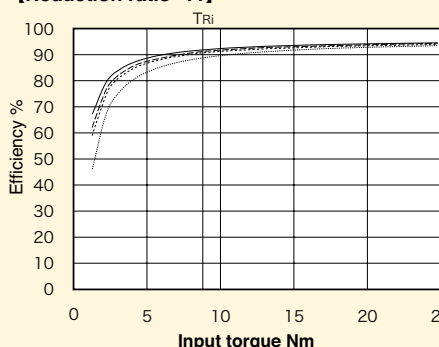
— Speed reducer only - - - Gear head type (standard item) DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item) — Input Shaft Type T_{Ri} Input torque corresponding to output torque

Model No. 32 : Gear Head Type Input Shaft Type

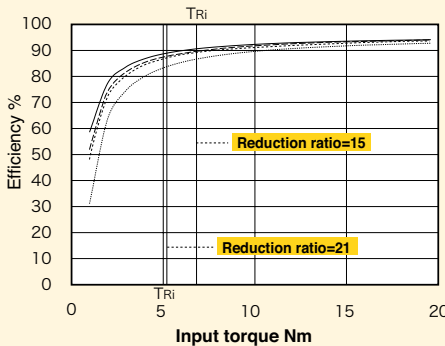
[Reduction ratio=3, 5]^{*1}



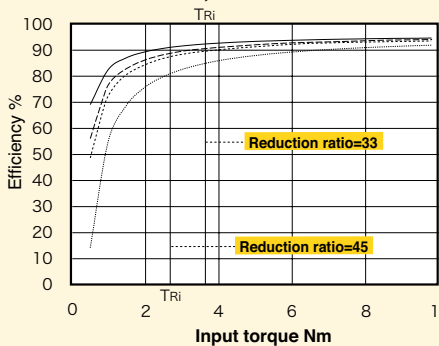
[Reduction ratio=11]



[Reduction ratio=15, 21]



[Reduction ratio=33, 45]

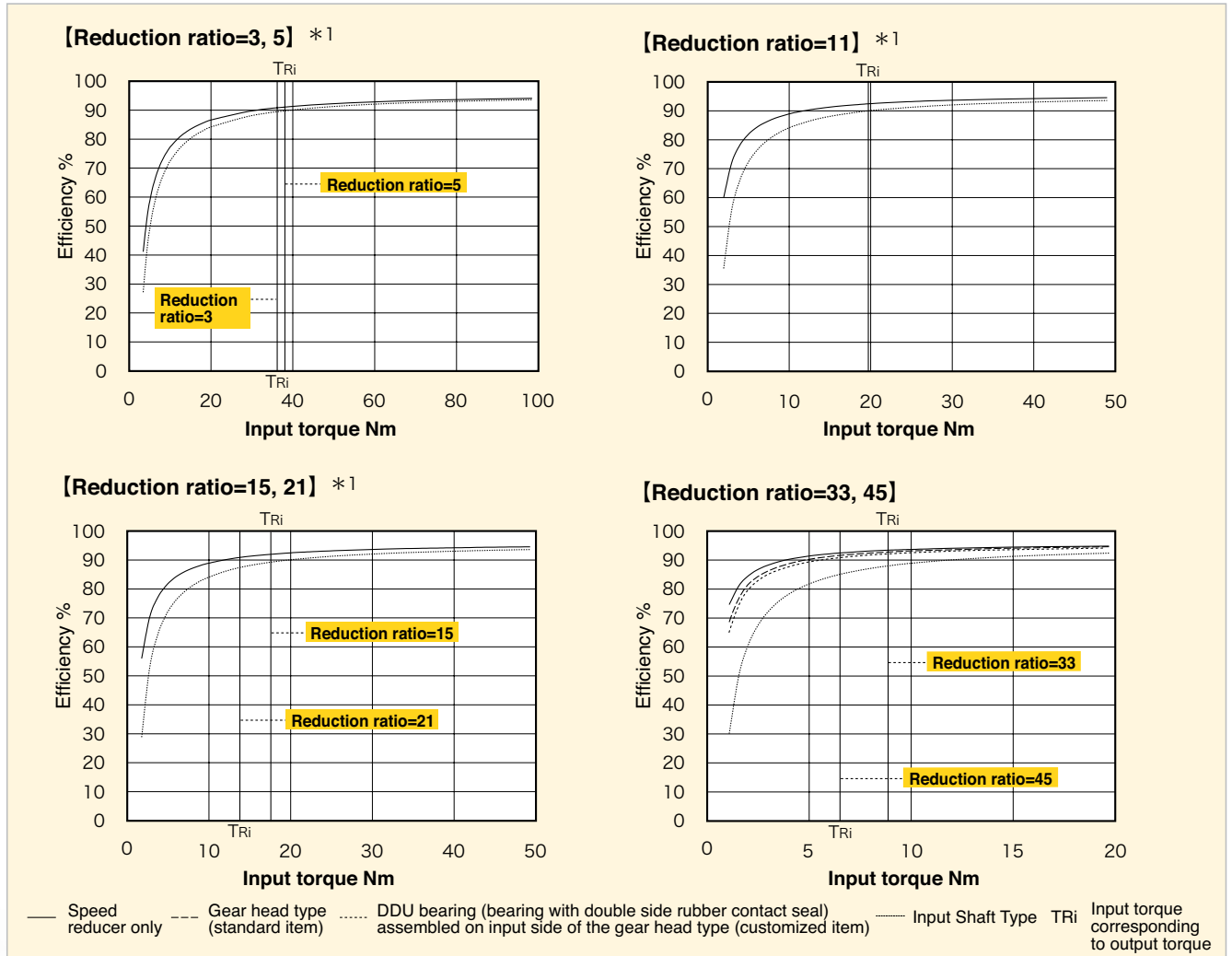


— Speed reducer only - - - Gear head type (standard item) DDU bearing (bearing with double side rubber contact seal) assembled on input side of the gear head type (customized item) — Input Shaft Type T_{Ri} Input torque corresponding to output torque

*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.

Efficiency

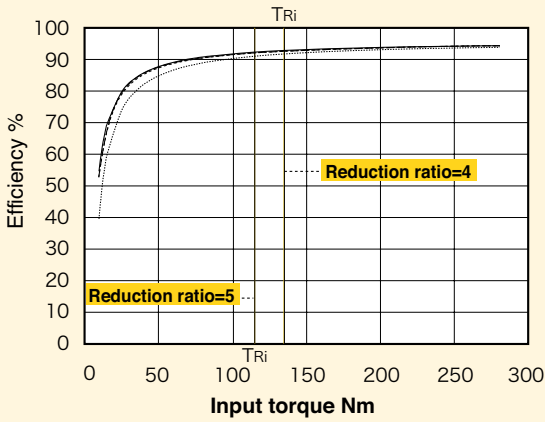
Model No. 50 : **Gear Head Type** **Input Shaft Type**



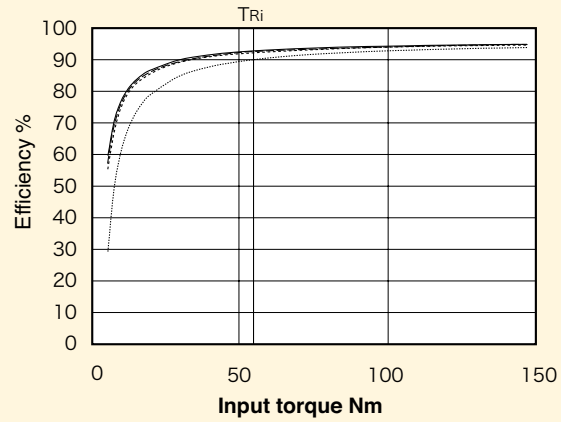
*1 Only one line is shown in graphs because the difference between the speed reducer and a bearing assembled on the input side is small.

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

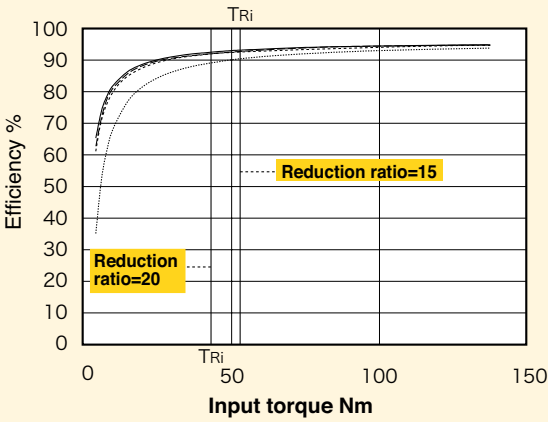
[Reduction ratio=4, 5] *1



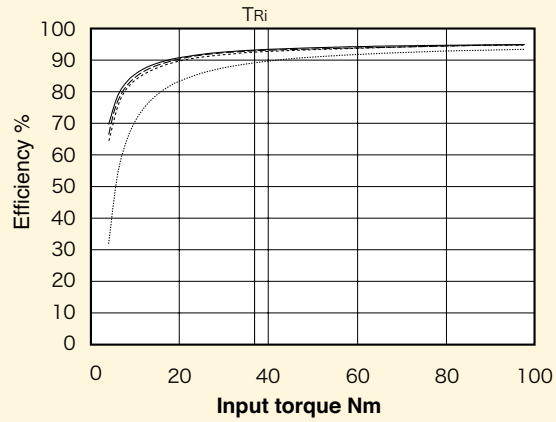
[Reduction ratio=12] *1



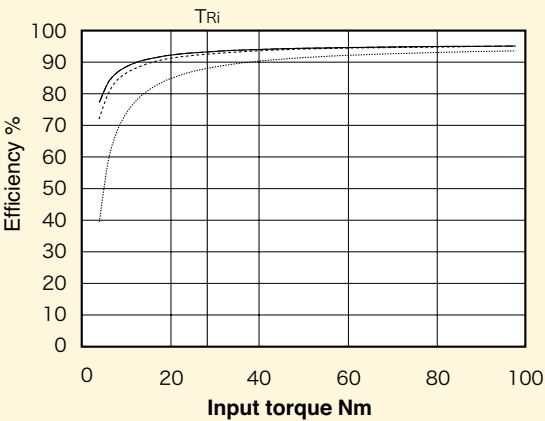
[Reduction ratio=15, 20] *1



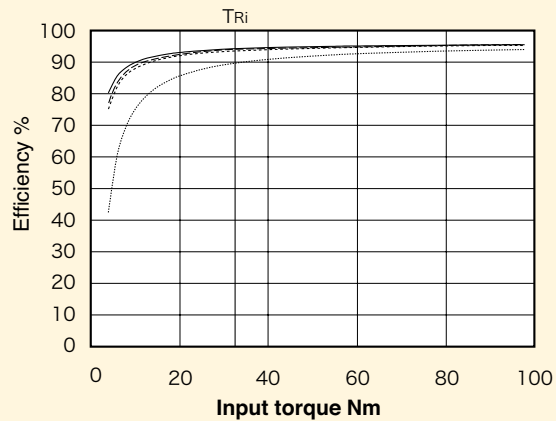
[Reduction ratio=25] *1



[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.

Fig. 20

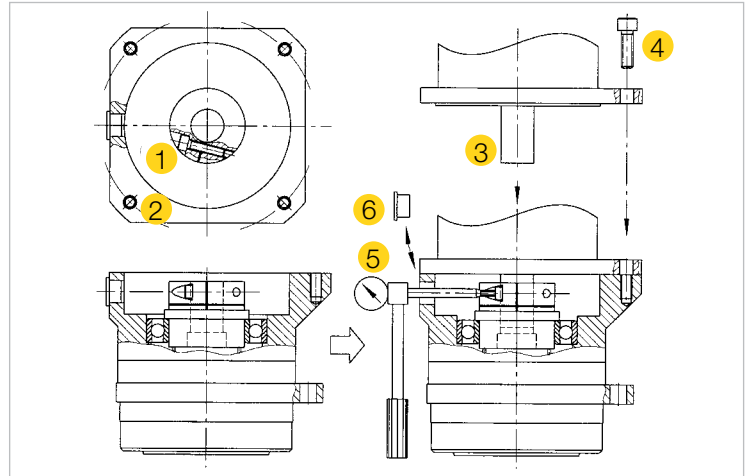


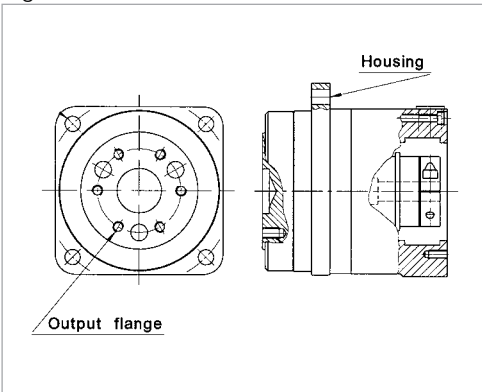
Table 5

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

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 stiffness 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}) \leq Permissible moment (M_c)

- (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 (P_0). ●●▶ Check the static safety coefficient. (f_s)

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	Circular Pitch of roller	Offset Amount R	Basic Rated Load		Permissible Moment Load M_c *3 Nm	Moment Stiffness K_m $\times 10^4$ Nm/rad
	dp		Basic dynamic rated load C *1 N	Basic static rated load C_0 *2 N		
	m	m				
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
20	45	910	1360
	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
50	45	3670	5480
	3	3700	5570
	5	4350	6490
	11	5500	8220
	15	6050	9030
	21	6690	9980
65	33	7660	11400
	45	8400	12500
	4	8860	13200
	5	9470	14100
	12	12300	18300
	15	13100	19600
	20	14300	21400
	25	15300	22900
	40	17600	26300
	50	18900	28200

Output Bearing Life

How to obtain the maximum load moment load

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

● Formula (1)

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

Symbol of formula (1)

Fr_{max}	Max. radial load	N (kgf)	See Fig. 1.
Fa_{max}	Max. axial load	N (kgf)	See Fig. 1.
L_r, La		m	See Fig. 1.
R	Offset amount	m	See Fig. 1 and Table 1.

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)

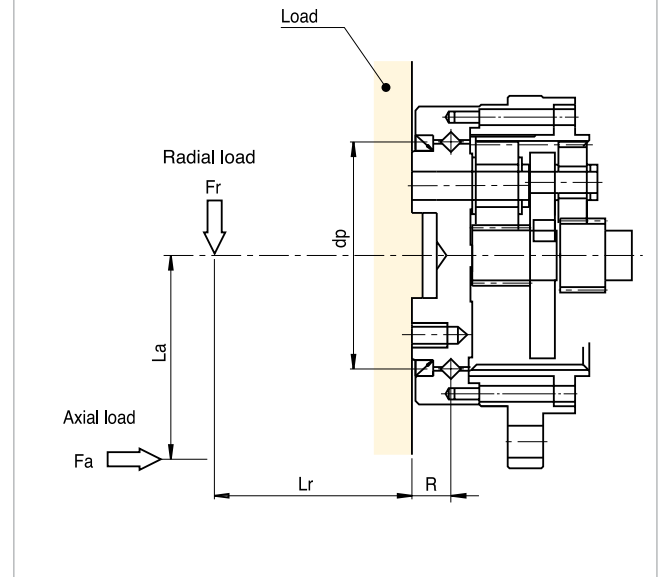
● Formula (2)

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

Symbol of formula (2)

Fr_{av}	Average radial load	N (kgf)	See "How to obtain the ave. load."
Fa_{av}	Average axial load	N (kgf)	See "How to obtain the ave. load."
L_r, 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.

Fig. 1 External load influence diagram



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 (F_r^{av})

$$F_r^{av} = \sqrt[10/3]{\frac{n_1 t_1 (|F_{r1}|)^{10/3} + n_2 t_2 (|F_{r2}|)^{10/3} + \dots + n_n t_n (|F_{rn}|)^{10/3}}{n_1 t_1 + n_2 t_2 + \dots + n_n t_n}}$$

Note that the maximum radial load within the t_1 section is F_{r1} and the maximum radial load within the t_3 section is F_{r3} .

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

$$F_a^{av} = \sqrt[10/3]{\frac{n_1 t_1 (|F_{a1}|)^{10/3} + n_2 t_2 (|F_{a2}|)^{10/3} + \dots + n_n t_n (|F_{an}|)^{10/3}}{n_1 t_1 + n_2 t_2 + \dots + n_n t_n}}$$

Note that the maximum axial load within the t_1 section is F_{a1} and the maximum axial load within the t_3 section is F_{a3} .

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

$$N^{av} = \frac{n_1 t_1 + n_2 t_2 + \dots + n_n t_n}{t_1 + t_2 + \dots + t_n}$$

How to obtain the life

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

●Formula (6)

$$L_{10} = \frac{10^6}{60 \times N_{av}} \times \left(\frac{C}{f_w \cdot P_c} \right)^{10/3}$$

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.
P_c	Dynamic equivalent radial load	N (kgf)	See Formula (7).
f_w	Load coefficient	_____	See Table 3.

Table 3 Load coefficient

Load status	f_w
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

●Formula (7)

$$P_c = X \cdot \left(F_{rav} + \frac{2(F_{rav}(L_r + R) + F_{aav} \cdot L_a)}{dp} \right) + Y \cdot F_{aav}$$

Symbol of formula (7)

F_{rav}	Average radial load	N (kgf)	See "How to obtain the average load."
F_{aav}	Average axial load	N (kgf)	See "How to obtain the average load."
dp	Circular pitch of roller	m	See Table 1 on page 76.
X	Radial load coefficient	_____	See Table 2 on page 77.
Y	Axial load coefficient	_____	See Table 2 on page 77.
L_r, L_a	_____	m	See Fig. 1 on page 77.
R	Offset amount	m	See Fig. 1 on p.77 and Table 1 on p.76.

How to obtain the life under oscillating movement

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

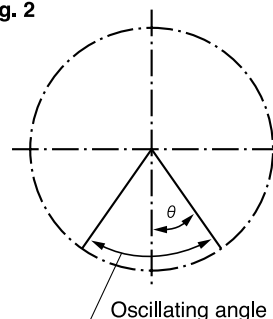
●Formula (8)

$$L_{oc} = \frac{10^6}{60 \times n_1} \times \frac{90}{\theta} \times \left(\frac{C}{f_w \cdot P_c} \right)^{10/3}$$

Symbol of formula (8)

L_{oc}	Rated life under oscillating movement	hour	_____
n_1	No. of reciprocating oscillation per min.	cpm	_____
C	basic dynamic rated load	N (kgf)	See Table 1 on page 76.
P_c	Dynamic equivalent radial load	N (kgf)	See Formula (7).
f_w	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.

Life of Output Bearing for Oscillating Motion

How to obtain the static safety coefficient

In general, the basic static rated load (C_0) 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 (P_0) by Formula (10).

●Formula (9)

$$f_s = \frac{C_0}{P_0}$$

Symbol of formula (9)

C_0	Basic static rated load	N (kgf)	See Table 1 on page 76.
P_0	Static equivalent radial load	N (kgf)	See Formula (10).

●Formula (10)

$$P_0 = F_{rmax} + \frac{2M_{max}}{dp} + 0.44F_{amax}$$

Symbol of formula (10)

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

Table 4 Static safety coefficient

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

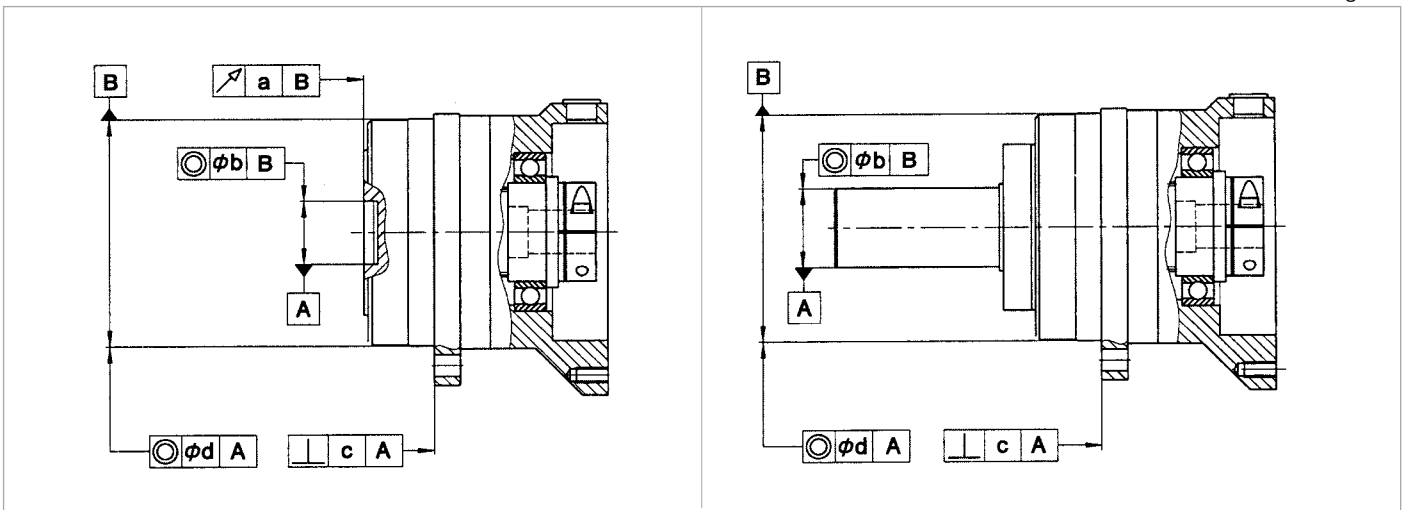
Table 13

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



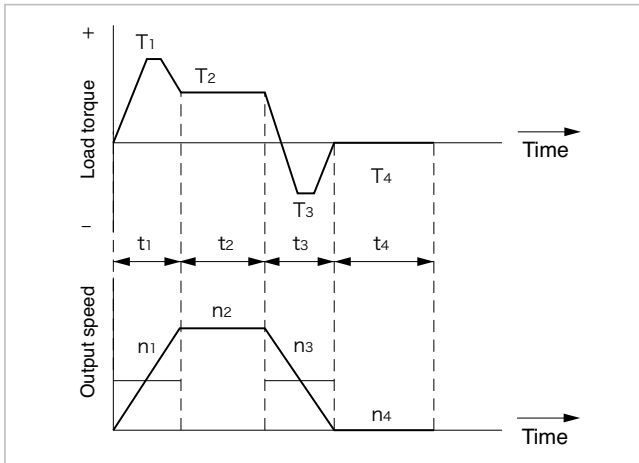
Check your operating conditions and select suitable model Nos. based on the flowchart to fully demonstrate the excellent performance of the Harmonic Planetary® HPG series.

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	T1 to Tn (Nm)
Time	t1 to tn (sec)
Output speed	n1 to nn (r/min)

<Normal operation pattern>

Starting time	T1, t1 n1
Steady operation time	T2, t2, n2
Stopping (slowing) time	T3, t3, n3
Break time	T4, t4 n4

<Maximum rotational speed>

Max. output speed	$no_{max} \geq n1$ to n_n
Max. input speed (Restricted by motors)	$ni_{max} \geq n1 \times R$ to $n_n \times R$
	R: Reduction ratio

<Impact torque>

When impact torque is applied	Ts
-------------------------------	----

<Required lifespan>

$$L_{10} = L \text{ (hours)}$$

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: T_{av} (Nm).

$$T_{av} = \sqrt[10/3]{\frac{|n1| \cdot t1 \cdot |T1|^{10/3} + |n2| \cdot t2 \cdot |T2|^{10/3} + \dots + |nn| \cdot tn \cdot |Tn|^{10/3}}{n1 \cdot t1 + n2 \cdot t2 + \dots + nn \cdot tn}}$$

Calculate the average output speed based on the load torque pattern: no_{av} (r/min)

$$no_{av} = \frac{|n1| \cdot t1 + |n2| \cdot t2 + \dots + |nn| \cdot tn}{t1 + t2 + \dots + tn}$$

Tentatively select a model No. under the following condition:
 $T_{av} \leq$ 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).

$$\frac{ni_{max}}{no_{max}} \geq R$$

(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).

$$ni_{max} = no_{max} \cdot R$$

Calculate the average input speed (ni av) based on the average output speed (no av) and reduction ratio (R): $ni_{av} = no_{av} \cdot R \leq$ Permissible average input speed (nr).

NG

OK

Check if the maximum input speed is within the values in the rating table.
 $ni_{max} \leq$ maximum input speed (r/min)

NG

OK

Check that T1 and T3 are within peak torques (Nm) on start and stop in the rating table.

NG

OK

Check that Ts 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: $T_s > T_P$
Ts: Shock torque T_P: Peak torque on start and stop

$$\chi = 8.5 - 1.5 \times \frac{T_s}{T_P} \quad N_s = 1.0 \times 10^\chi \text{ (cycle)}$$

NG

OK

Calculate the life (hours) and check if it meets the specification requirement.

Tr: Output torque
nr: Permissible average input speed

$$L_{10} = 20000 \cdot \left(\frac{T_r}{T_{av}} \right)^{10/3} \cdot \left(\frac{nr}{ni_{av}} \right) \text{ (Hour)}$$

NG

OK

The model number is determined.

Check the description in Caution below.

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

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 (T_{av}) > Permissible maximum value of average load torque.

Selection Example

Value of each load torque pattern.

Load torque	T_n (Nm)	<Maximum speed>	
Time	t_n (sec)	Max. output speed	$no_{max} = 120$ r/min
Output speed	n_n (r/min)	Max. input speed	$ni_{max} = 5,000$ r/min (Restricted by motors)
<Regular operation pattern>			
Starting time	$T_1 = 70$ Nm, $t_1 = 0.3$ sec, $n_1 = 60$ r/min	<Impact torque>	
Steady operation time	$T_2 = 18$ Nm, $t_2 = 3$ sec, $n_2 = 120$ r/min	When impact torque is applied	$T_s = 180$ Nm $N_s = 1,000$ (cycle)
Stopping (slowing) time	$T_3 = 35$ Nm, $t_3 = 0.4$ sec, $n_3 = 60$ r/min	<Required lifespan>	
Break time	$T_4 = 0$ Nm, $t_4 = 5$ sec, $n_4 = 0$ r/min		$L_{10} = 30,000$ (hours)

Calculate average load torque applied to the output side based on the load torque pattern: T_{av} (Nm).

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

Calculate average output speed based on the load torque pattern: no_{av} (r/min)

$$no_{av} = \frac{|60 \text{ r/min}| \cdot 0.3\text{sec} + |120 \text{ r/min}| \cdot 3\text{sec} + |60 \text{ r/min}| \cdot 0.4\text{sec} + |0 \text{ r/min}| \cdot 5\text{sec}}{0.3\text{sec} + 3\text{sec} + 0.4\text{sec} + 5\text{sec}}$$

Tentatively select a model No. under the following condition. $T_{av} = 30.2\text{Nm} \leq 60\text{Nm}$. (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.)

OK

Determine a reduction ratio (R) based on the maximum output speed (no_{max}) and maximum input speed (ni_{max}).

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

Calculate the maximum input speed (ni_{max}) based on the maximum output speed (no_{max}) and reduction ratio (R):
 $ni_{max} = 120 \text{ r/min} \cdot 33 = 3,960 \text{ r/min}$

OK

Calculate the average input speed (ni_{av}) based on the average output speed (no_{av}) and reduction ratio (R):
 $ni_{av} = 46.2 \text{ r/min} \cdot 33 = 1,525 \text{ r/min} \leq$ Permissible average input speed of model No. 20 3000 (r/min)

OK

Check if the maximum input speed is within the values specified in the rating table.
 $ni_{max} = 3960 \text{ r/min} \leq 6000 \text{ r/min}$ (maximum input speed of model No. 20)

OK

Check if T_1 and T_3 are smaller than peak torques (Nm) on start and stop in the rating table.
 $T_1 = 70\text{Nm} \leq 100\text{Nm}$ (Peak torques on start and stop of model No. 20)
 $T_3 = 35\text{Nm} \leq 100\text{Nm}$ (Peak torques on start and stop of model No. 20)

OK

Check if T_s is within the values of the instantaneous max. torque (Nm) in the rating table.
 $T_s = 180\text{Nm} \leq 217\text{Nm}$ (instantaneous max. torque of model No. 20)

OK

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

$$\chi = 5.8 = 8.5 - 1.5 \times \frac{180}{30.2} \quad N_s = 1.0 \times 10^{5.8} \text{ (cycle)} = 631,000 \text{ (cycle)} \geq 1,000 \text{ (cycle)}$$

OK

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

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

OK

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

Check the description in Caution at the bottom of page 82

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

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. BL 1 = 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			

