Harmonic Planetary®

HPG Series

Planetary Gearhead

HARMONIC DRIVE

Total Motion Control

harmonic planetary®

Precision Gearing & Motion Control

Harmonic Drive LLC

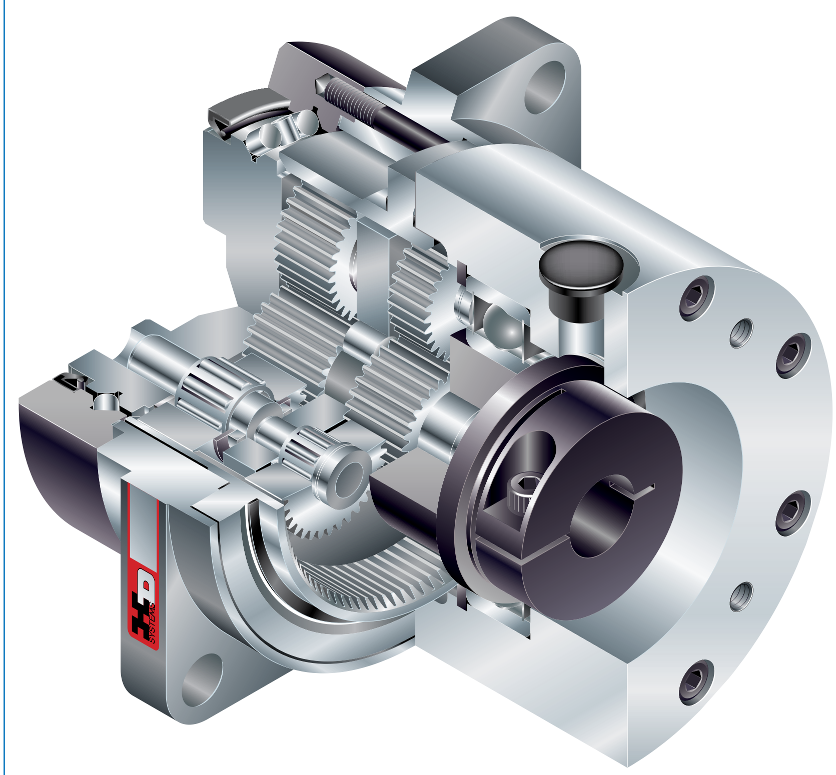
is the world's largest manufacturer of harmonic drive gearing and motion control systems, with an installed base of over 4 million products worldwide. Known for its high precision, zero backlash harmonic drive products, Harmonic Drive LLC was a pioneer in developing high precision mechanical drive products 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. All Harmonic Drive LLC products are produced in the company's 150,000 square foot, ultra-modern facility in Nagano, Japan. The facility is ISO 9001 certified. Complete application engineering, custom design, customer service, and technical support are provided in the United States at its technical centers in Peabody, Massachussettes and Hauppauge, New York.

Harmonic Drive LLC
800-921-3332

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 harmonic drive gears 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.

<u>Backlash less than 1 arc-min</u>

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

<u>High moment stiffness</u>
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.

<u>High efficiency</u>
As a result of the optimized tooth profile efficiencies of more than 90 % can be achieved.

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

<u>Easy motor assembly</u>
The supported motor shaft coupling and the variable adapter flange guarantee an extremely rapid and easy motor assembly.

<u>Reduction ratios between 3:1 and 45:1</u>
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.

<u>Flange or Shaft Output Configuration</u>
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.

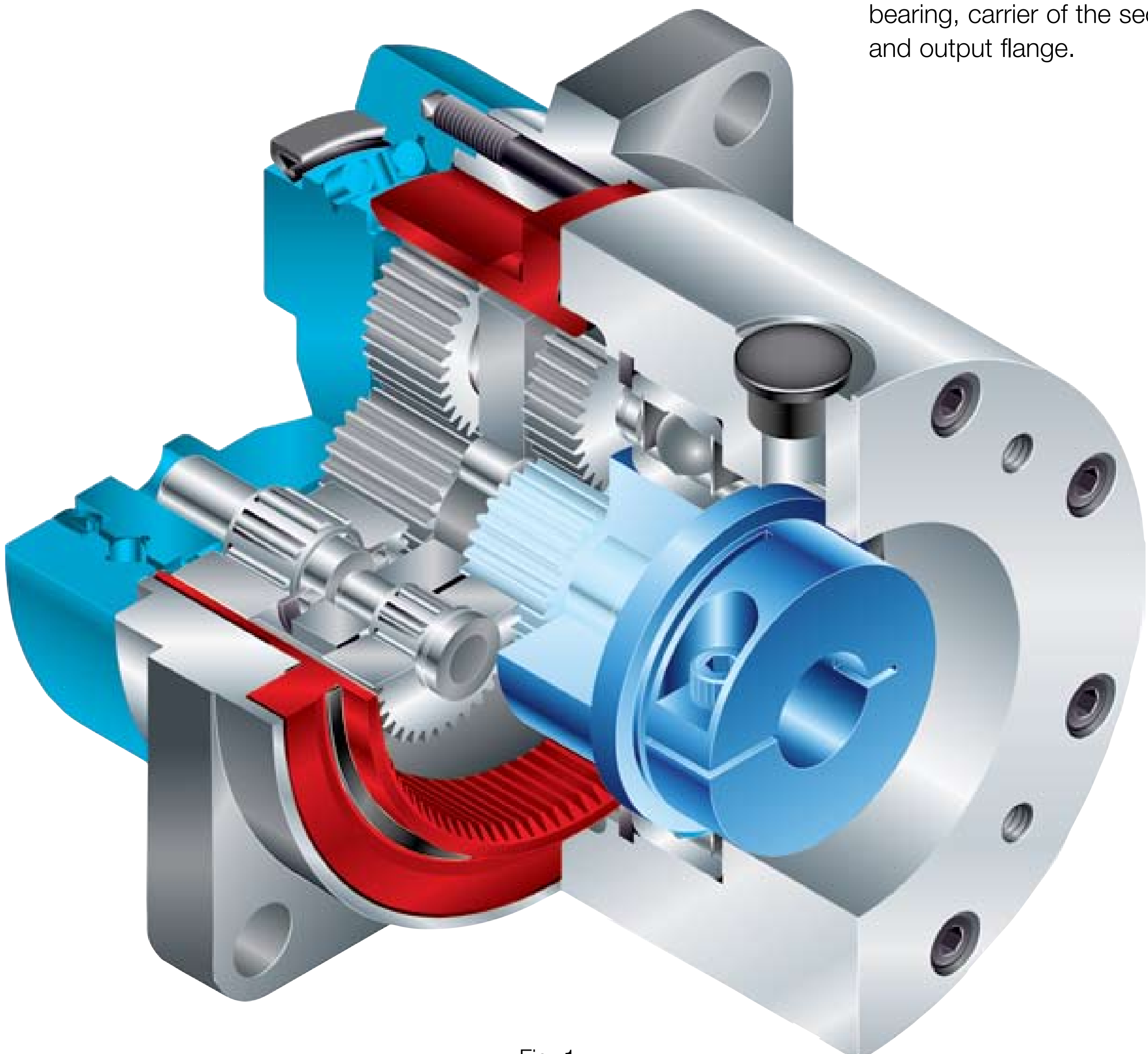
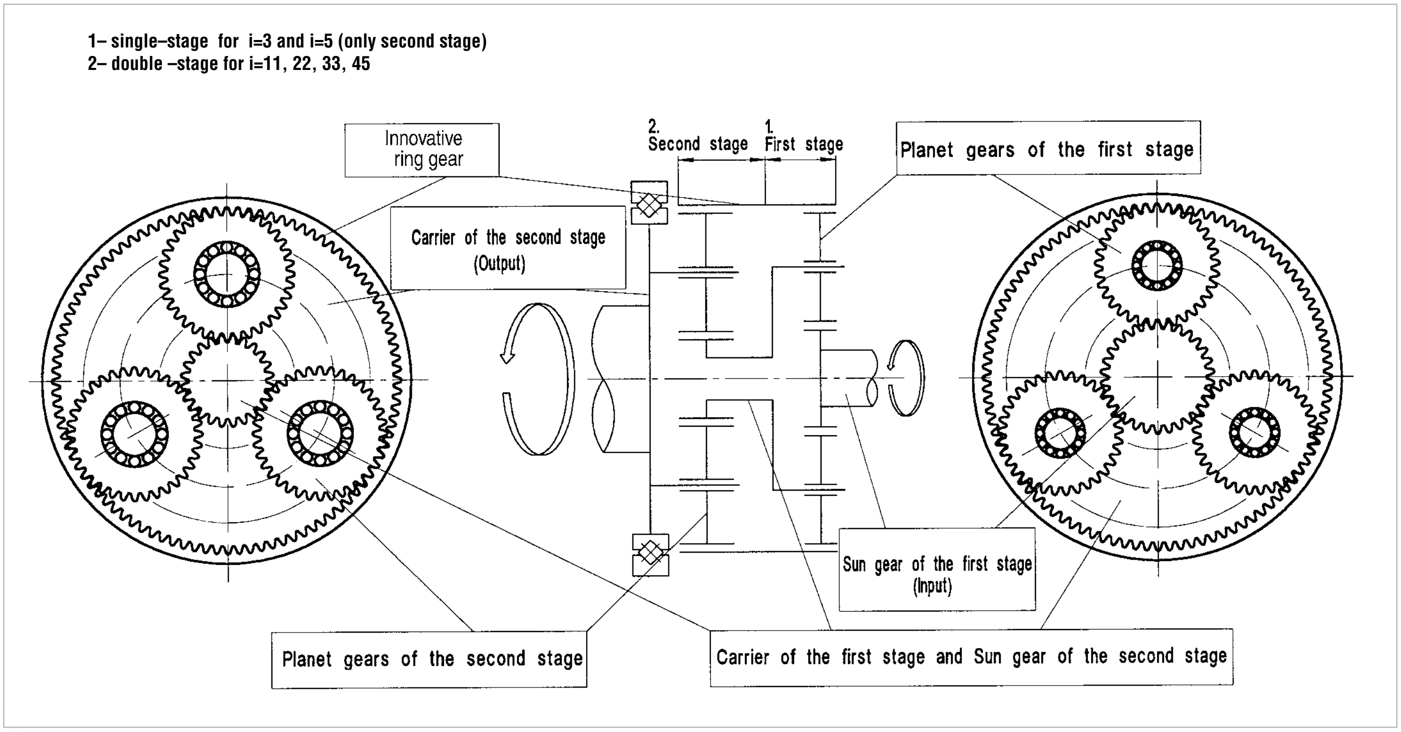


Fig. 1

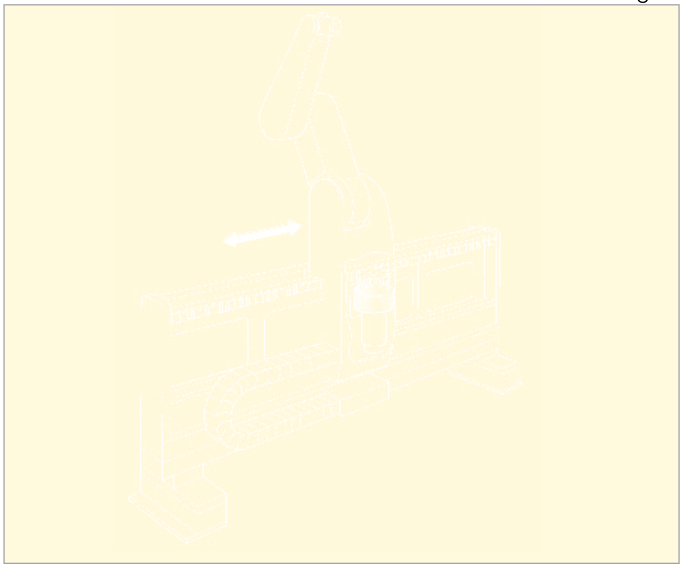
Fig. 2



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.

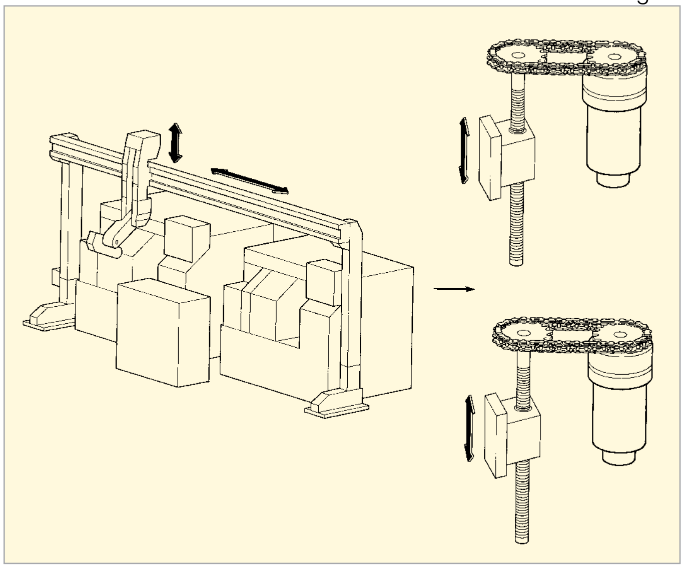
Linear axis for robots

Fig. 3



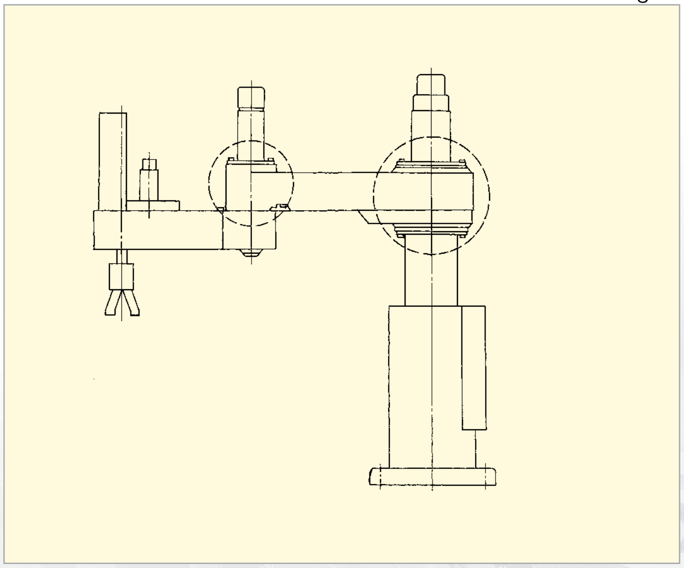
Loading and unloading equipment

Fig. 4



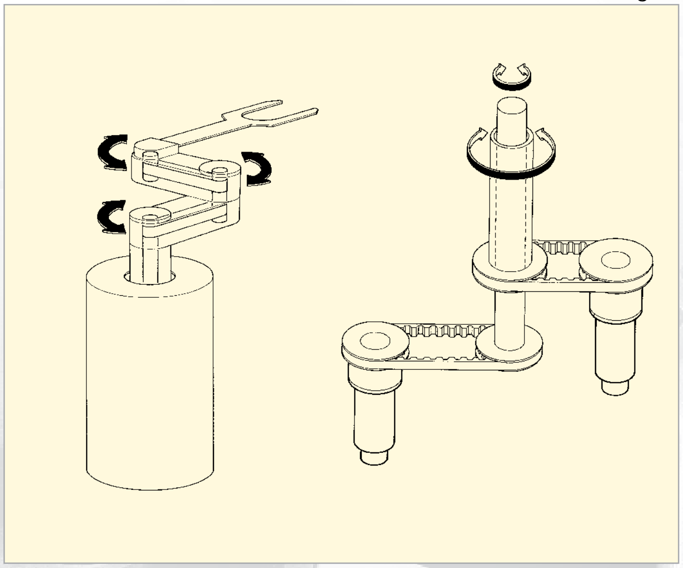
Primary axes of scara robots

Fig. 5



Wafer handling robots

Fig. 6



Rating Table

Size	Gear Ratio	Rated Torque at 3000rpm *1		Max.Average load Torque *2		Repeated Peak Torque*3		Max.Momentary Torque *4		Limit for Average Input Speed *5	Max. Input Speed *6	Moment of Inertia *7				Weight *8			
												Gear heads w/Output		Input Shaft Type w/Output		Gear heads w/ Output		Input Shaft Type w/Output	
		N.m	In.lb	N.m	In.lb	N.m	In.lb	N.m	In.lb	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
11	5	2.5	22	5	44	7.8	69	20	177	3000	10000	0.0036	0.0021	–	–	0.18	0.14	–	–
	9	2.5	22	3.9	35	3.9	35					0.0012	0.0007						
	21	3.4	30	6	53	9.8	87					0.0019	0.0018			0.24	0.20	–	–
	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	3000	5000	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		6000	0.026	0.020	0.073	0.067				
	11	7.8	69	15	133							0.019	0.018	0.059	0.058	0.60	0.50	0.90	0.80
	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	1097	3000	4000	0.57	0.46	0.80	0.69	1.6	1.2	2.4	2.0
	5	16	142	35	310	100	885	217	1920		6000	0.21	0.17	0.44	0.40				
	11	20	177	45	398							0.16	0.15	0.32	0.31	1.8	1.4	2.7	2.1
	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	1991	507	4487	3000	3600	2.8	2.0	4.2	3.4	4.3	2.9	6.3	4.9
	5	66	584	150	1328	300	2655	650	5753		6000	1.0	0.73	2.4	2.2				
	11	88	779	170	1505							0.84	0.78	2.0	1.9	4.9	3.5	6.9	5.3
	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	1770							0.13	0.12	1.3	1.3				
	45	108	956	200	1770							0.12	0.11	1.3	1.3				
50	3	97	858	195	1726	657	5814	1850	16373	2000	3000	17	13	21	18	13	10	17	14
	5	170	1505	340	3009	850	7523				4500	6.1	4.8	11	9.2				
	11	200	1770	400	3540							3.6	3.3	7.4	7.1	15	12	19	16
	15	230	2036	450	3983							3.1	2.9	6.8	6.7				
	21	260	2301	500	4425							1.7	1.6	5.5	5.4				
	33	270	2390									0.63	0.6	4.4	4.3				
	45	270	2390									0.59	0.6	4.3	4.3				
65	4	500	4425	900	7965	2200	19470	4500	39825	2000	2500	(42) *9	28	–	–	(32) *9	22	–	–
	5	530	4691	1000	8850						3000	(27) *9	18						
	12	600	5310	1100	9735							(18) *9	17			(47) *9	37	–	–
	15	730	6461	1300	11505							(17) *9	16						
	20	800	7080	1500	13275							(7.1) *9	6.5						
	25	850	7523	1500	13275							(6.5) *9	6.1						

1Nm = 8.85in-lbs

Contact Harmonic Drive LLC for additional sizes and gear ratios

Please note:

*1: Output torque set based on the life of L10=20000 hours when Input speed is 3000 rpm, which is the rated rotational speed of ordinary servo motors. Input speed for Models 50 and 65 are set at 20000 rpm. *2: A maximum tolerance of average load torque calculated based on a load torque pattern . A life of 2000 hours or more is a critarion when operate at an Input speed of 2000 rpm. *3: Maximum tolerance of torque applied on start and stop in operation cycles.*4: Maximum tolerance for shock torque in an emergency stop and for external shock torque. Always operate within these ranges. Calculate permissible frequency in model selection and check whether or not they meet operating conditions. *5: Maximum permissible Input speed in operation modes other than continuous operation. *6: It depends on the operating environment and a driving condition, but it is the permissible scale for the continuous operation and the operating pattern of the average Input speed. It is limited in the terms of heat generated in the reduction gears. *7: The value indicated including the input shaft coupling, the motor flange and other parts. *8: Weight for gear with standard motor flange and coupling.

How to use the Rating Table

Limit for Average Torque (T_A) - Load Limit 1

When a gear is used under a variable load, an average torque should be calculated for the complete operating cycle, (see equation 15, page 21). The value calculated should not exceed the limit T_A given in the rating table. Otherwise the performance and life of the gear may be impaired.

Limit for Repeated Peak Torque (T_R) - Load Limit 2

This is the allowable output torque that can be developed during acceleration or deceleration. The peak torque that occurs during starting or stopping can be calculated if the load moment of inertia and acceleration (or deceleration) time are known. This torque limit must not be exceeded during the normal operating cycle.

Limit for Momentary Peak Torque (T_M) - Load Limit 3

The gear may be subjected to momentary peak torques in the event of a collison or emergency stop. The magnitude and frequency of occurrence of such peak torques must be kept to a minimum and they should under no circumstance occur during the normal operating cycle, (see equation 22, page 21).

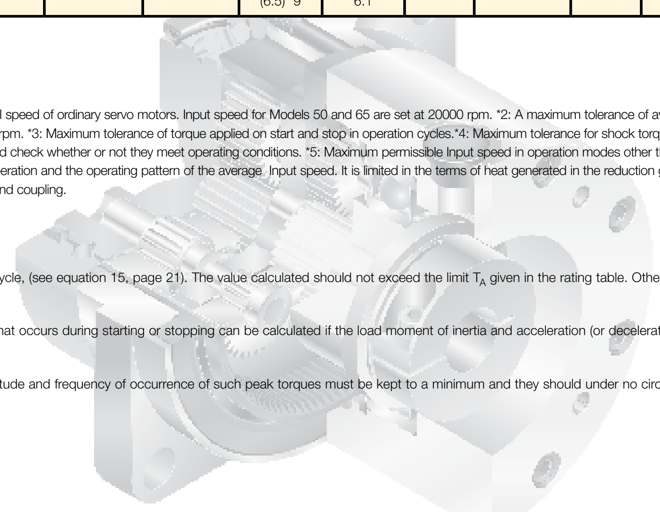
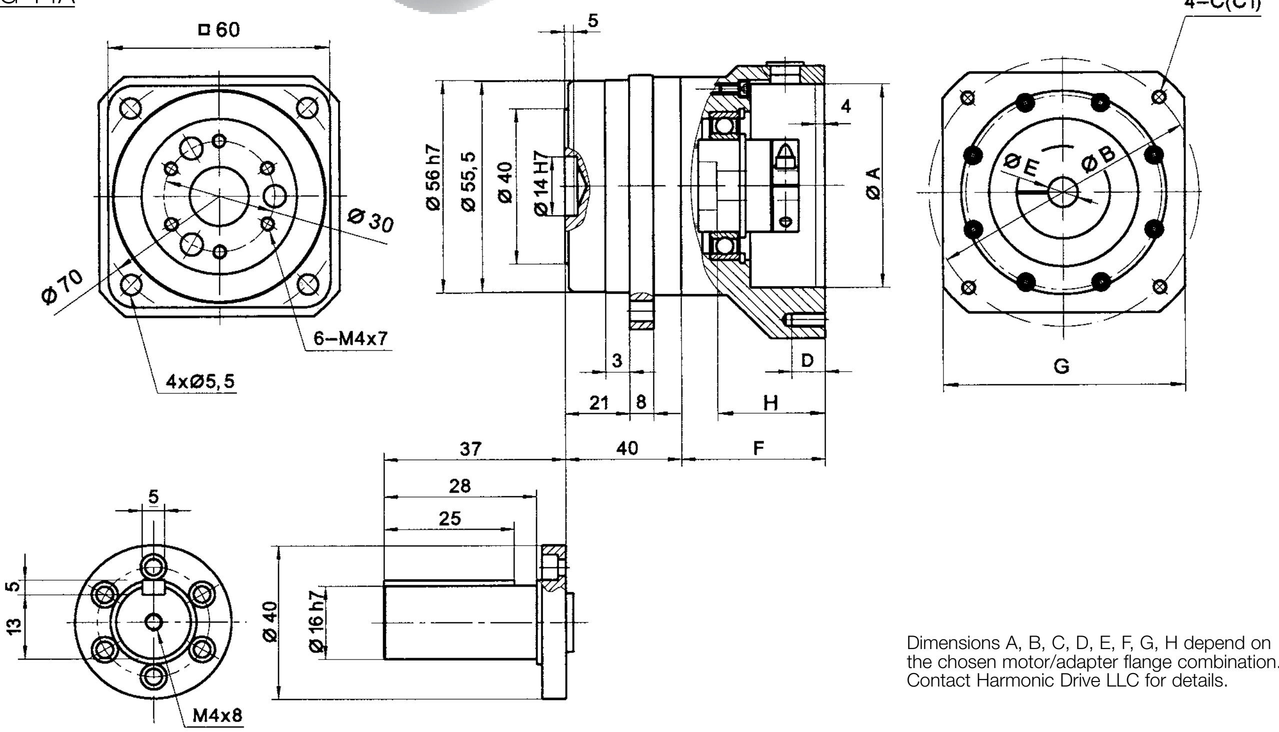


Fig. 7

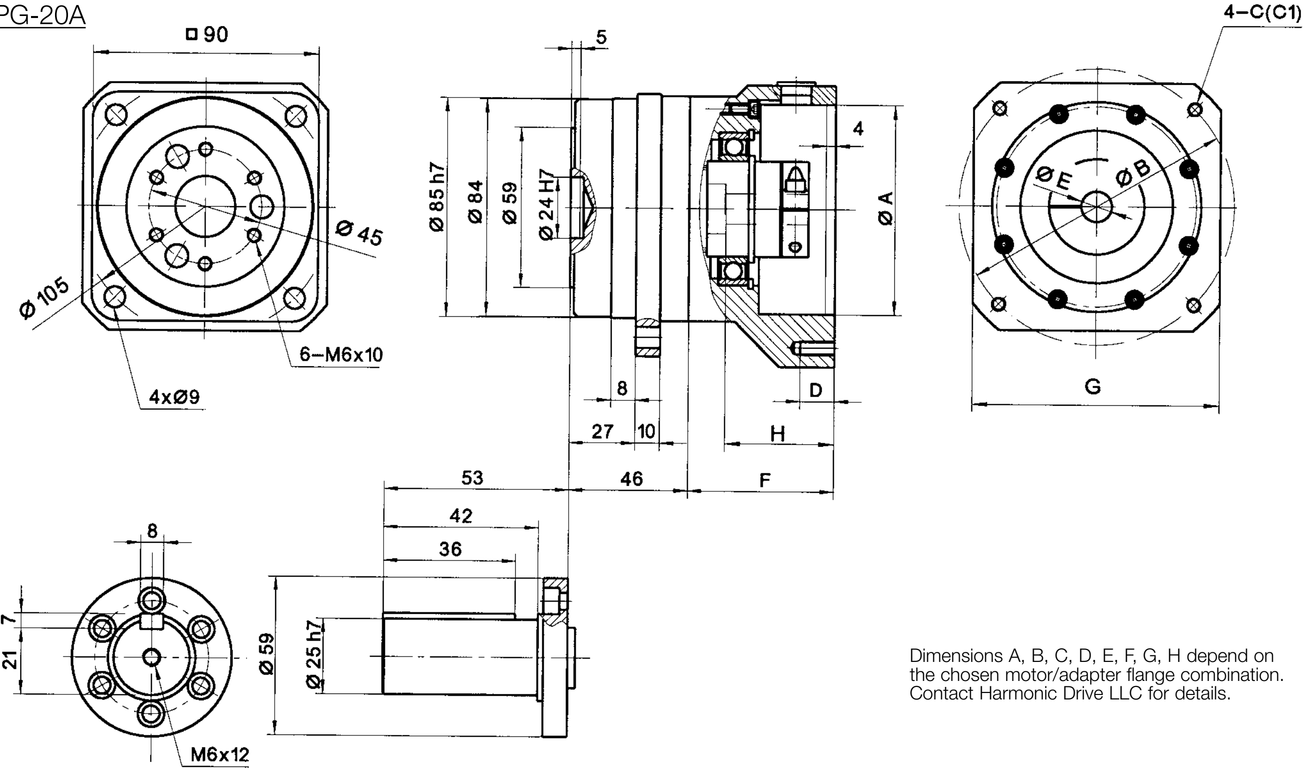
HPG-14A



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

Fig. 8

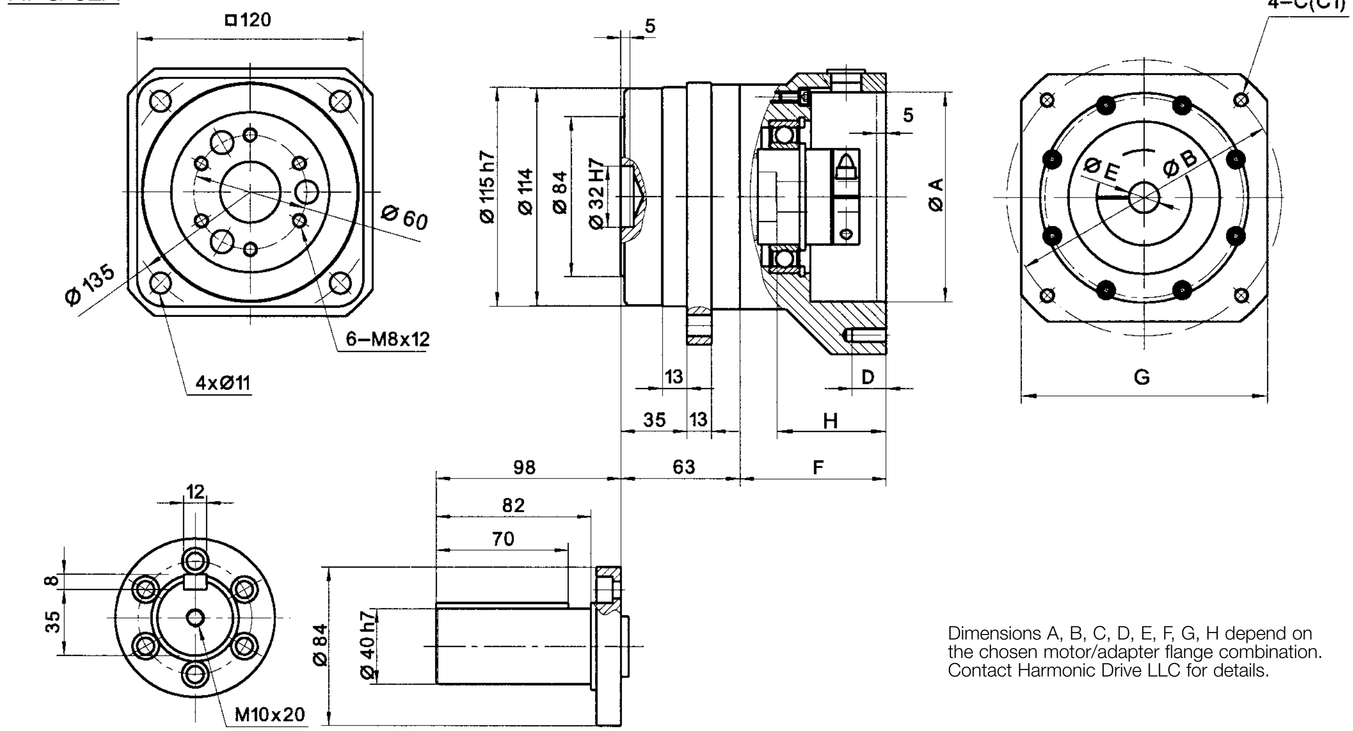
HPG-20A



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

Fig. 9

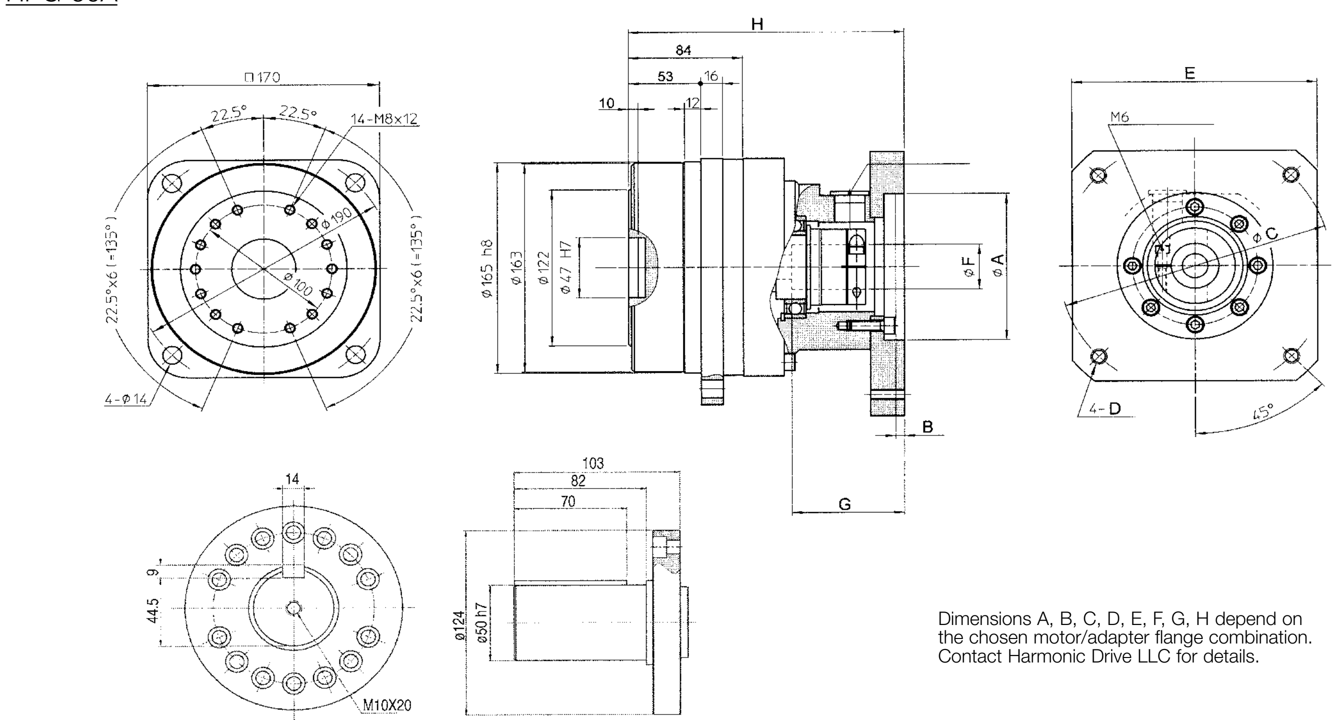
HPG-32A



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

Fig. 10

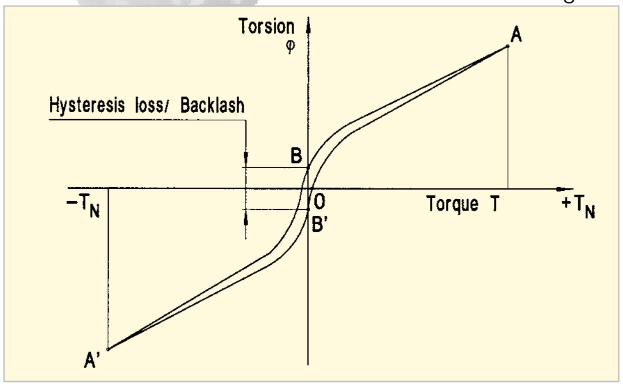
HPG-50A



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

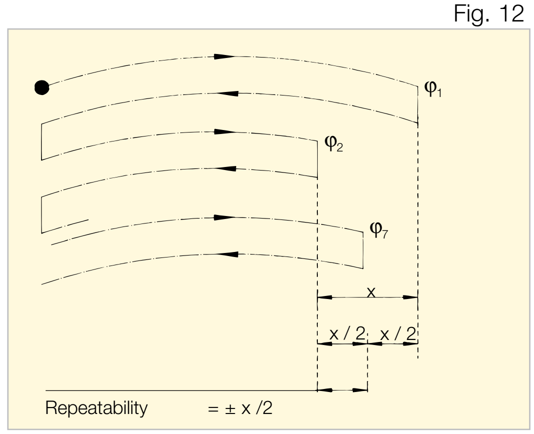
When a torque is applied to the output of a Harmonic Planetary® Gear HPG with the input rotationally locked, the torque-torsion relationship measured at the output typically follows the hysteresis curve 0-A-B-A'-B'-A, as shown in Fig. 11.

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.

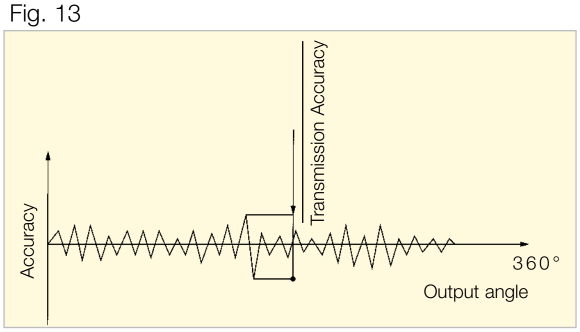
Fig. 12



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

Table 2

Accuracy of HPG Harmonic Planetary® Gears

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

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

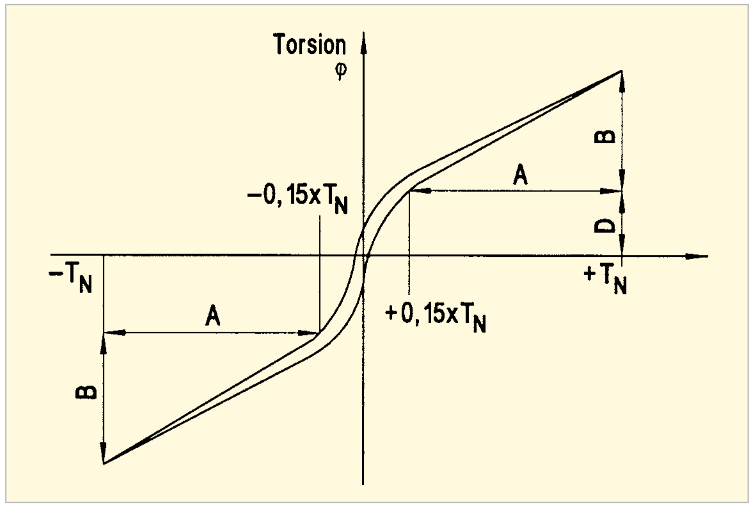


Table 3

Size	Torsional Stiffness = $\frac{A}{B}$		D [arc-min]			
			Backlash Class			
			BL3		BL1	
	[Nm/min]	[Nm/rad]	i = 5	i > 5	i = 5	i > 5
14	1.4	4700	2.2	2.7	1.1	1.7
20	5.4	18500	1.5	2.0	0.6	1.1
32	22.0	74100	1.3	1.7	0.5	1.0
50	66.6	230000	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

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

[Equation 1]

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

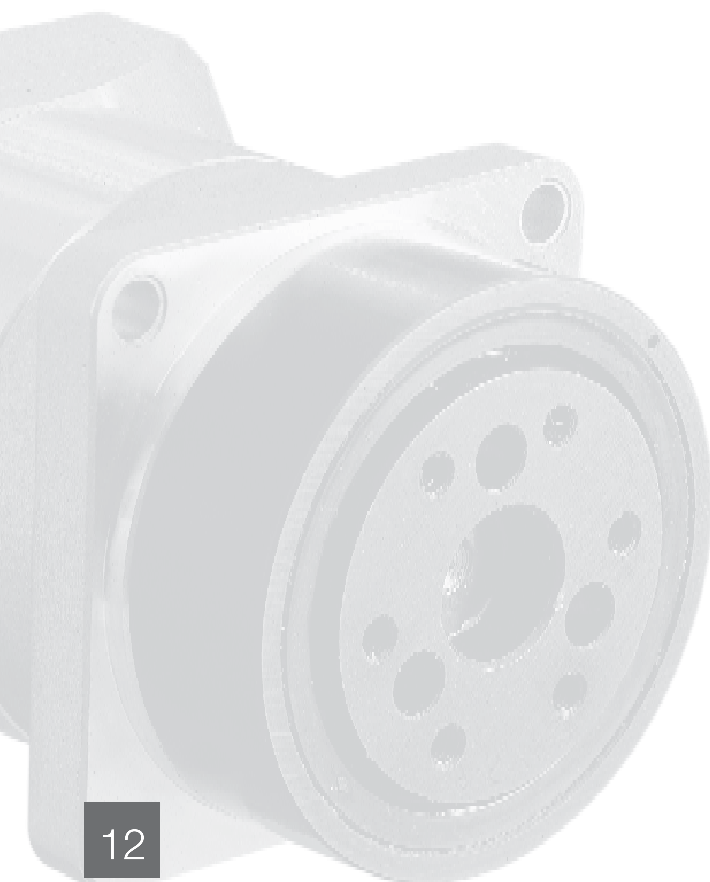


Table 4

Size	Ratio	No-load starting torque Ncm	No-load back driving torque Ncm	No-load* running torque at 3000 rpm Ncm
14	3	14	43	21
	5	8.6	43	10
	11	8.0	90	5
	15	2.4	110	3
	21	6.1	130	3
	33	4.5	150	2
	45	3.9	180	2
20	3	31	93	50
	5	18.6	93	28
	11	15.1	170	15
	15	12	180	11
	21	9.3	200	9
	33	7.1	240	6
	45	6.5	290	5
32	3	56	170	135
	5	33.3	170	73
	11	26.7	290	38
	15	25	370	29
	21	22.4	470	24
	33	17.2	570	14
	45	16.1	730	13
50	3	134	400	250
	5	80	400	130
	11	45	500	60
	15	40	600	47
	21	38	800	40
	35	30	1000	24
	45	29	1300	20

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

No-load Starting Torque

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

No-load Back Driving Torque

The no-load back driving torque is the torque required to commence 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.

No-load Running Torque

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

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]

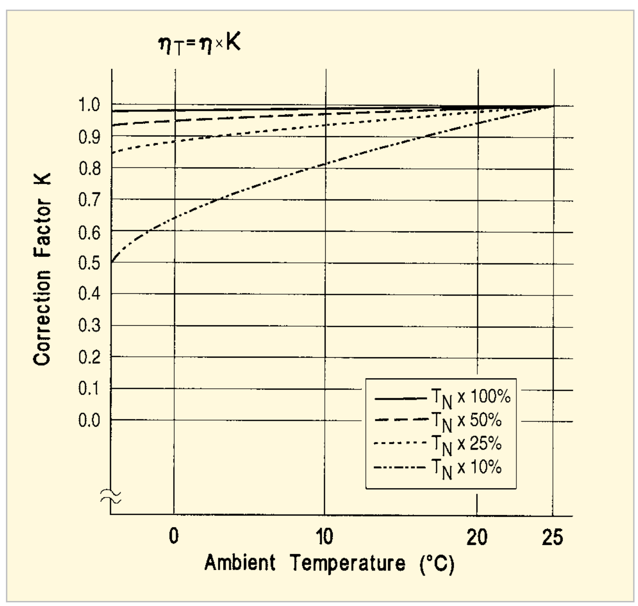


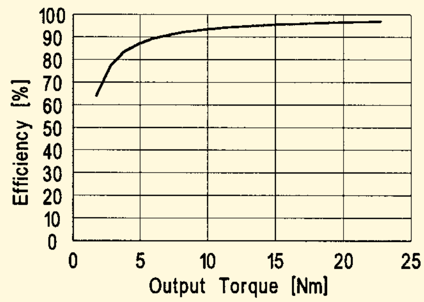
Fig. 15

Efficiency

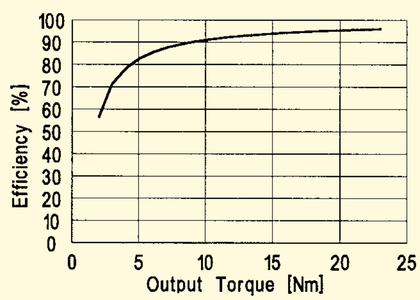
Size 14

Fig. 16

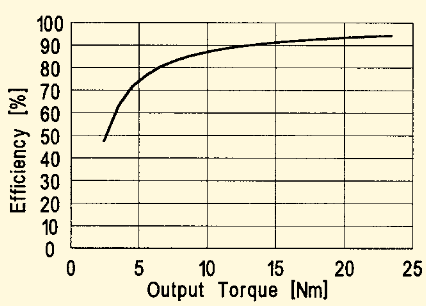
Ratio = 3 & 5



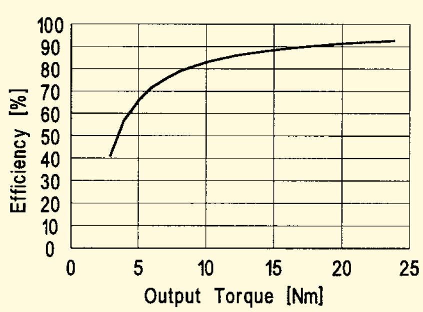
Ratio = 11



Ratio = 21



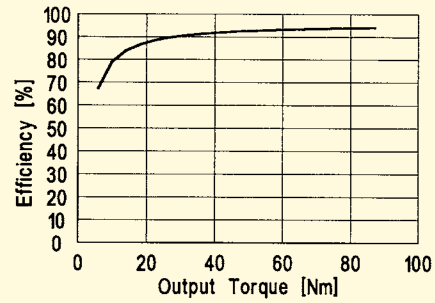
Ratio = 33, 45



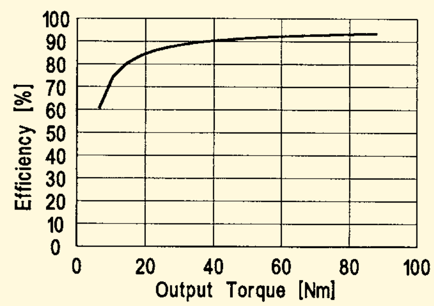
Size 20

Fig. 17

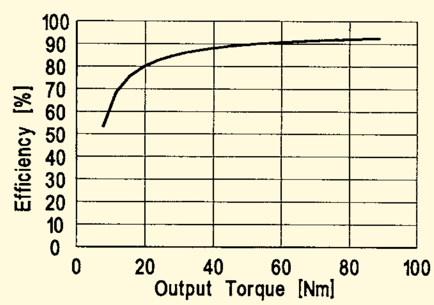
Ratio = 3 & 5



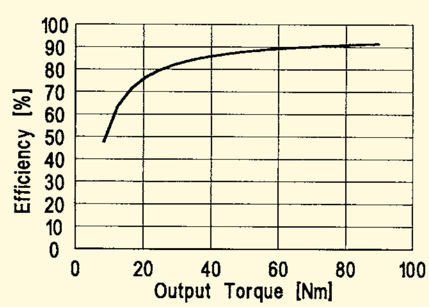
Ratio = 11



Ratio = 21



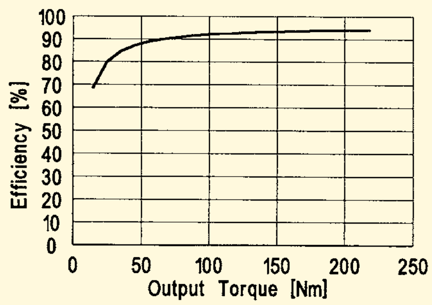
Ratio = 33, 45



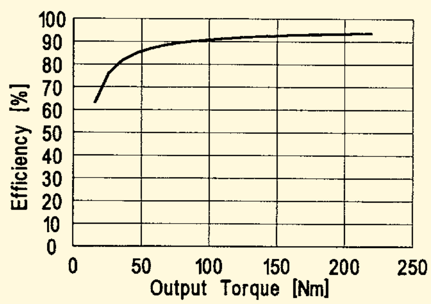
Size 32

Fig. 18

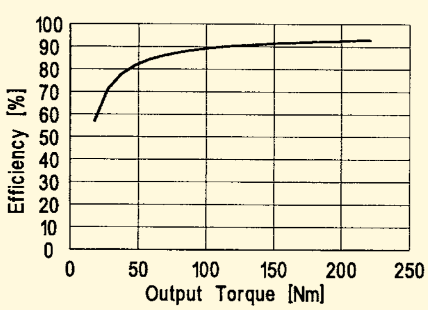
Ratio = 3 & 5



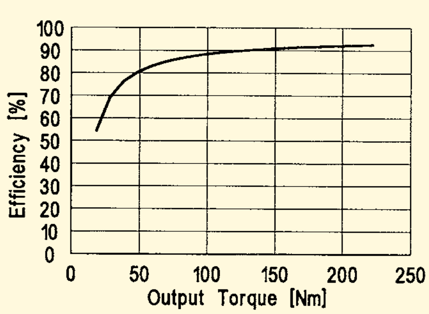
Ratio = 11



Ratio = 21



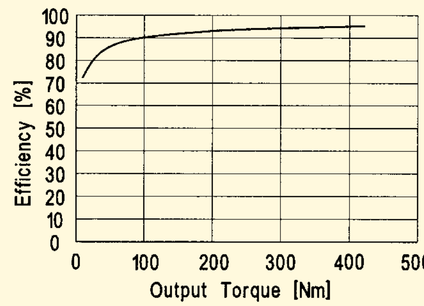
Ratio = 33, 45



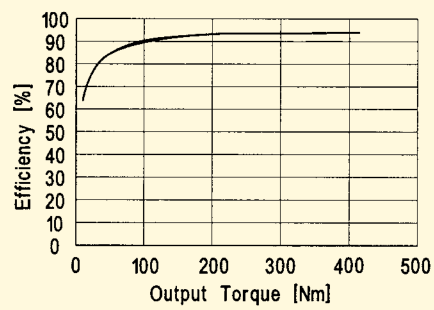
Size 50

Fig. 19

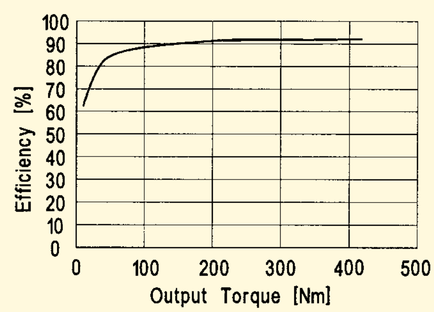
Ratio = 3 & 5



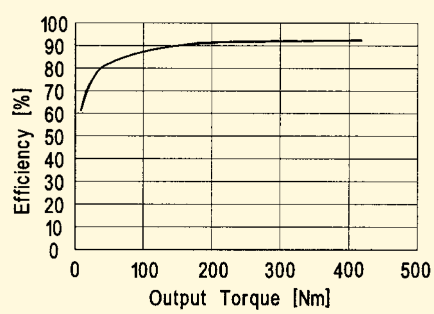
Ratio = 11



Ratio = 21



Ratio = 33, 45



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.

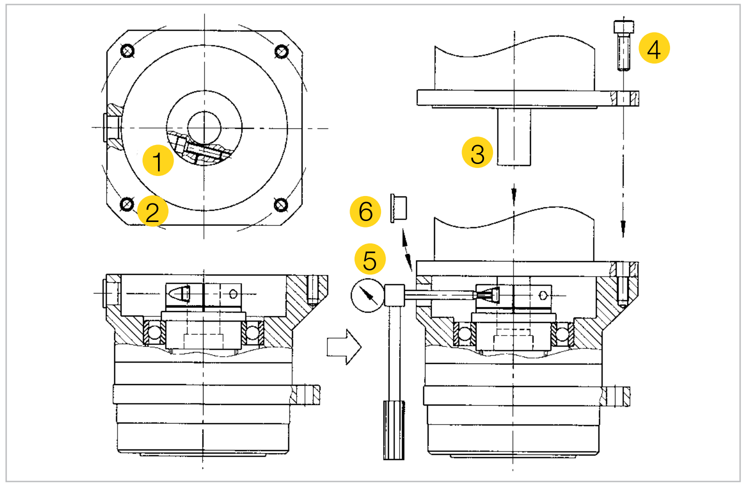
Table 5

Bolt Size							
Tightening Torque [Nm]	1.4	3.1	6.3	10.7	26.1	51.5	75.5

Table 6

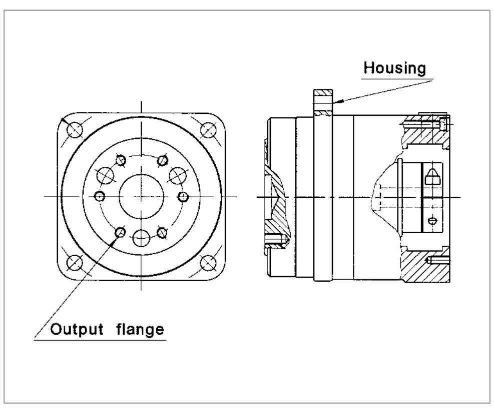
Bolt Size	M3	M4	M5	M6	M8
Tightening Torque [Nm]	2.0	4.5	9.0	15.3	37.2

Fig. 20



Assembly of the Housing and Output Flange

Fig. 21



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-14A	HPG-20A	HPG-32A	HPG-50A
Number of Bolts	4	4	4	4
Bolt Size	M5	M8	M10	M12
Bolt pitch diameter [mm]	70	105	135	190
Tightening Torque [Nm]	6.3	26.1	51.5	102.7
Torque transmitting capacity [Nm]	110	428	868	2033

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

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

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. Table 9 lists ratings and important dimensions for the output bearings.

Table 9

Size	Pitch Circle	Offset	Dynamic Load Rating	Stating Load Rating	Permissible Dynamic Tilting Moment	Permissible [2] Static Tilting Moment	Tilting Moment Stiffness	Permissible [1] Dynamic Axial Load	Permissible [1] Dynamic Radial Load	Permissible [3] Static Axial Load	Permissible [3] Static Radial Load
	ø d_p [m]	R [m]	C [N]	C_0 [N]	M [Nm]	M_0 [Nm]	K_B [Nm/arc min]	F_a [N]	F_r [N]	F_a [N]	F_r [N]
14	0.0405	0.011	5110	7060	27	95	5.9	1093	732	10697	4707
20	0.064	0.0115	10600	17300	145	369	39.2	2267	1519	26212	11533
32	0.085	0.014	20500	32800	258	929	68.7	4385	2938	49697	21867
50	0.123	0.019	41600	76000	797	3116	215	8899	5962	115152	50667

[1] These values are valid for the following conditions:

For F_a : M = 0; F_r = 0
F_r : M = 0; F_a = 0
n =140 rpm
L_{10} = 20000 h
f_w = 1.5

These values correspond to a static safety factor f_s = 1.5. For other values of f_s please refer to equations on page 21.

$$\gamma = \frac{M}{K_B}$$

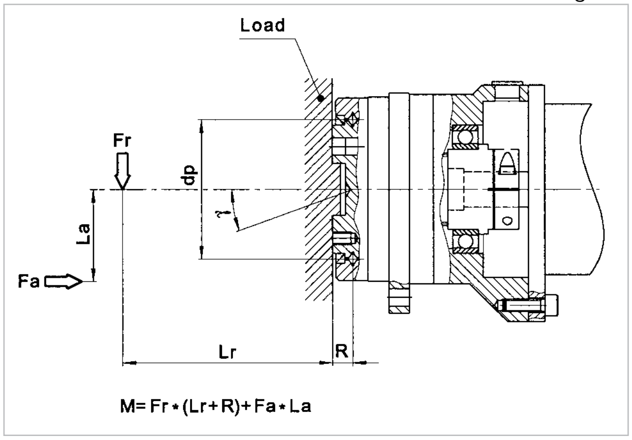
[Equation 3]

The angle of inclination of the output flange as a function of the tilting moment acting on the output bearing, can be calculated by means of equation 3:

with:

γ [arc min]	= Angle of inclination of the output flange
M [Nm]	= Tilting moment acting on the output bearing
K_B [Nm/min]	= Moment stiffness of the output bearing

Fig. 22



$$f_s = \frac{C_0}{P_0} \quad \text{with} \quad P_0 = x_0 \left(Fr + \frac{2M}{dp} \right) + Y_0 \cdot Fa$$

and so Equation 4]

$$M_0 = \frac{d_p \cdot C_0}{2 \cdot f_s}$$

[Equation 5]

Calculation of the Permissible Static Tilting Moment

In case of static load, the bearing load capacity can be determined as follows:

f_s	= Static load safety factor (f_s = 1.5 ... 3) (Tab. 10)
C_0	= Static load rating (Tab. 9)
x_0	= 1
y_0	= 0.44
P_0	= Static equivalent load
d_p	= Pitch circle diameter of the output bearing (Tab. 9)

Table 10

Rotation Conditions of Bearing	Lower limit value for f_s
Normal	≥ 1.5
Impacts	≥ 2
Vibrations	≥ 2
High Positioning Accuracy	≥ 3

Output Bearing Life

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

[Equation 6]

where:
L_{10} [h] = Operating life
n_{av} [rpm] = Actual output speed
C [N] = Dynamic load rating
P_c [N] = Dynamic equivalent load
fw = Operating factor

The operating life of the output bearing can be calculated using equation 6.

Table 11

Load Conditions	f_w
No impact loads or vibrations	1 ...1,2
Normal rotating, normal loads	1,2 ... 1,5
Impact loads and/or vibrations	1,5 ... 3

Calculation of the dynamic equivalent load

$$P_c = x \left(F_{rav} + \frac{2(F_{rav} \cdot (Lr+R)+F_{aav} \cdot La)}{dp}\right) + y \cdot F_{aav}$$

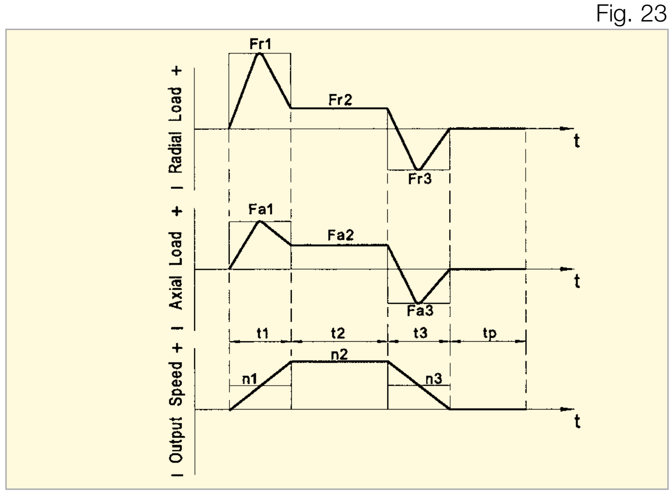
[Equation 7]

where:
F_{rav} [N] = Average of Radial force
F_{aav} [N] = Average of Axial force
d_p [m] = Pitch circle (Tab. 15)
x = Radial load factor (Tab. 18)
y = Axial load factor (Tab. 18)
Lr, La, R = see Fig. 23

$$F_{rav} = \sqrt[10/3]{\frac{n_1 t_1 |F_r 1|^{10/3} + n_2 t_2 |F_r 2|^{10/3} \ldots n_n t_n |F_r n|^{10/3}}{n_1 t_1 + n_2 t_2 + \ldots n_n t_n}}$$

[Equation 8]

Fig. 23



Please note:
Fr1 represents the maximum radial force acting for the duration t1. Fr3 represents the maximum radial force for the duration t_3. tp represents the pause time between cycles.

$$F_{aav} = \sqrt[10/3]{\frac{n_1 t_1 |F_a 1|^{10/3} + n_2 t_2 |F_a 2|^{10/3} \ldots n_n t_n |F_a n|^{10/3}}{n_1 t_1 + n_2 t_2 + \ldots n_n t_n}}$$

[Equation 9]

Please note:
Fa1 represents the maximum axial force acting for the duration t_1. Fa3 represents the maximum axial force for the duration t_3. t_p represents the pause time between cycles.

Calculation of the average output speed

$$n_{av} = \frac{n_1 t_1 + n_2 t_2 + \ldots n_n t_n}{t_1 + t_2 + \ldots t_n + t_p}$$

[Equation 10]

Table 12

Load Factors		x	y
$\dfrac{F_{aav}}{F_{rav} + 2\,(F_{rav}\ (Lr + R) + F_{aav} \cdot\ La)\ /d_p}$	≤ 1.5	1	0.45
$\dfrac{F_{aav}}{F_{rav} + 2\,(F_{rav}\ (Lr + R) + F_{aav} \cdot\ La)\ /d_p}$	> 1.5	0.67	0.67

Calculation of the Permissible Dynamic Tilting Moment M

Equation 11 is valid for a tilting moment load only. The values for M given in Table 9 must not be exceeded.

$$M \;=\; \frac{C \cdot d_p}{2 \cdot f_w} \cdot \left(\frac{10^6}{L_{10} \cdot 60 \cdot n_{av}}\right)^{3/10}$$

[Equation 11]

Permissible Axial Load

Equation 12 is valid for axial load only, Fig. 24. Values referring to typical load conditions are given in Table 9.

$$F_a \;=\; \frac{C}{f_w \cdot 0{,}67} \cdot \left(\frac{10^6}{L_{10} \cdot 60 \cdot n_{av}}\right)^{3/10}$$

[Equation 12]

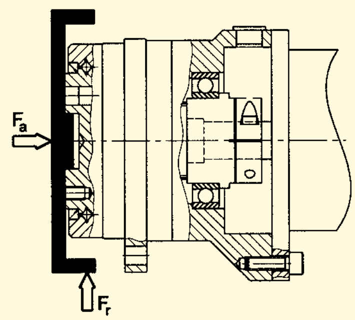
Permissible Radial Load

Equation 13 is valid for radial load only, Fig. 24. Values referring to typical load conditions are given in Table 9.

$$F_r \;=\; \frac{C}{f_w} \cdot \left(\frac{10^6}{L_{10} \cdot 60 \cdot n_{av}}\right)^{3/10}$$

[Equation 13]

Fig. 24



Life of Output Bearing for Oscillating Motion

The operating life with oscillating motion can be calculated using equation 14.

$$L_{oc} = \frac{10^6}{60 \cdot n_1} \cdot \frac{180}{\varphi} \cdot \left(\frac{C}{f_w \cdot P_c} \right)^{10/3}$$

[Equation 14]

where:

L_{oc} [h] = Operating life for oscillating motion

n_1 [cpm] = Number of oscillations/minute

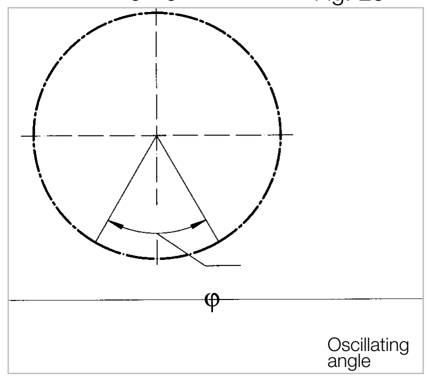
C [N] = Dynamic load rating

P_c [N] = Dynamic equivalent load

φ [Degree] = Oscillating angle

f_w = Load factor (Table 11)

Fig. 25



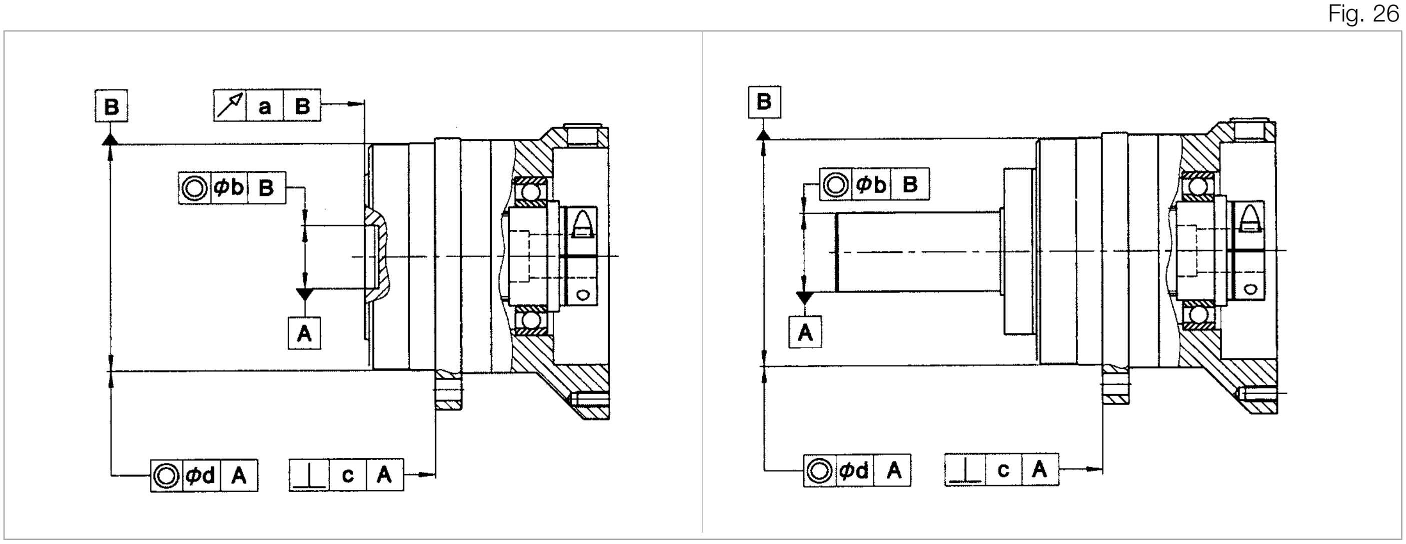
At oscillating angles < 5° fretting corrosion may occur due to insufficient lubrication.
In this case please contact Harmonic Drive LLC.

Output Bearing Tolerances

Table 13 [mm]

Size	Run-out a	Run-out b	Perpendicularity c	Concentricity d
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	0.050

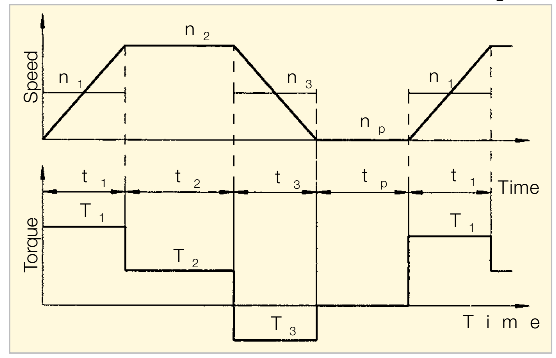
Fig. 26



Output Data

Fig. 27

Torque	$T_1 \ldots T_n$	[Nm]
Duration of Torque	$t_1 \ldots t_n$	[s]
Dwell time	t_p	[s]
Output Speeds	$n_1 \ldots n_n$	[rpm]
Emergency-Stop		
Momentary Peak Torque	T_k	[Nm]
Gear Ratio	R	
Is gearhead oriented with output flange/shaft pointing up? (yes/no)		



Please note:
All torques and speeds are used as scalar values (with a positive sign).

Calculation of the Average Output Torque

[Equation 15]

$T_{av} \leq T_A$
(Values for T_A see page 8)
[Equation 16]

No → Select a bigger size

Yes

Calculation of the Average Output Speed

$$n_{out\ av} = \frac{|n_1| \cdot t_1 + |n_2| \cdot t_2 + \ldots + |n_n| \cdot t_n}{t_1 + t_2 + \ldots + t_n + t_p}$$

[Equation 17]

Average Input Speed

$$n_{in\ av} = R \cdot n_{out\ av}$$

[Equation 18]

Permissible maximum input speed

$n_{in\ max} = n_{out\ max} \cdot R \leq$ Maximum Input Speed (page 8)

[Equation 19]

Load Limit 2, T_R

$T_{max} \leq T_R$

[Equation 20]

Load Limit 3, T_M

$T_k \leq T_M$

[Equation 21]

Allowable number of Momentary Peak Torques

$$N_k \max = 10^X$$

$$x = 8.5 - 1.5 \cdot \frac{T_k}{T_R}$$

$$T_k > T_R$$

[Equation 22]

Operating Life

$$L_{10} = 20\,000 \cdot \frac{3000}{n_{in\ av}} \cdot \left(\frac{T_N}{T_{av}}\right)^{10/3}$$

[Equation 23]

If gearhead is oriented with output flange/shaft pointing up, then select **"D" Gearhead Orientation** option in ordering code.
Otherwise select **"Z" Gearhead Orientation** option.

Selection Example

Output Data

T_1 = 40 Nm	t_1 = 0,3 s	n_1 = 125 rpm
T_2 = 32 Nm	t_2 = 3 s	n_2 = 250 rpm
T_3 = 20 Nm	t_3 = 0,4 s	n_3 = 125 rpm
	t_p = 4 s	
T_k = 200 Nm		
Gear Ratio	R = 11	

Is gearhead oriented with output flange/shaft pointing up? yes

Based on these conditions,
a HPG-20-11 is tentatively selected

Load limit 1, Calculation of the Average Output Torque T_{av}

$$T_{av} = \sqrt[10/3]{\frac{125\text{ rpm} \cdot 0.3\text{ s} \cdot (40\text{ Nm})^{10/3} + 250\text{ rpm} \cdot 3\text{ s} \cdot (32\text{ Nm})^{10/3} + 125\text{ rpm} \cdot 0.4\text{ s} \cdot (20\text{ Nm})^{10/3}}{125\text{ rpm} \cdot 0.3\text{ s} + 250\text{ rpm} \cdot 3\text{ s} + 125\text{ rpm} \cdot 0.4\text{ s}}}$$

T_{av} = 32 Nm ≤ T_A = 45 Nm

Selected size

HPG-20-11 Satisfies this condition

yes

Calculation of the Average Output Speed

$$n_{out\ av} = \frac{125\text{ min}^{-1}\cdot 0.3\text{ s} + 250\text{ min}^{-1}\cdot 3\text{ s} + 125\text{ min}^{-1}\cdot 0.4\text{ s}}{0.3\text{ s} + 3\text{ s} + 0.4\text{ s} + 4\text{ s}} = 109\text{ min}^{-1}$$

Average Input Speed

$n_{in\ av}$ = 11 · 109 rpm = 1199 rpm

Permissible Maximum Input Speed

$n_{in\ max}$ = 250 rpm· 11 = 2750 rpm ≤ 6000 rpm

Load Limit 2, T_R

T_{max} = 40 Nm ≤ T_R = 100 Nm

Load Limit 3, T_M

T_k = 200 Nm ≤ T_M = 217 Nm

Allowable number of Momentary Peak Torques

$N_{k\ max} = 10^x$

$$x = 8.5 - 1.5\ \frac{200\text{ Nm}}{100\text{ Nm}} = 5.5$$

$N_{k\ max} = 10^{5.5}$ = 316227

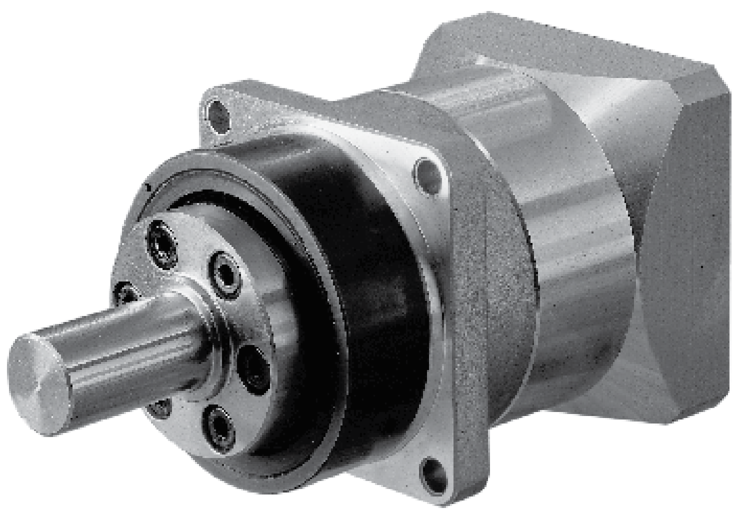
Operating Life

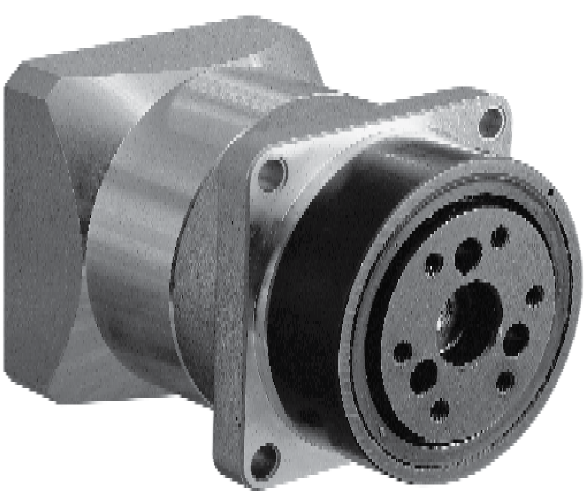
$$L_{10} = 20000 \cdot \frac{3000\text{ rpm}}{1199\text{ rpm}} \cdot \left(\frac{20\text{ Nm}}{32\text{ Nm}}\right)^{10/3} = 10445\text{ h}$$

Select **“D” Option** in ordering code since the gearhead is oriented with the output flange/shaft pointing up.

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	**A:** Latest 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.	**BL1 =** Backlash of less than 1 arc-min. special specification (Model No.14-65) **D =** Input side shield bearing is a contact shield type (DDU) **NR6 =** Silent specification Backlash of less than 6 arc-min (Model No.14-50)
	14		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			





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