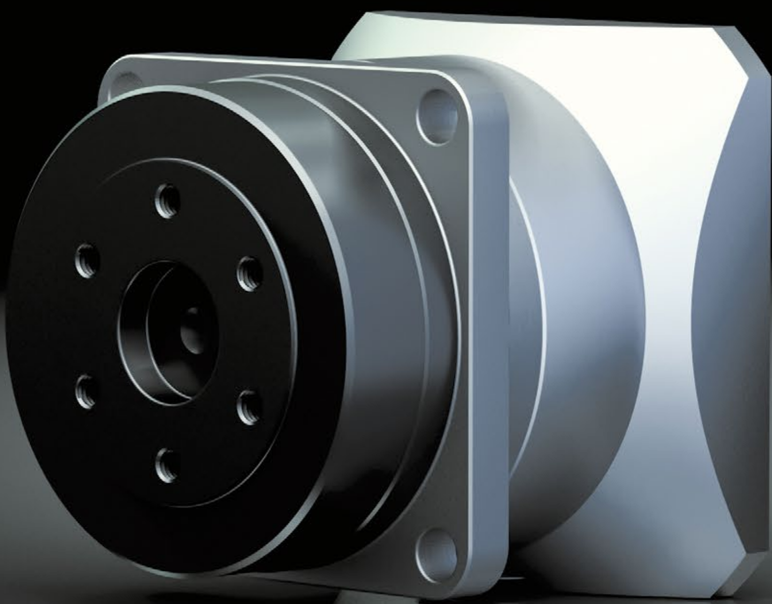
Engineering Data
HPGP Harmonic Planetary Gears

Harmonic Drive AG



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Contents

1. General

About this documentation
This document contains safety instructions, technical data and operation rules for products of Harmonic Drive AG. The documentation is aimed at planners, project engineers, commissioning engineers and machine manufacturers, offering support during selection and calculation of the servo actuators, servo motors and accessories.

Rules for storage
Please keep this document for the entire life of the product, up to its disposal. Please hand over the documentation when re-selling the product.

Additional documentation
For the configuration of drive systems using the products of Harmonic Drive AG, you may require additional documents. Documentation is provided for all products offered by Harmonic Drive AG and can be found in pdf format on the website.

www.harmonicdrive.de

Third-party systems
Documentation for parts supplied by third party suppliers, associated with Harmonic Drive® components, is not included in our standard documentation and should be requested directly from the manufacturers.

Before commissioning products from Harmonic Drive AG with servo drives, we advise you to obtain the relevant documents for each device.

Your feedback
Your experiences are important to us. Please send suggestions and comments about the products and documentation to:

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1.1 Description of Safety Alert Symbols

Symbol	**Meaning**
DANGER	Indicates an imminent hazardous situation. If this is not avoided, death or serious injury could occur.
WARNING	Indicates a possible hazard. Care should be taken or death or serious injury may result.
ATTENTION	Indicates a possible hazard. Care should be taken or slight or minor injury may result.
ADVICE	Describes a possibly harmful situation. Care should be taken to avoid damage to the system and surroundings.
INFORMATION	This is not a safety symbol. This symbol indicates important information.
	Warning of a general hazard. The type of hazard is determined by the specific warning text.
	Warning of dangerous electrical voltage and its effects.
	Beware of hot surfaces.
	Beware of suspended loads.
	Precautions when handling electrostatic sensitive components.

1.2 Disclaimer and Copyright

We have checked the contents of this document. Since errors cannot be ruled out entirely, we do not accept liability for mistakes which may have occurred. Notification of any mistake or suggestions for improvements will be gratefully received and any necessary correction will be included in subsequent editions.

2. Safety and Installation Instructions

Please take note of the information and instructions in this document. Specialy designed models may differ in technical detail. If in doubt, we strong recommend that you contact the manufacturer, giving the type designation and serial number for clarification.

2.1 Hazards

⚠ DANGER

Electric products have dangerous live and redating parts. All work during connection, operation, repair and disposal must be carried out by qualified personnel as described in the standards EN50110-1 and IEC 60364! Before starting any work, and especially before opening covers, the actuator must be properly isolated. In addition to the main circuits, the user also has to pay attention to any auxilliary circuits.

Observing the five safety rules:
- Disconnect mains
- Prevent reconnection
- Test for absence of harmful voltages
- Ground and short circuit
- Cover or close off nearby live parts

The measures taken above must only be withdrawn when the work has been completed and the device is fully assembled. Improper handling can cause damage to persons and property. The respective national, local and factory specific regulations must be adhered to.

⚠ DANGER

Electric, magnetic and electromagnetic fields are dangerous, in particular for persons with pacemakers, implants or similiar. Vulnerable groups must not be in the immediate vicinity of the products themselves.

⚠ DANGER

Built-in holding brakes alone are not functional safe. Particularly with unsupported vertical axes, the functional safety and security can only be achieved with additional, external mechanical brakes.

⚠ WARNING

The successful and safe operation of gears, products requires proper transport, storage and assembly as well as correct operation and maintenance.

⚠ ATTENTION

The surface temperature of gears, motors and actuators can exceed 55 degrees Celsius. The hot surfaces should not be touched.

ADVICE

Movement and lifting of products with a mass > 20 Kg should only be carried out with suitable lifting gear.

ADVICE

Cables must not come into direct contact with hot surfaces.

INFORMATION

Special versions of drive systems and motors may have differing specifications. Please consider all data sheet, catalogues and offers etc. sent concerning these special versions.

2.2 Intended Purpose

The Harmonic Drive® products are intended for industrial or commercial applications. They comply with the relevant parts of the harmonised EN 60034 standards series.

Typical areas of application are robotics and handling, machine tools, packaging and food machines and similar machines.

The products may only be operated within the operating ranges and environmental conditions shown in the documentation (altitude, degree of predection, temperature range etc).
Before plant and machinery which have Harmonic Drive® products built into them are commissioned, the compliance must be established with the Machinery Directive, Low Voltage Directive and EMC guidelines.

Plant and machinery with inverter driven motors must satisfy the predection requirements in the EMC guidelines. It is the responsibility of the installer to ensure that installation is undertaken correctly.
Signal and power lines must be shielded. The EMC instructions from the inverter manufacturer must be observed in order that installation meets the EMC regulations.

2.3 Non Intended Purpose

The use of products outside the areas of application mentioned above or, inter alia, other than in the operating areas or environmental conditions described in the documentation is considered as non-intended purpose.

ADVICE

The following areas of application are, inter alia, those considered as non-intended purpose:

- Aerospace
- Areas at risk of explosion
- Machines specially constructed or used for a nuclear purpose whose breakdown might lead to the emission of radio-activity
- Vacuum
- Machines for domestic use
- Medical equipment which comes into direct contact with the human body
- Machines or equipment for transporting or lifting people
- Special devices for use in annual markets or leisure parks

2.4 Declaration of Conformity

Harmonic Drive® gears are components for installation in machines as defined by the machine directive 2006/42/EG. Commissioning is prohibited until such time as the end product has been proved to conform to the provisions of this directive.

Essential health and safety requirements were considered in the design and manufacture of these gear component sets. This simplifies the implementation of the machinery directive by the end user for the machinery or the partly completed machinery. Commissioning of the machine or partly completed machine is prohibited until the final product conforms to the EC Machinery Directive.

3. Technical Description

3.1 Product Description

Enhanced performance with Permanent Precision®

The HPGP Series Planetary Gears are available in six sizes with gear ratios between 4 and 45:1 offering repeatable peak torques from 10 to 2920 Nm. The precision output bearing with high tilting rigidity enables the direct introduction of high payloads without further support and thus permits simple and space saving designs.

HPGP enhanced series of Planetary Gears are available in three versions: with output flange, with smooth output shaft and output shaft with keyway.

Standard servo motors can be simply coupled to our Planetary Gears.
Gearbox and motor together form a compact and lightweight system capable of withstanding high payloads ensuring stable machine properties with short cycle times are guaranteed.

3.2 Ordering Code

Table 9.1

Series	Size	Ratio							Version	Code for motor adaptation	Backlash class	Special design
HPGP	11A		5			21	37	45	F0, J20, J60	Depending on motor type	BL3	According to customer requirements
	14A		5	11	15	21	33	45	F0 J2 J6		BL1 BL3	
	20A		5	11	15	21	33	45				
	32A		5	11	15	21	33	45				
	50A		5	11	15	21	33	45				
	65A	4	5	12	15	20	25					
Ordering code												
HPGP	**- 14A**	**-**		**11**				**-**	**F0**	**- E14.20**	**- BL1**	**- SP**

Table 9.2

Output	
Ordering code	**Description**
F0	Output flange
J2/J20	Output shaft without key
J6/J60	Output shaft with key

Table 9.3

Backlash class	
Ordering code	**Backlash**
BL1	≤ 1 arcmin
BL3	≤ 3 arcmin

Clarification of the technical data can be found in the Glossary

3.3 Technical Data

3.3.1 General Technical Data

Table 10.1

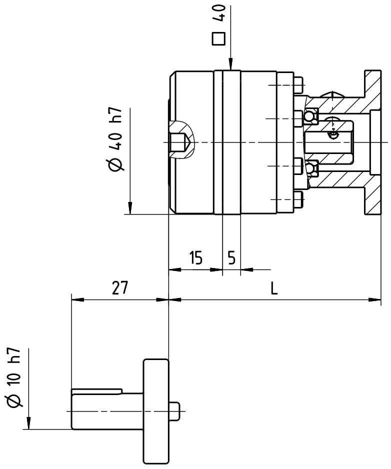
	Unit	HPGP-11				HPGP-14					
Ratio	i [ ]	5	21	37	45	5	11	15	21	33	45
Repeatable peak torque	T_R [Nm]	10	13	13	13	30	30	30	30	30	30
Average torque	T_A [Nm]	6.7	8.0	8.0	8.0	17	20	20	20	20	20
Rated torque	T_N [Nm]	3.4	4.6	4.6	4.6	7.8	10	12	12	13	13
Momentary peak torque	T_M [Nm]	20	20	20	20	56	56	56	56	56	56
Maximum input speed (grease lubrication)	$n_{in\,(max)}$ [rpm]	10000				6000					
Average input speed (grease lubrication)	$n_{av\,(max)}$ [rpm]	3000				3000					
Moment of inertia with output flange (F0)	J_{in} [x10^{-6} kgm^2]	0.24	0.18	0.07	0.05	1.7	1.8	1.6	0.90	0.29	0.27
Moment of inertia with output shaft (Jx)	J_{in} [x10^{-6} kgm^2]	0.40	0.19	0.07	0.05	2.3	1.9	1.7	0.93	0.30	0.28
Weight with output flange (F0)	m [kg]	0.14	0.20			0.42	0.51				
Weight with output shaft (Jx)	m [kg]	0.18	0.24			0.54	0.63				
Transmission accuracy	[arcmin]	< 5				< 4					
Repeatability	[arcmin]	< ±0.5				< ±0.35					
Backlash	[arcmin]	≤ 3				≤ 3 or ≤ 1					
Torsional Stiffness	K_3 [x10^3 Nm/rad]	2.2				4.7					
Ambient operating temperature	[°C]	0 ... 40				0 ... 40					
Output bearing											
Dynamic radial load	$F_{R\,dyn\,(max)}$ [N]	280	440	520	550	470	600	650	720	830	910
Dynamic axial load	$F_{A\,dyn\,(max)}$ [N]	430	660	780	830	700	890	980	1080	1240	1360
Dynamic tilting moment	$M_{dyn\,(max)}$ [Nm]	9.5				32.3					

Table 10.2

	Unit	HPGP-20						HPGP-32					
Ratio	i [ ]	5	11	15	21	33	45	5	11	15	21	33	45
Repeatable peak torque	T_R [Nm]	133	133	133	133	133	133	400	400	400	400	400	400
Average torque	T_A [Nm]	47	60	70	73	80	80	200	226	226	226	266	266
Rated torque	T_N [Nm]	21	26	32	33	39	39	87	104	122	130	143	143
Momentary peak torque	T_M [Nm]	217	217	217	217	217	217	650	650	650	650	650	650
Maximum input speed (grease lubrication)	$n_{in\,(max)}$ [rpm]	6000						6000					
Average input speed (grease lubrication)	$n_{av\,(max)}$ [rpm]	3000						3000					
Moment of inertia with output flange (F0)	J_{in} [x10^{-6} kgm^2]	16	17	15	7.1	2.9	2.2	80	100	74	35	17	12
Moment of inertia with output shaft (Jx)	J_{in} [x10^{-6} kgm^2]	20	17	16	7.3	3.0	2.3	110	110	77	37	17	12
Weight with output flange (F0)	m [kg]	1.2	1.5	1.5	1.5	1.6	1.5	3.0	3.7	3.7	3.7	4.0	3.7
Weight with output shaft (Jx)	m [kg]	1.6	1.9	1.9	1.9	2.0	1.9	4.4	5.1	5.1	5.1	5.4	5.1
Transmission accuracy	[arcmin]	< 4						< 4					
Repeatability	[arcmin]	< ±0.25						< ±0.25					
Backlash	[arcmin]	≤ 3 or ≤ 1						≤ 3 or ≤ 1					
Torsional Stiffness	K_3 [x10^3 Nm/rad]	18						74					
Ambient operating temperature	[°C]	0 ... 40						0 ... 40					
Output bearing													
Dynamic radial load	$F_{R\,dyn\,(max)}$ [N]	980	1240	1360	1510	1729	1890	1900	2410	2640	2920	3340	3670
Dynamic axial load	$F_{A\,dyn\,(max)}$ [N]	1460	1850	2030	2250	2580	2830	2830	3590	3940	4360	4990	5480
Dynamic tilting moment	$M_{dyn\,(max)}$ [Nm]	183						452					

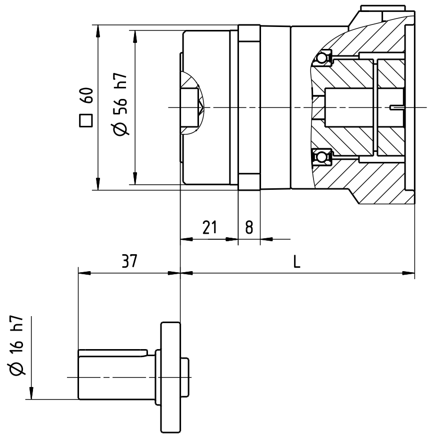
3.3.2 Dimensions

Illustration 11.1 HPGP-11 [mm]



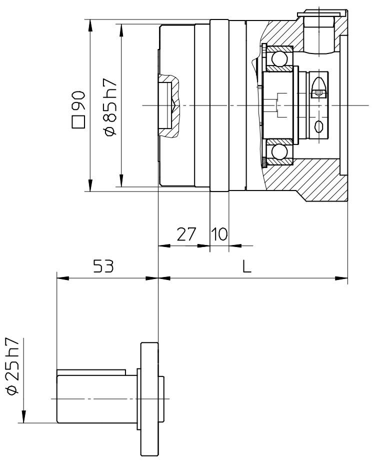
[1] L = Depending on motor type

Illustration 11.2 HPGP-14 [mm]



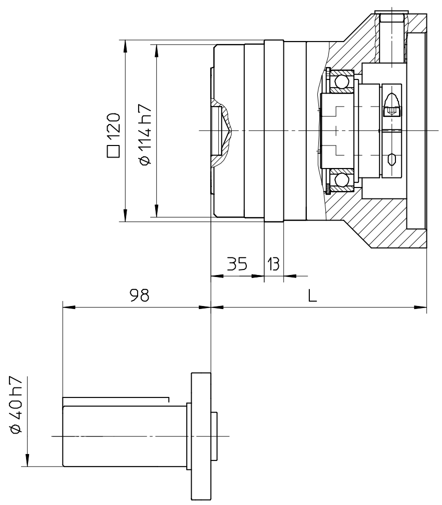
[1] L = Depending on motor type

Illustration 11.3 HPGP-20 [mm]



[1] L = Depending on motor type

Illustration 11.4 HPGP-32 [mm]



[1] L = Depending on motor type

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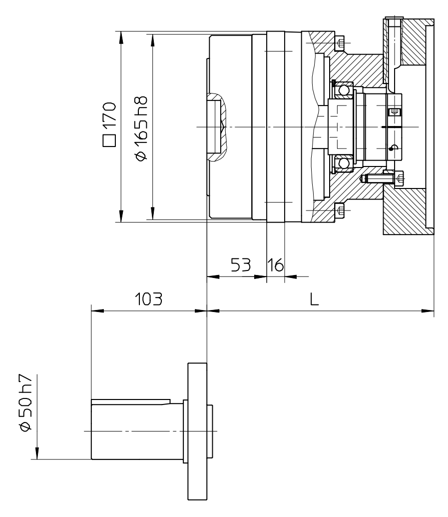
Table 12.1

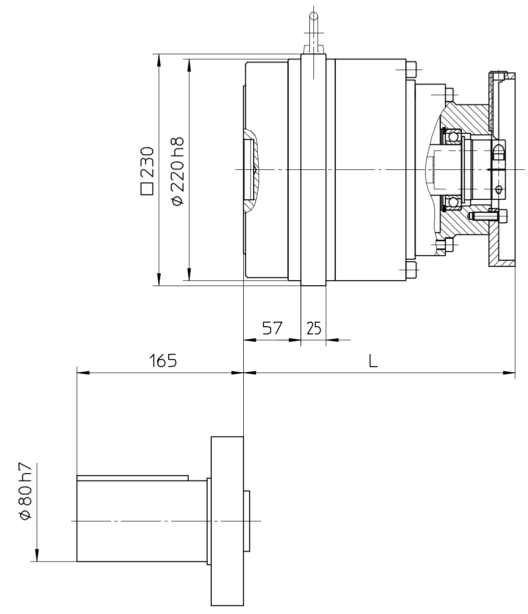
	Unit	HPGP-50						HPGP-65					
Ratio	i [ ]	5	11	15	21	33	45	4	5	12	15	20	25
Repeatable peak torque	T_R [Nm]	1130	1130	1130	1130	1130	1130	2920	2920	2920	2920	2920	2920
Average torque	T_A [Nm]	452	532	600	665	665	665	1200	1330	1460	1730	2000	2000
Rated torque	T_N [Nm]	226	266	306	346	359	359	605	705	798	971	1060	1130
Momentary peak torque	T_M [Nm]	1850	1850	1850	1850	1850	1850	4500	4500	4500	4500	4500	4500
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	4500						2500	3000				
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	2000						2000					
Moment of inertia with output flange (F0)	J_{in} [x10^{-6} kgm²]	490	400	350	160	72	50	3100	2100	2000	1900	730	680
Moment of inertia with output shaft (Jx)	J_{in} [x10^{-6} kgm²]	620	420	370	170	75	52	4600	3000	2200	2000	780	720
Weight with output flange (F0)	m [kg]	10	12					22		37			
Weight with output shaft (Jx)	m [kg]	13	15					32		47			
Transmission accuracy	[arcmin]	< 3						< 3					
Repeatability	[arcmin]	< ±0.25						< ±0.25					
Backlash	[arcmin]	≤ 3 or ≤ 1						≤ 3 or ≤ 1					
Torsional Stiffness	K_3 [x10³ Nm/rad]	470						1300					
Ambient operating temperature	[°C]	0 … 40						0 … 40					
Output bearing													
Dynamic radial load	$F_{R\ dyn\ (max)}$ [N]	4350	5500	6050	6690	7660	8400	8860	9470	12300	13100	14300	15300
Dynamic axial load	$F_{A\ dyn\ (max)}$ [N]	6490	8220	9030	9980	11400	12500	13200	14100	18300	19600	21400	22900
Dynamic tilting moment	$M_{dyn\ (max)}$ [Nm]	1076						3900					

Illustration 13.1 HPGP-50 [mm]



[1] L = Depending on motor type

Illustration 13.2 HPGP-65 [mm]



[1] L = Depending on motor type

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3.3.3 Accuracy

Table 14.1

Size			11	14	20	32	50	65
Backlash	Standard BL3	[arcmin]	≤ 3					
	Reduced BL1	[arcmin]	-	≤ 1				
Repeatability		[arcsec]	< ± 30	< ± 20	< ± 15	< ± 15	< ± 15	< ± 15
Transmission accuracy		[arcmin]	< 5	< 4	< 4	< 4	< 3	< 3

3.3.4 Torsional Stiffness

Table 14.2

Size		11	14	20	32	50	65
Torsional Stiffness	[Nm/arcmin]	0.64	1.40	5.24	21.5	136.7	378.2
	[x10^3 Nm/rad]	2.2	4.7	18	74	470	1300

3.3.5 Bearings

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, so ensuring 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 14.3 and table 15.1 lists ratings and important dimensions for the output bearings.

Output bearing

Table 14.3

Size		11	14	20	32	50	65
Pitch circle ø	d_p [m]	0.0275	0.0405	0.0640	0.0850	0.1230	0.1700
Offset	R [m]	6	11	11.5	14	19	23
Dynamic load rating	C [N]	3116	5110	10600	20500	41600	90600
Static load rating	C_0 [N]	4087	7060	17300	32800	76000	148000
Permissible dynamic tilting moment [1]	M [Nm]	9.5	32.3	183	452	1076	3900
Permissible static tilting moment [2]	M_0 [Nm]	37	95	369	929	3116	8387
Tilting moment stiffness	K_B [Nm/arcmin]	2.55	8.8	49	123	291	1060
Permissible static axial load [3]	F_a [N]	6192	10697	26212	49697	115152	224242
Permissible static radial load [3]	F_r [N]	2725	4707	11533	21867	50667	98667

Table 15.1

Ratio	Permissible dynamic axial load		Size 11	14	20	32	50	65
3	axial load 1)	F_a [N]	-	600	1250	2430	5570	-
	radial load 1)	F_r [N]	-	400	840	1630	3700	-
4	axial load 1)	F_a [N]	-	-	-	-	-	13200
	radial load 1)	F_r [N]	-	-	-	-	-	8860
5	axial load 1)	F_a [N]	430	700	1410	2830	6490	14100
	radial load 1)	F_r [N]	280	470	980	1900	4350	9470
9	axial load 1)	F_a [N]	510	-	-	-	-	-
	radial load 1)	F_r [N]	340	-	-	-	-	-
11	axial load 1)	F_a [N]	-	890	1850	3590	8220	-
	radial load 1)	F_r [N]	-	600	1240	2410	5500	-
12	axial load 1)	F_a [N]	-	-	-	-	-	18300
	radial load 1)	F_r [N]	-	-	-	-	-	12300
15	axial load 1)	F_a [N]	-	980	2030	3940	9030	19600
	radial load 1)	F_r [N]	-	650	1360	2640	6050	13100
20	axial load 1)	F_a [N]	-	-	-	-	-	21400
	radial load 1)	F_r [N]	-	-	-	-	-	14300
21	axial load 1)	F_a [N]	660	1080	2250	4360	9980	-
	radial load 1)	F_r [N]	440	720	1510	2920	6690	-
25	axial load 1)	F_a [N]	-	-	-	-	-	22900
	radial load 1)	F_r [N]	-	-	-	-	-	15300
33	axial load 1)	F_a [N]	-	1240	2580	4990	11400	-
	radial load 1)	F_r [N]	-	830	1729	3340	7660	-
37	axial load 1)	F_a [N]	780	-	-	-	-	-
	radial load 1)	F_r [N]	520	-	-	-	-	-
40	axial load 1)	F_a [N]	-	-	-	-	-	26300
	radial load 1)	F_r [N]	-	-	-	-	-	17600
45	axial load 1)	F_a [N]	830	1360	2830	5480	12500	-
	radial load 1)	F_r [N]	550	910	1890	3670	8400	-
50	axial load 1)	F_a [N]	-	-	-	-	-	28200
	radial load 1)	F_r [N]	-	-	-	-	-	18900

1) These values are valid for the following conditions:

M : $F_a = 0$ $F_r = 0$
F_a : $M = 0$; $F_r = 0$
F_r : $M = 0$; $F_a = 0$
n_{Input} = 3000 rpm
L_{10} = 20000 h
f_w = 1.5

2)3) These values correspond to a static safety factor f_s =1.5.
For other values of f_s please refer to page 26.3.

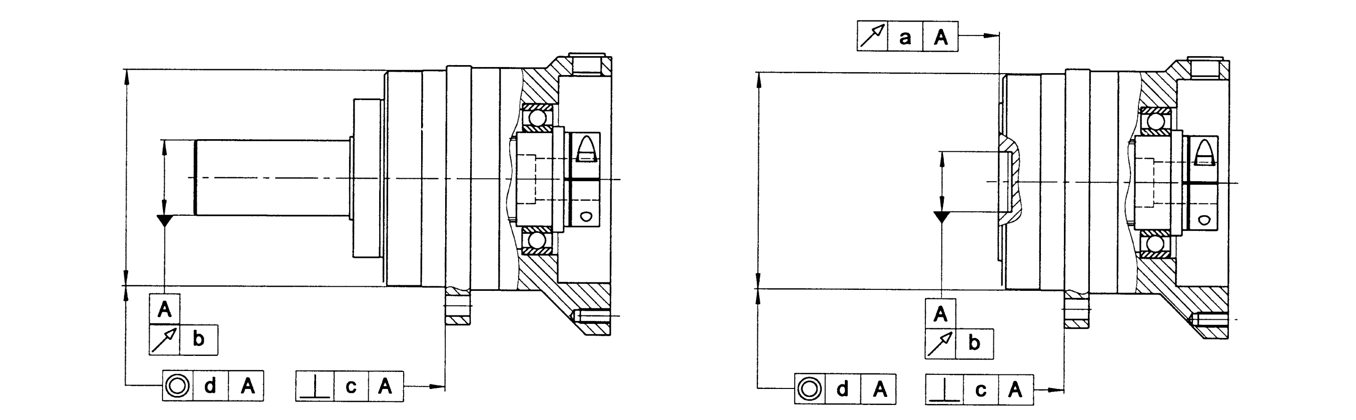
3.3.6 Housing Tolerances HPGP

Output Bearing Tolerances

Table 16.1 [mm]

Size	11	14	20	32	50	65
a	0.02	0.02	0.02	0.02	0.02	0.04
b	0.03	0.04	0.04	0.04	0.04	0.06
c	0.05	0.06	0.06	0.06	0.06	0.09
d	0.04	0.05	0.05	0.05	0.05	0.08

Illustration 16.2



3.3.7 Materials Used

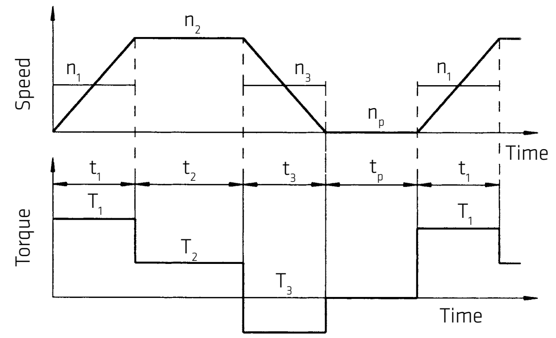
The ambient medium should not have any corrosive effects on the materials listed below.

Gearbox: Blank aluminium, corrosion protected roller bearing steel, blank steel (output shaft).
Adapter flange: (if provided by Harmonic Drive AG) high-strength aluminium or blank steel.
Screws: black phosphated.

4.1 Selecting Harmonic Drive® Planetary Gears

Torques	$T_1...T_n$	[Nm]
during the load phases	$t_1...t_n$	[s]
during the pause time	t_p	[s]
and output speeds	$n_1...n_n$	[rpm]
Emergency stop/momentary peak torque	T_k	[Nm]

Illustration 17.1



Equation 17.2

Load limit 1,
Calculation of the average output torque T_{av}

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

Equation 17.3

Values for T_A see rating tables
$T_{av} \leq T_A$

No

Selection of a bigger size

Equation 17.4

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 17.5

Average input speed
$n_{in\ av} = i \cdot n_{out\ av}$

Equation 17.6

Permissible maximum input speed
$n_{in\ max} = n_{out\ max} \cdot i \leq$ Maximum input speed (see rating table)

Equation 17.7

Load limit 2, T_R

$T_{max} \leq T_R$

Equation 17.8

Load limit 3, T_M

$T_k \leq T_M$

Equation 17.9

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 17.10

Life

$$L_{10} = 20000\ h \cdot \frac{\text{Rated input speed}}{n_{in\ av}} \cdot \left(\frac{T_N}{T_{av}}\right)^{10/3}$$

Output data

T_1 = 40 Nm	t_1 = 0.3 s	n_1 = 125 rpm
T_2 = 32 Nm	t_2 = 3.0 s	n_2 = 250 rpm
T_3 = 20 Nm	t_3 = 0.4 s	n_3 = 125 rpm
	t_p = 4.0 s	
T_k = 200 Nm		
Ratio i=11		

Equation 18.1

Load limit 1,
Calculation of the average output torque T_{av}

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

Equation 18.2

$$T_{av} = 32\text{ Nm} \leq T_A = 45\text{ Nm}$$

Selected size

HPG-20-11

Equation 18.3

Calculation of the average output speed

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

Equation 18.4

Average input speed

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

Equation 18.5

Permissible maximum input speed

$$n_{in\ max} = 250\text{ rpm} \cdot 11 = 2750\text{ rpm} \leq 6000\text{ rpm}$$

Equation 18.6

Load limit 2, T_R

$$T_{max} = 40\text{ Nm} \leq T_R = 100\text{ Nm}$$

Equation 18.7

Load limit 3, T_M

$$T_k = 200\text{ Nm} \leq T_M = 217\text{ Nm}$$

Equation 18.8

Permissible average input speed

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

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

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

Equation 18.9

Operating life

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

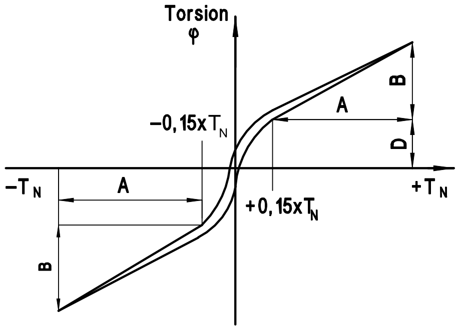
$\text{rpm} \hat{=} \text{rpm}$

We will be pleased to make a gear calculation and selection on your behalf. Please contact our application engineers.

4.2 Calculation of the Torsion Angle

The torsional stiffness may be evaluated by means of the torque-torsion curve shown in illustration 19.1. The values quoted in the tables are the average of measurements made during numerous practical tests.

Illustration 19.1



Calculation of the torsion angle φ at load torque T

Equation 19.2

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

$\frac{A}{B}$: Torsional Stiffness [Nm/arcmin]

T_N : Rated torque [Nm]

D : Average torsion angle at 0.15 x T_N [arcmin]

φ : Output rotation angle [arcmin]

T : Load torque [Nm]

T_L = T_n*0.15 [Nm]

Table 19.3

Size				11	14	20	32	50	65
Average torsion angle (D)	BL3	i < 11	[arcmin]	2.5	2.2	1.5	1.3	1.3	1.3
		i ≥ 11	[arcmin]	3.0	2.7	2.0	1.7	1.7	1.7
	BL1	i < 11	[arcmin]	–	1.1	0.6	0.5	0.5	0.5
		i ≥ 11	[arcmin]	–	1.7	1.1	1.0	1.0	1.0

4.3 Efficiency Versus Load

4.3.1 Efficiency Calculations

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

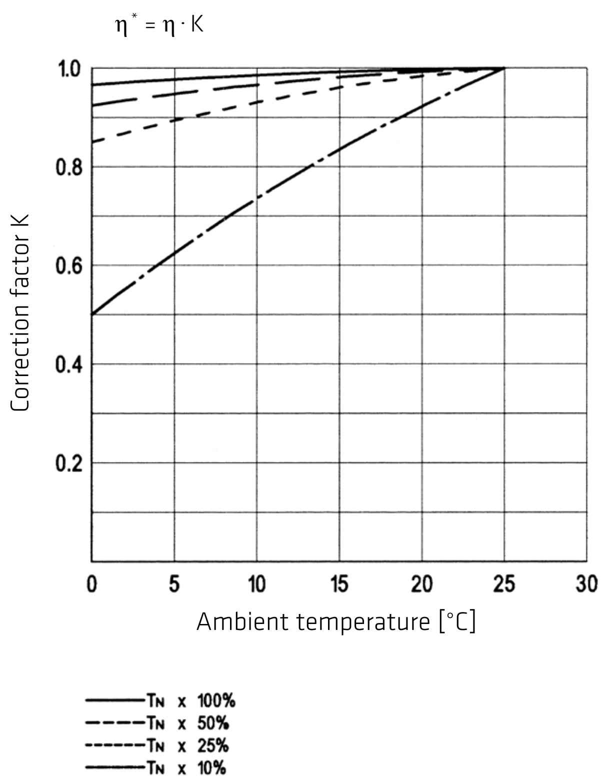
Input Speed:	n = 3000 rpm
Ambient Temperature:	25° C
Lubrication:	SK-2 Grease (Size 14, 20, 32) Epnoc Grease AP(N)2 (Size 11, 50, 65)
Backlash class:	BL3 (for BL1 efficiency approx. 2 % lower)

In case of an ambient temperature below 25° C the efficiency η_T can be determined using equation 20.1.

Equation 20.1

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

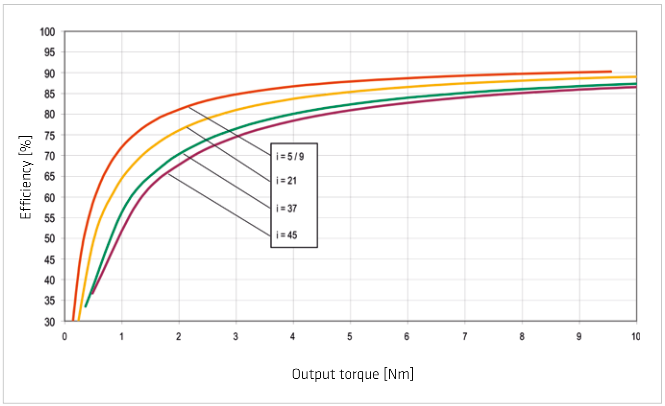
Illustration 20.2



4.3.2 Efficiency Tables

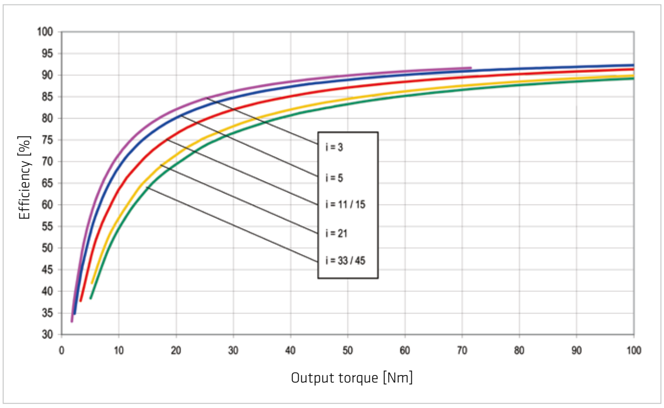
Size 11

Illustration 21.1



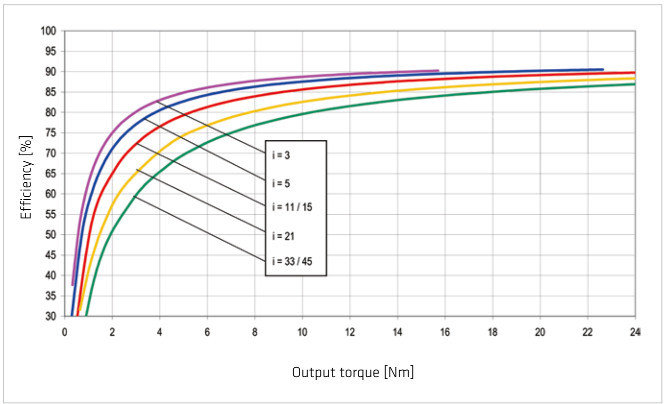
Size 32

Illustration 21.4



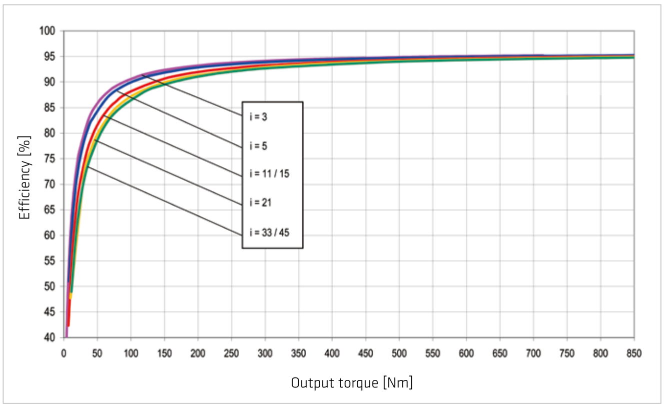
Size 14

Illustration 21.2



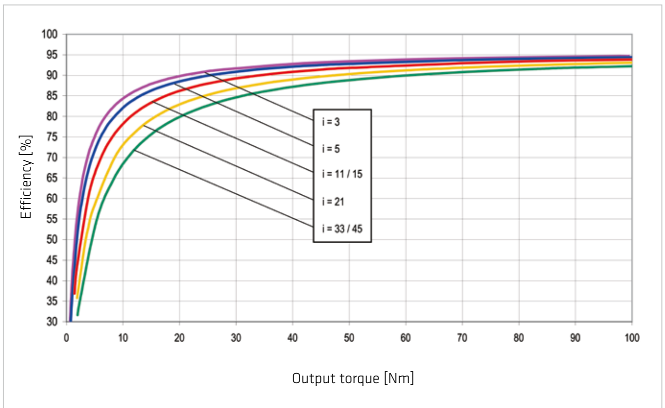
Size 50

Illustration 21.5



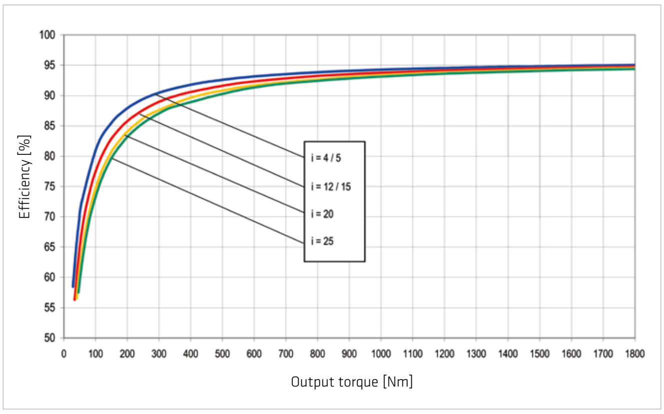
Size 20

Illustration 21.3



Size 65

Illustration 21.6



4.4 No Load Starting-, Back Driving- and Running Torque

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).

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 the matching table. In no case should the values given be regarded as a margin in a system that must hold an external load. Where back driving is not permissible a brake must be fitted.

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 to the output.

No Load Starting Torque

Table 22.1 [Ncm]

Ratio	Size					
	11	14	20	32	50	65
3	-	13.3	29	53	127	-
4	-	-	-	-	-	290
5	4.0	8.6	19	33	80	240
9	3.7	-	-	-	-	-
11	-	8.0	15	27	45	-
12	-	-	-	-	-	125
15	-	7.4	12	25	40	110
20	-	-	-	-	-	95
21	2.9	6.1	9.3	22	38	-
25	-	-	-	-	-	84
33	-	4.4	7.2	17	30	-
37	2.0	-	-	-	-	-
40	-	-	-	-	-	75
45	1.8	3.9	6.6	16	28	-
50	-	-	-	-	-	70

No Load Back Driving Torque

Table 22.2 [Nm]

Ratio	Size					
	11	14	20	32	50	65
3	-	0.4	0.9	1.6	4.0	-
4	-	-	-	-	-	12
5	0.2	0.4	0.9	1.7	4.0	12
9	0.3	-	-	-	-	-
11	-	0.9	1.7	2.9	5.0	-
12	-	-	-	-	-	15
15	-	1.1	1.8	3.7	6.0	17
20	-	-	-	-	-	19
21	0.6	1.3	2.0	4.7	8.0	-
25	-	-	-	-	-	21
33	-	1.5	2.4	5.7	10	-
37	0.8	-	-	-	-	-
40	-	-	-	-	-	30
45	0.8	1.8	2.9	7.3	13	-
50	-	-	-	-	-	35

No Load Running Torque at 3000 rpm

Table 23.1 [Ncm]

Ratio	Size					
	11	14	20	32	50	65
3	-	14	41	110	200	-
4	-	-	-	-	-	420
5	5.0	10	28	72	130	360
9	2.5	-	-	-	-	-
11	-	5.0	15	38	60	-
12	-	-	-	-	-	190
15	-	3.0	11	29	47	160
20	-	-	-	-	-	130
21	2.0	3.0	9.0	23	40	-
25	-	-	-	-	-	110
33	-	2.0	6.0	14	24	-
37	1.0	-	-	-	-	-
40	-	-	-	-	-	76
45	1.0	2.0	5.0	14	20	-
50	-	-	-	-	-	64

4.5 Life for Continuous Operation

The operating life of the output bearing can be calculated using equation 23.2

Equation 23.2

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

with:

L_{10} [h] = Operating life

n_{av} [rpm] = Average output speed (equation 17.4)

C [N] = Dynamic load rating, see table 14.3 “Output Bearing Ratings”

P_C [N] = Dynamic equivalent load (equation 24.1)

f_W = Operating factor (table 23.3)

Operating factor

Table 23.3

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

Dynamic Equivalent Load

Equation 24.1

$$P_C = x \cdot \left(F_{rav} + \frac{2M}{dp}\right) + y \cdot F_{aav}$$

mit:

F_{rav} [N]	=	Radial force (equation 24.2)	x	=	Radial load factor (table 24.4)
F_{aav} [N]	=	Axial force (equation 24.3)	y	=	Axial load factor (table 24.4)
d_p [m]	=	Pitch circle (table 16.3)	M	=	Tilting moment

Equation 24.2

$$F_{rav} = \left(\frac{|n_1| \cdot t_1 \cdot (|F_{r1}|)^{10/3} + |n_2| \cdot t_2 \cdot (|F_{r2}|)^{10/3} + \ldots + |n_n| \cdot t_n \cdot (|F_{rn}|)^{10/3}}{|n_1| \cdot t_1 + |n_2| \cdot t_2 + \ldots + |n_n| \cdot t_n}\right)^{10/3}$$

Equation 24.3

$$F_{aav} = \left(\frac{|n_1| \cdot t_1 \cdot (|F_{a1}|)^{10/3} + |n_2| \cdot t_2 \cdot (|F_{a2}|)^{10/3} + \ldots + |n_n| \cdot t_n \cdot (|F_{an}|)^{10/3}}{|n_1| \cdot t_1 + |n_2| \cdot t_2 + \ldots + |n_n| \cdot t_n}\right)^{10/3}$$

Table 24.4

Load factors	**x**	**y**
$\frac{F_{aav}}{F_{rav} + 2 \cdot M / dp} \leq 1.5$	1	0.45
$\frac{F_{aav}}{F_{rav} + 2 \cdot M / dp} > 1.5$	0.67	0.67

Illustration 24.5

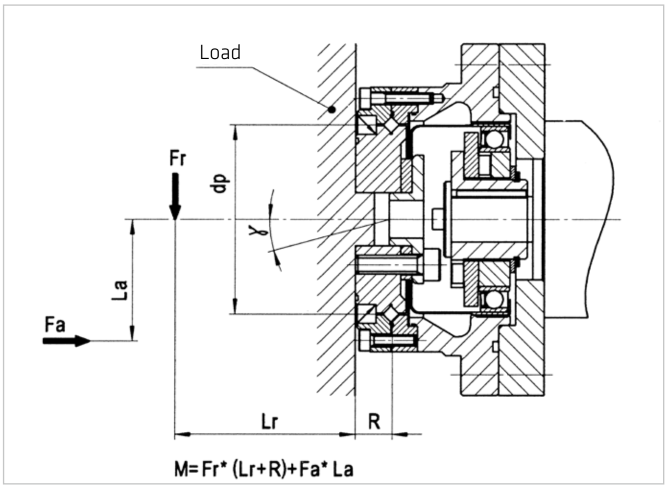
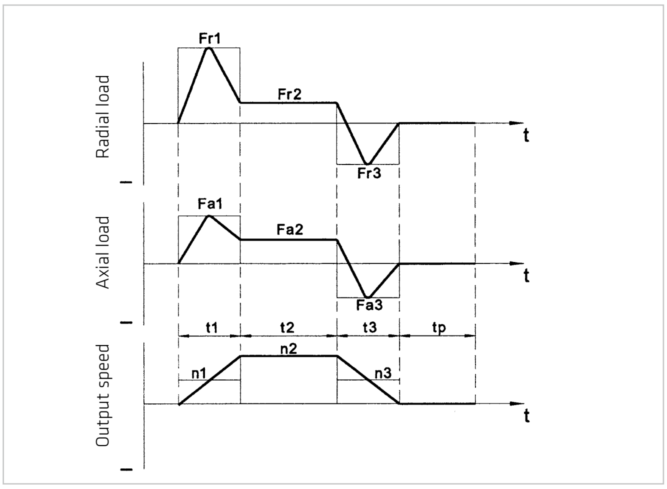


Illustration 24.6



Please note:
F_{rx} = represents the maximum radial force.
F_{ax} = represents the maximum axial force.
t_p = represents the pause time between cycles.

4.5.1 Output Bearing at Oscillating Motion

Life for Oscillating Motion
The operating life at oscillating motion can be calculated using equation 25.1.

Equation 25.1

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

with:

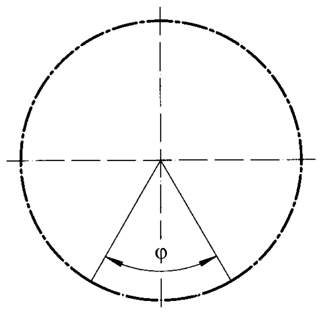
L_{OC} [h] = Operating life for oscillating motion
n_1 [cpm] = Number of oscillations/minute*
C [N] = Dynamic load rating, see table 14.3
P_C [N] = Dynamic equivalent load (equation 24.1)
φ [deg] = Oscillating angle
f_W = Operating factor (table 23.3)

* one oscillation means 2φ

Oscillating angle

At oscillating angles < 5° fretting corrosion may occur due to insufficient lubrication.
In this case please contact our sales engineer for counter measures.

Illustration 25.2



4.6 Permissible Static Tilting Moment

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

Equation 26.1

$$f_S = \frac{C_0}{P_0} \quad \text{with} \quad P_0 = x_0\left(F_r + \frac{2M}{d_p}\right) + y_0 \cdot F_a$$

and so

Equation 26.2

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

f_s = Static load safety factor
(f_s = 1.5 ... 3) (table 26.3)
C_0 = Static load rating
F_r = F_a = 0
x_0 = 1
y_0 = 0.44
P_0 = Static equivalent load (equation 26.1)
d_p = Pitch circle diameter of the output bearing (table 14.3)
M_0 = Allowable static overturning moment

Table 26.3

Rotation conditions of bearing	**Lower limit value for f_s**
Normal	≥ 1.5
Vibrations / Impacts	≥ 2
High transmission accuracy	≥ 3

4.7 Angle of Inclination

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 26.4:

Equation 26.4

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

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

4.8 Lubrication

HPG Planetary Gears are delivered grease-packed. An additional grease lubrication is not necessary, either during assembly or during operation.

Applied lubricant:

SK-2 grease (Sizes 14, 20, 32),
Epnoc grease AP(N)2 (Sizes 11, 50, 65)
The output bearing is also lifetime lubricated.
Lubricant: Multitemp HL-D Grease
Ambient temperature range: -10° C up to +40° C
Maximum operating temperature: + 80° C

5. Installation and Operation

5.1 Transport and Storage

Gears should be transported in the original packaging. If the gear is not put into service immediately on receipt, it should be stored in a dry area in the original packaging. The permissible storage temperature range is -20° C to +60° C.

5.2 Gear Condition at Delivery

The gears are generally delivered according to the dimensions indicated in the confirmation drawing.

Gears with Grease Lubrication
Units are supplied with grease lubricant as standard.

5.3 Assembly Information

ADVICE

Screws which have been tightened by the gear manufacturer must not be loosened.

5.4 Assembly Instructions

A motor shaft without key groove should be used. For motor shafts with key groove the groove can be filled with a half key to prevent imbalance.

Contact between sharp-edged or abra-sive objects (cutting chips, splinters, metallic or mineral dust etc.) and the output shaft seal must be prevented.

In addition, permanent contact between the output shaft seal and a permanent liquid covering should be prevented. Please note that the changing operating temperature of a completely sealed actuator can lead to a pressure differential between the environment and the inside of the actuator. This can cause liquid covering the output shaft seal to be drawn into the gear housing, which can lead to corrosive damage. As a countermeasure we recommend the use of an additional shaft seal (to be provided by the user) or the maintenance of a constant pressure inside the gear by applying dry filtered air at a pres-sure of not more than 104 Pa. Please contact Harmonic Drive AG for further advice.

5.4.1 Preparation for Assembly

Assembly preparation
The gear assembly must be carried out very carefully and within a clean environment. Please make sure that during the assembly procedure no foreign particles enter the gear.

General information
Clean, degrease and dry all mating surfaces to ensure an adequate coefficient of friction. The values given in table 8 are valid for 12.9 quality screws which must be tightened by means of a torque wrench. Locking devices such as spring washers or toothed washers should not be used.

Auxiliary materials for assembly
For the assembly, we recommend the application of the following auxiliary materials or the use of those with similar characteristics. Please pay attention to the application guidelines given by the manufacturer. Auxiliary materials must not enter the gear.

Surface sealing
- Loctite 5203
- Loxeal 28-10

Recommended for all mating surfaces, if the use of o-ring seals is not intended. Flanges provided with O-ring grooves must be sealed with sealing compound when a proper seal cannot be achieved using the O-ring alone.

Screw fixing
- Loctite 243

This adhesive ensures that the screw is fixed and also provides a good sealing effect. Loctite 243 is recommended for all screw connections.

Assembly paste
- Klüber Q NB 50

Recommended for o-rings which may come out of the groove during the assembly procedure. Before starting with the assembly you should spread some grease (which you can take from the gear) on all other o-rings.

Adhesives
- Loctite 638

Apply Loctite 638 to the connections between motor shaft and Wave Generator. You should make use of it only if this is specified in the confirmation drawing.

5.5 Assembly

Screws which have been tightened by the gear manufacturer must not be loosened.

5.5.1 Motor Assembly

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

- Turn the coupling on the input side so that the head of the bolt aligns with the bore for the rubber cap.
- Gently insert the motor vertically into the gear.
- Fix the motor and gear by tightening the bolts on the flange (see table 29.1).
- Fasten the bolt on the input coupling (see table 29.2).
- Finally, insert the rubber cap provided.

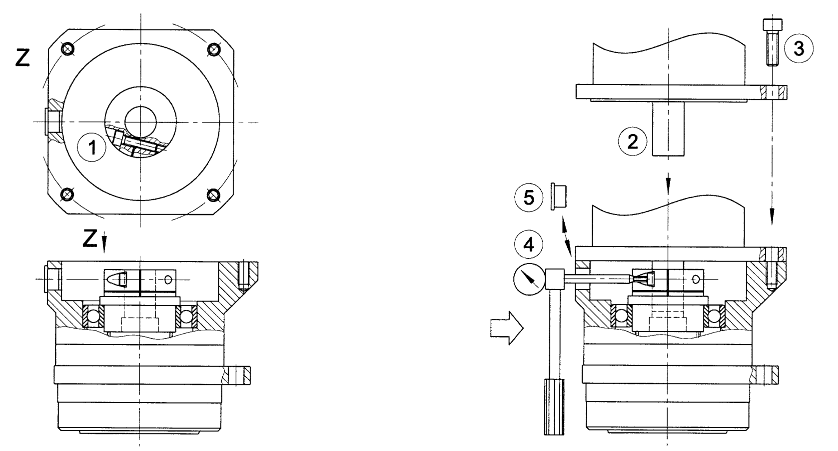
Table 29.1 [Nm]

Bolt Size	**M2,3**	**M3**	**M4**	**M5**	**M6h**	**M8**	**M10**	**M12**	**M14**	**M16**
Tightening Torque	0.73	1.28	3.0	5.9	10.1	24.6	48.0	84.0	133.0	206.0

Table 29.2 [Nm]

Bolt Size	**M3** HPGP-11	**M3**	**M4**	**M5**	**M6**	**M8**	**M10**	**M12**
Tightening Torque	0.69	1.8	4.6	8.6	14.9	36.1	71.0	123

Illustration 29.3



5.5.2 Assembly of the Output Flange

First connect the unit housing to the machine housing. Then the load should be connected to the output flange. It is important to obey this sequence when the output bearing of the unit must support large tilting moments, radial or axial forces.

When installing the HPG in a machine, please ensure that the assembly surfaces are flat and the tapped holes are free of burrs. Fix the flange by tightening the bolts on the housing flange. During the housing assembly for size HPG-50 it is necessary to use special washers between the screw head and housing.

Table 30.1

Size		**11**	**14**	**20**	**32**	**50**	**65**
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	123	255
Torque transmitting	[Nm]	26.3	110	428	868	2030	5180

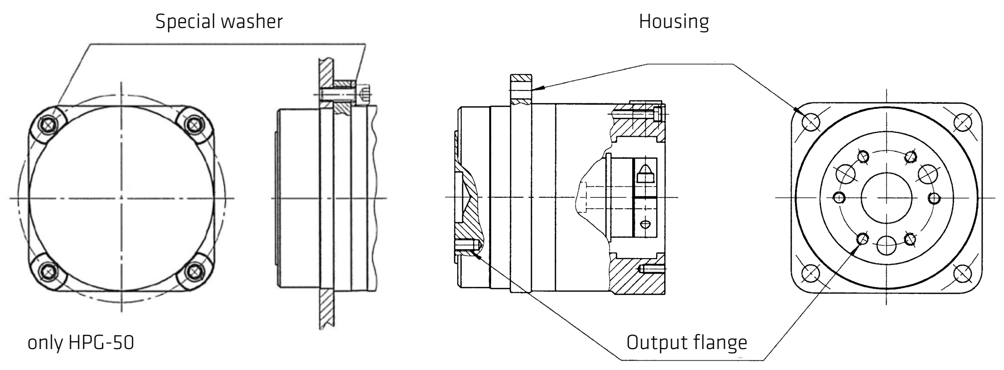
5.5.3 Assembly of the Housing

When connecting the load to the output flange please respect the specifications for the output bearing (see illustration 30.3).

Table 30.2

Size		**11**	**14**	**20**	**32**	**50**	**65**
Number of Bolts		4	8	8	8	8	8
Bolt Size		M4	M4	M6	M8	M12	M16
Bolt pitch diameter	[mm]	18	30	45	60	90	120
Tightening Torque	[Nm]	4.5	4.5	15.3	37.2	128.4	319
Torque transmitting	[Nm]	25.3	84	286	697	2407	5972

Illustration 30.3



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

6. Glossary

6.1 Technical Data

AC Voltage constant k_{EM} [V_{rms} / 1000 rpm]

Effective value of the induced motor voltage measured at the motor terminals at a speed of 1000 rpm and an operating temperature of 20° C.

Ambient operating temperature [°C]

The intended operating temperature for the operation of the drive.

Average input speed (grease lubrication) $n_{av\,(max)}$ [rpm]

Maximum permissible average gear input speed for grease lubrication.

Average input speed (oil lubrication) $n_{av\,(max)}$ [rpm]

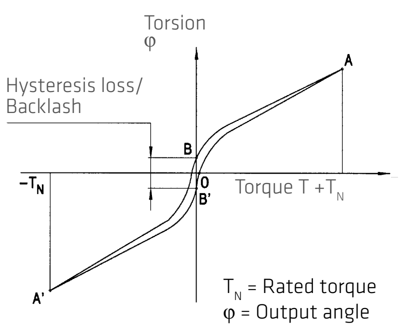
Maximum permissible average gear input speed for oil lubrication.

Average torque T_A [Nm]

When a variable load is applied to the gear, an average torque should be calculated for the complete operating cycle. This value should not exceed the specified T_A limit.

Backlash (Harmonic Planetary gears) [arcmin]

When subjected to the rated torque, Harmonic Planetary gears display characteristics shown in the hysteresis curve. When a torque is applied to the output shaft of the gear with the input shaft locked, the torque-torsion relationship can be measured at the output. Starting from point 0 the graph follows successive points A-B-A-B-A A where the value B-B is defined as the backlash or hysteresis.



Brake closing time t_C [ms]

Delay time to close the brake.

Brake current to hold I_{HBr} [A_{DC}]

Current for applying the brake.

Brake current to open I_{OBr} [A_{DC}]

Current required to open the brake.

Brake holding torque T_H [Nm]

Torque the actuator can withstand when the brake is applied, with respect to the output.

Brake opening time t_O [ms]

Delay time for opening the brake.

Brake voltage U_{Br} [VDC]

Terminal voltage of the holding brake.

Collision torque T_M [Nm]

In the event of an emergency stop or collision, the Harmonic Drive® Gearing may be subjected to a brief collision torque. The magnitude and frequency of this collision torque should be kept tom a minimum and under no circumstances should the collision torque occur during the normal operating cycle.

Continuous stall current I_0 [A_{rms}]

Effective value of the motor phase current to produce the stall torque.

Continuous stall torque T_0 [Nm]

Allowable actuator stall torque.

Demagnetisation current I_E [A_{rms}]

Current at which rotor magnets start to demagnetise.

Dynamic axial load $F_{A\ dyn\ (max)}$ [N]

With bearing rotating this is the maximum allowable axial load, with no additional radial forces or tilting moments applied.

Dynamic load rating C [N]

Maximum dynamic load that can be absorbed by the output bearing before permanent damage may occur.

Dynamic radial load $F_{R\ dyn\ (max)}$ [N]

With bearing rotating this is the maximum allowable radial load, with no additional axial forces or tilting moments applied.

Dynamic tilting moment $M_{dyn\ (max)}$ [Nm]

With the bearing rotating this is the maximum allowable tilting moment, with no additional axial forces or radial forces applied.

Electrical time constant τ_e [s]

The electrical time constant is the time required for the current to reach 63% of its final value.

Hollow shaft diameter d_H [mm]

Free inner diameter of the continuous axial hollow shaft.

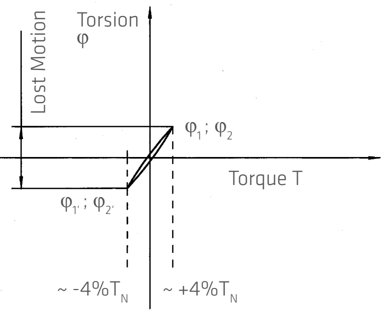
Inductance (L-L) L_{L-L} [mH]

Terminal inductance calculated without taking into account the magnetic saturation of the active motor parts.

Lost Motion (Harmonic Drive® Gearing) [arcmin]

Harmonic Drive® Gearing exhibits zero backlash in the teeth. Lost motion is the term used to characterise the torsional stiffness in the low torque region.

The illustration shows the angle of rotation φ measured against the applied output torque as a hysteresis curve, with the Wave Generator locked. The lost motion measurement of the gear is taken with an output torque of about ± 4% of the rated torque.



Maximum DC bus voltage $U_{DC\,(max)}$ [VDC]

The maximum DC bus power supply for the correct operation of the actuator. This value may only be exceeded for a short period during the braking or deceleration phase.

Maximum hollow shaft diameter $d_{H\,(max)}$ [mm]

For gears with a hollow shaft, this value is the maximum diameter of the axial hollow shaft.

Maximum input speed (grease lubrication) $n_{in\,(max)}$ [rpm]

Maximum allowed input speed for gearing with grease lubrication.

Maximum input speed (oil lubrication) $n_{in\,(max)}$ [rpm]

Maximum allowed input speed for gearing with oil lubrication.

Maximum motor speed n_{max} [rpm]

The maximum allowable motor speed.

Maximum output speed n_{max} [rpm]

The maximum output speed. Due to heating issues, this may only be momentarily applied during the operating cycle. The maximum output speed can occur any number of times as long as the rated speed is greater than the permissible continuous operation calculated in the duty cycle.

Maximum output torque T_{max} [Nm]

Specifies the maximum allowable acceleration and deceleration torques. For highly dynamic processes, this is the maximum torque available for a short period. The maximum torque can be parameterized by the control unit where the maximum current can be limited. The maximum torque can be applied as often as desired, as long as the average torque is within the permissible continuous operation calculated in the duty cycle.

Maximum power P_{max} [W]

Maximum power output.

Mechanical time constant τ_m [s]

The mechanical time constant is the time required to reach 63% of its maximum rated speed in a no-load condition.

Momentary peak torque T_M [Nm]

In the event of an emergency stop or collision, the Harmonic Drive® Gearing may be subjected to a brief collision torque. The magnitude and frequency of this collision torque should be kept tom a minimum and under no circumstances should the momentary peak torque occur during the normal operating cycle.

Moment of inertia J [kgm^2]

Mass moment of inertia at motor side.

Moment of inertia J_{in} [kgm^2]

Mass moment of inertia of the gearing with respect to the input.

Moment of inertia J_{out} [kgm^2]

Mass moment of inertia with respect to the output.

Motor terminal voltage (Fundamental wave only) U_M [V_{rms}]

Required fundamental wave voltage to achieve the specified performance. Additional power losses can lead to restriction of the maximum achievable speed.

Number of pole pairs p

Number of magnetic pole pairs on the rotor of the motor.

Offset R [mm]

Distance between output bearing and contact point of load.

Pitch circle diameter d_p [mm]

Pitch circle diameter of the output bearing.

Protetcion IP

The degree of protection according to EN 60034-5 provides suitability for various environmental conditions.

Rated current I_N [A]

Rms value of the sinusoidal current when driven at rated torque and rated speed.

Rated motor speed n_N [rpm]

The motor speed which can be continuously maintained when driven at rated torque T_N, when mounted on a suitably dimensioned heat sink.

Rated power P_N [W]

Output power at rated speed and rated torque.

Rated speed n_N [rpm]

The output speed which can be continuously maintained when driven at rated torque T_N, when mounted on a suitably dimensioned heat sink.

Rated torque T_N [Nm], Servo

The output torque which can be continuously transmitted when driven at rated input speed, when mounted on a suitably dimensioned heat sink.

Rated torque T_N [Nm], Mechanic

The rated torque is a reference torque for the calculation of the gear life. When loaded with the rated torque and running at rated speed the gear will reach the average life L_{50}. The rated torque T_N is not used for the dimensioning of the gear.

Rated voltage U_N [V_{rms}]

Supply voltage for operation with rated torque and rated speed.

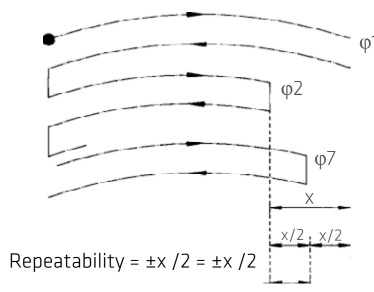
Ratio i [ ]

The ratio is the reduction of input speed to the output speed.

Note for Harmonic Drive® transmission: The standard version of the wave is generating the drive element, the output element of the flexspline and the circular Spline is fixed to the housing. Since the direction of rotation of the drive (Wave Generator) to output reverses (Flexspline), a negative ratio for results Calculations in which the direction of rotation must be considered.

Repeatability [arcmin]

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.



Repeatable peak torque T_R [Nm]

Specifies the maximum allowable acceleration and braking torques. During the normal operating cycle the repeatable peak torque T_R should be not be exceeded.

Resistance (L-L, 20° C) R_{L-L} [Ω]

Winding resistance measured between two conductors at a winding temperature of 20° C.

Size

1) Actuators / Gears with Harmonic Drive® gears or Harmonic Planetary gears
The frame size is derived from the pitch circle diameter of the gear teeth in inches multiplied by 10.

2) CHM Servo motor series
The size of the CHM servo motors is derived from the stall torque in Ncm.

3) Direct drives from the TorkDrive® series
The size of the TorkDrive® series is the outer diameter of theiron core of the stator.

Static load rating C_0 [N]

Maximum static load that can be absorbed by the output bearing before permanent damage may occur.

Static tilting moment M_0 [Nm]

With the bearing stationary this is the maximum allowable radial load, with no additional axial forces or tilting moments applied.

Tilting moment stiffness K_B [Nm/arcmin]

The tilting angle of the output bearing at an applied moment load.

Torque constant (motor) k_{TM} [Nm/A_{rms}]

Quotient of stall torque and stall current.

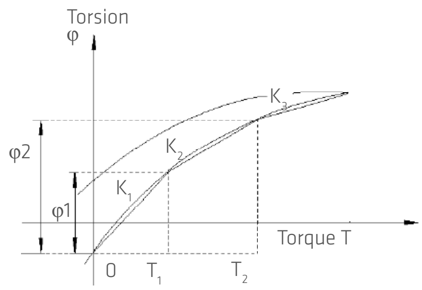
Torque constant (output) k_{Tout} [Nm/A_{rms}]

Quotient of stall torque and stall current, taking into account the transmission losses.

Torsional stiffness (Harmonic Drive® Gears) K_3 [Nm/rad]

The amount of elastic rotation at the output for a given torque and the Wave Generator blocked. The torsional stiffness K_3 describes the stiffness above a defined reference torque where the stiffness is almost linear. Values below this torque can be requested or found on our web site.

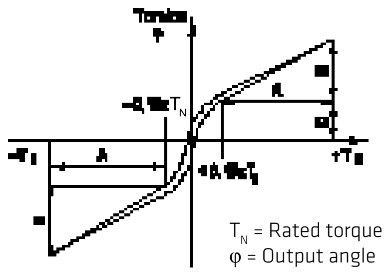
The value given for the torsional stiffness K_3 is an average that has been determined during numerous tests. The limit torques T_1 and T_2 and calculation example for the total torsional angle Gesamtverdrehwinkels can be found in the secondary technical documentation.



K_1, K_2, K_3 = Torsional stiffness, w = Output angle
φ1 = Torsion angle, with output torque T_1
φ2 = Torsion angle, with output torque T_2

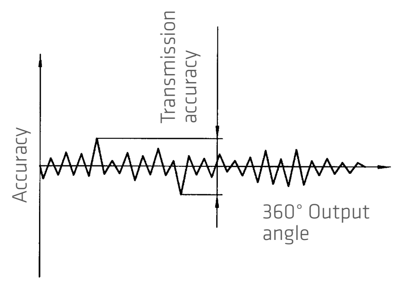
Torsional stiffness (Harmonic Planetary gears) K [Nm/rad]

The amount of elastic rotation at the output for a given torque and blocked input shaft. The torsional rigidity of the Harmonic Planetary gear describes the rotation of the gear above a reference torque of 15% of the rated torque. In this area the torsional stiffness is almost linear.



Transmission accuracy [arcmin]

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.



Weight m [kg]

The weight specified in the catalog is the net weight without packing and only applies to standard versions.

6.2 Labelling, Guidelines and Regulations

CE-Marking

With the CE marking, the manufacturer or EU importer declares in accordance with EU regulation, that by affixing the CE mark the product meets the applicable requirements in the harmonization legislation established the Community.

REACH Regulation

REACH is a European Community Regulation on chemicals. REACH stands for Registration, Evaluation, Authorization and Restriction of Chemicals.

REACH
Verordnung
Nr. 1907/2006

RoHS EU Directive

The RoHS EU Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

RoHS
COMPLIANT

...just move it!

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