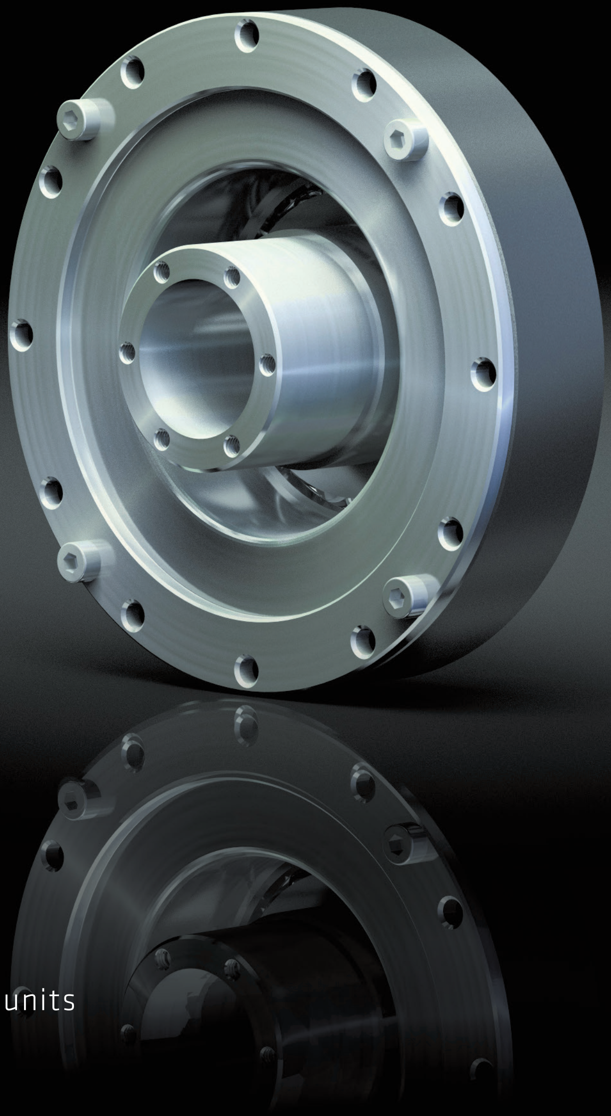
Engineering Data
SHG-2UH/2SO/2SH Units

Harmonic Drive AG



More information on our units
can be found **HERE**!

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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:

Harmonic Drive AG
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Hoenbergstraße 14
65555 Limburg / Lahn
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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 89/392/EWG. 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.

3.1 Product Description

Maximum torque capacity with largest hollow shaft

The SHG-2UH Series Units are available in ten sizes with gear ratios of 50, 80, 100, 120 and 160:1 offering repeatable peak torques from 23 to 3419 Nm.

The integrated output bearing with high tilting capacity enables the direct attachment of heavy payloads without the need for further support, ensuring a simple and space-saving design.

The SHG-2UH Unit is fully sealed with a large hollow shaft diameter to feed through supply lines, shafts or cables for further drive systems. The gears cover a wide torque range and feature a long service life, confirmed by many years of successful service.

The SHG-2SH and -2SO Simplicity Units are very short and lightweight. The absence of input and output flanges means maximum flexibility in design integration. The -2SH version comes with a large hollow shaft and the -2SO versions is delivered with a standard wave Generator.

3.2 Ordering Code

Table 9.1

Series	Size	Ratio [1]					Version	Special design
SHG	14	50	80	100			2UH 2SO 2SH	According to customer requirements
	17	50	80	100	120			
	20	50	80	100	120	160		
	25	50	80	100	120	160		
	32	50	80	100	120	160		
	40	50	80	100	120	160		
	45	50	80	100	120	160		
	50	50	80	100	120	160		
	58	50	80	100	120	160		
Ordering code								
SHG	- **25**	- **100**				-	**2UH**	- **SP**

[1] The ratios shown here are for a standard driving configuration with the circular spline fixed, the Wave Generator used for the input and the Flexspline attached to the output. Other configurations are possible. Please consult chapter 4 "Ratio".

Table 9.2

Version	
Ordering code	**Description**
2UH	Unit with hollow shaft
2SO	Simplicity Unit with standard Wave Generator
2SH	Simplicity Unit with hollow shaft

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	SHG-14		
Ratio	i [ ]	50	80	100
Repeatable peak toque	T_R [Nm]	23	30	36
Average torque	T_A [Nm]	9.0	14	14
Rated torque	T_N [Nm]	7.0	10	10
Momentary peak torque	T_M [Nm]	46	67	70
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	14000		
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	8500		
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	6500/1100[1)]		
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	3500/1100[1)]		
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm^2]	0.091		
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm^2]	0.033		
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm^2]	0.091		
Weight SHG-2UH	m [kg]	0.71		
Weight SHG-2SO	m [kg]	0.41		
Weight SHG-2SH	m [kg]	0.45		

[1)]Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

Table 10.2

	Unit	SHG-17			
Ratio	i [ ]	50	80	100	120
Repeatable peak toque	T_R [Nm]	44	56	70	70
Average torque	T_A [Nm]	34	35	51	51
Rated torque	T_N [Nm]	21	29	31	31
Momentary peak torque	T_M [Nm]	91	113	143	112
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	10000			
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	7300			
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	6500/1100[1)]			
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	3500/1100[1)]			
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm^2]	0.193			
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm^2]	0.079			
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm^2]	0.193			
Weight SHG-2UH	m [kg]	1.0			
Weight SHG-2SO	m [kg]	0.57			
Weight SHG-2SH	m [kg]	0.63			

[1)]Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

3.3.2 Dimensions

Illustration 11.1 SHG-14-2UH [mm]

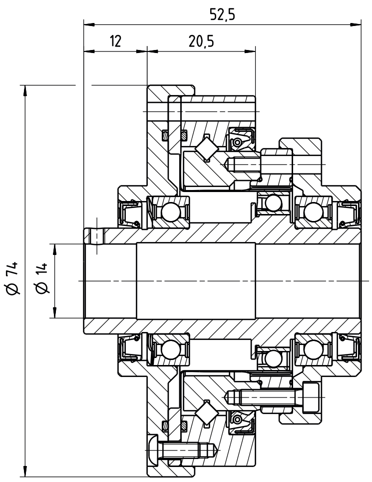

Illustration 11.2 SHG-14-2SO [mm]

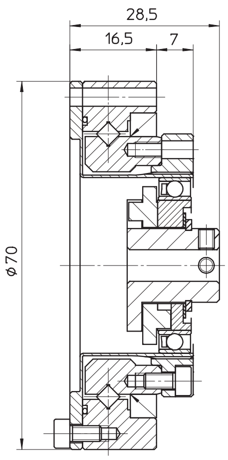

Illustration 11.3 SHG-14-2SH [mm]

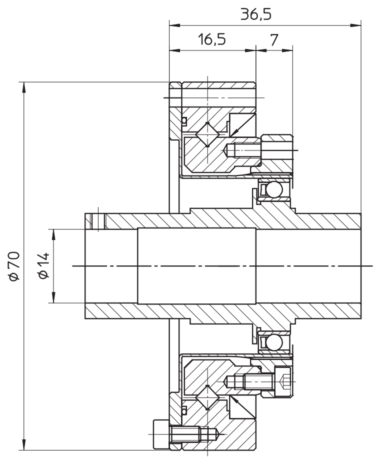

Illustration 11.4 SHG-17-2UH [mm]

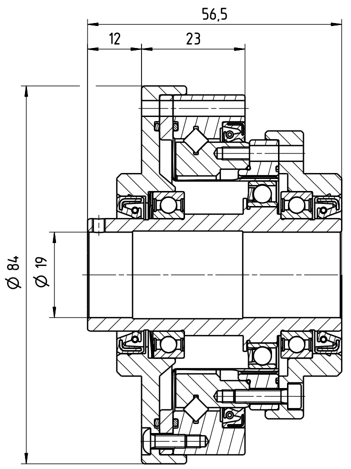

Illustration 11.5 SHG-17-2SO [mm]

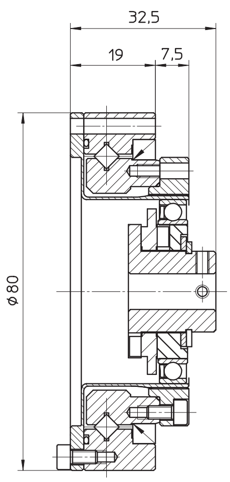

Illustration 11.6 SHG-17-2SH [mm]

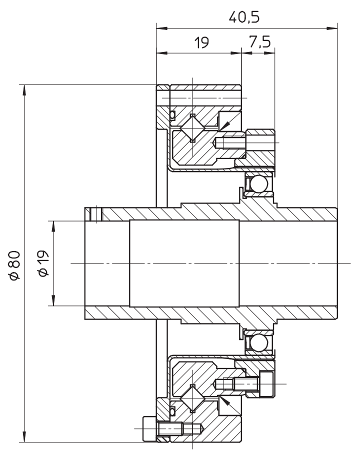

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Table 12.1

	Unit	SHG-20				
Ratio	i [ ]	50	80	100	120	160
Repeatable peak toque	T_R [Nm]	73	96	107	113	120
Average torque	T_A [Nm]	44	61	64	64	64
Rated torque	T_N [Nm]	33	44	52	52	52
Momentary peak torque	T_M [Nm]	127	165	191	191	191
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	10000				
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	6500				
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	6500/1100[1)]				
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	3500/1100[1)]				
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm²]	0.404				
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm²]	0.193				
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm²]	0.404				
Weight SHG-2UH	m [kg]	1.38				
Weight SHG-2SO	m [kg]	0.81				
Weight SHG-2SH	m [kg]	0.89				

[1)]Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

Table 12.2

	Unit	SHG-25				
Ratio	i [ ]	50	80	100	120	160
Repeatable peak toque	T_R [Nm]	127	178	204	217	229
Average torque	T_A [Nm]	72	113	140	140	140
Rated torque	T_N [Nm]	51	82	87	87	87
Momentary peak torque	T_M [Nm]	242	332	369	395	408
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	7500				
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	5600				
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	5600/1000[1)]				
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	3500/1000[1)]				
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm²]	1.07				
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm²]	0.413				
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm²]	1.07				
Weight SHG-2UH	m [kg]	2.1				
Weight SHG-2SO	m [kg]	1.31				
Weight SHG-2SH	m [kg]	1.44				

[1)]Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

Illustration 13.1 SHG-20-2UH [mm]

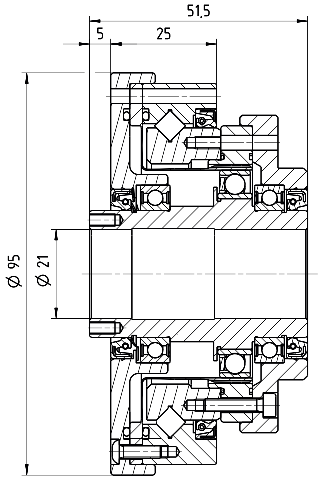

Illustration 13.2 SHG-20-2SO [mm]

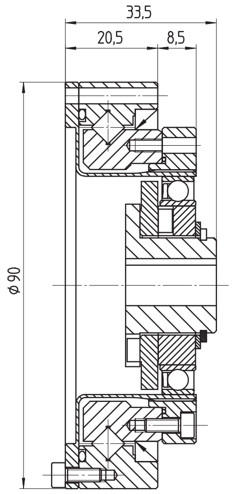

Illustration 13.3 SHG-20-2SH [mm]

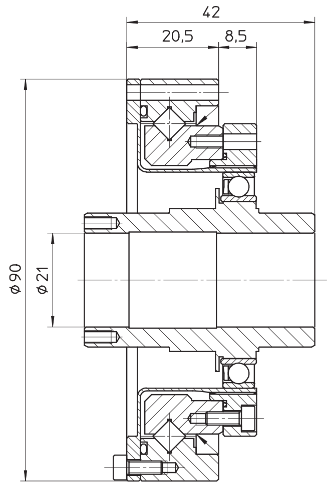

Illustration 13.4 SHG-25-2UH [mm]

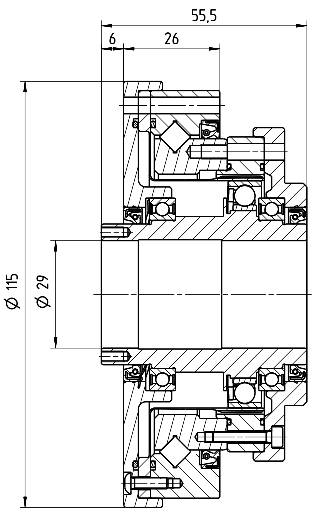

Illustration 13.5 SHG-25-2SO [mm]

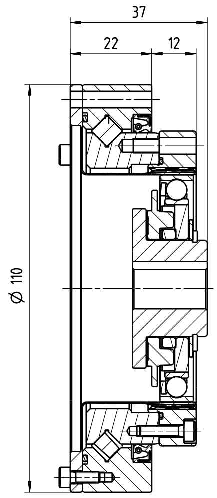

Illustration 13.6 SHG-25-2SH [mm]

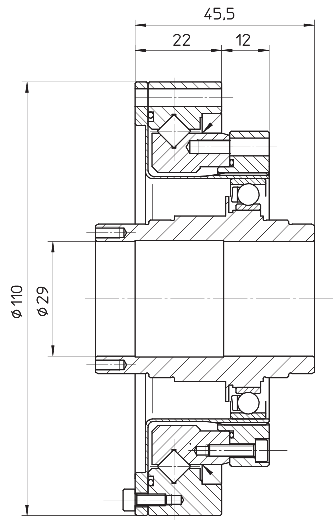

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Table 14.1

	Unit	SHG-32				
Ratio	i [ ]	50	80	100	120	160
Repeatable peak toque	T_R [Nm]	281	395	433	459	484
Average torque	T_A [Nm]	140	217	281	281	281
Rated torque	T_N [Nm]	99	153	178	178	178
Momentary peak torque	T_M [Nm]	497	738	841	892	892
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	7000				
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	4800				
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	4600/1000[1)]				
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	3500/1000[1)]				
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm²]	2.85				
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm²]	1.69				
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm²]	2.85				
Weight SHG-2UH	m [kg]	4.2				
Weight SHG-2SO	m [kg]	2.9				
Weight SHG-2SH	m [kg]	3.1				

[1)]Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

Table 14.2

	Unit	SHG-40				
Ratio	i [ ]	50	80	100	120	160
Repeatable peak toque	T_R [Nm]	523	675	738	802	841
Average torque	T_A [Nm]	255	369	484	586	586
Rated torque	T_N [Nm]	178	268	345	382	382
Momentary peak torque	T_M [Nm]	892	1270	1400	1530	1530
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	5600				
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	4000				
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	3600/950[1)]				
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	3000/950[1)]				
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm²]	9.28				
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm²]	4.50				
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm²]	9.28				
Weight SHG-2UH	m [kg]	7.7				
Weight SHG-2SO	m [kg]	5.1				
Weight SHG-2SH	m [kg]	5.4				

[1)]Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

Illustration 15.1 SHG-32-2UH [mm]

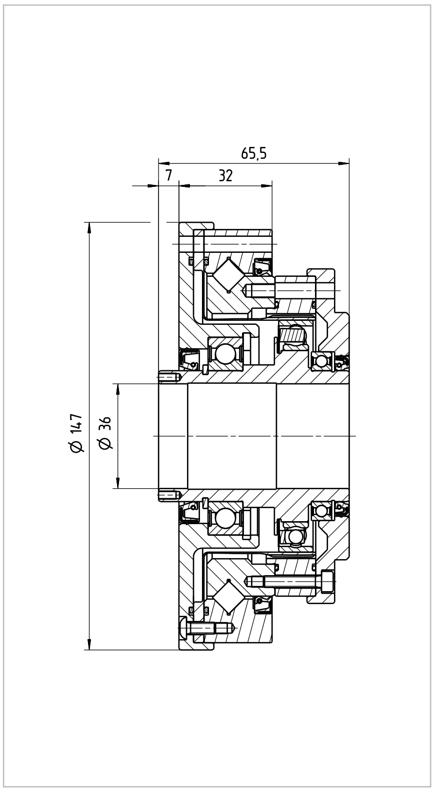

Illustration 15.2 SHG-32-2SO [mm]

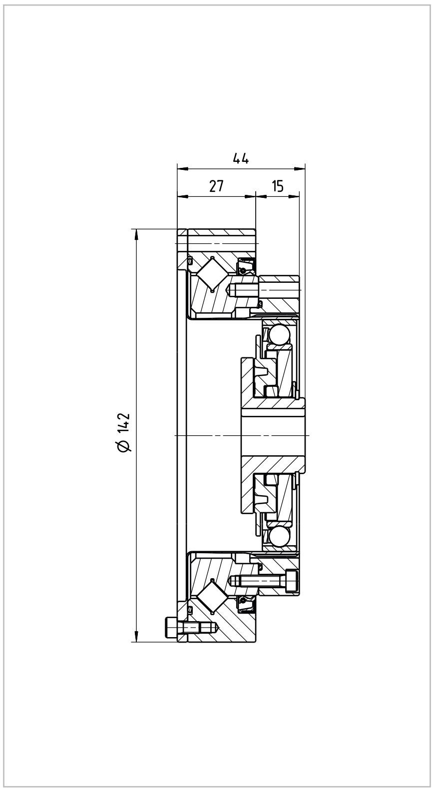

Illustration 15.3 SHG-32-2SH [mm]

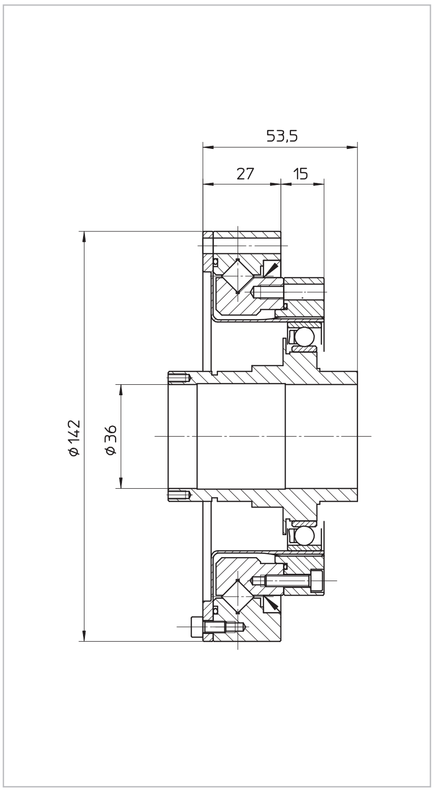

Illustration 15.4 SHG-40-2UH [mm]

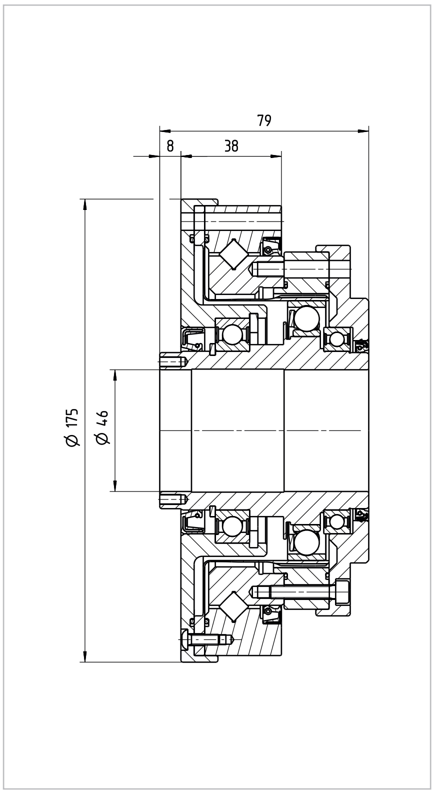

Illustration 15.5 SHG-40-2SO [mm]

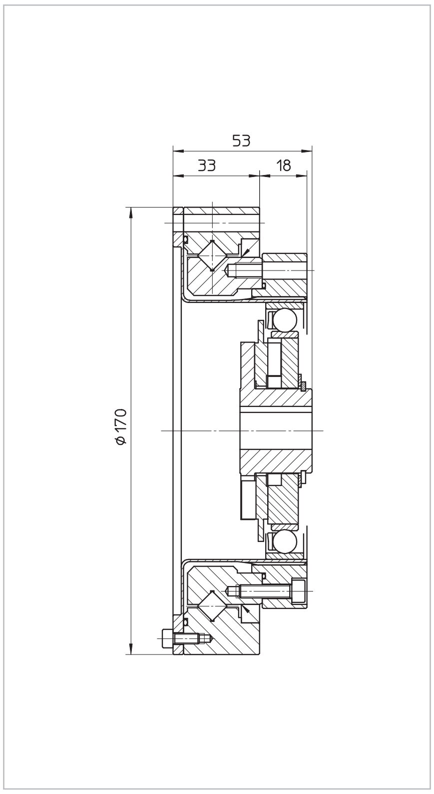

Illustration 15.6 SHG-40-2SH [mm]

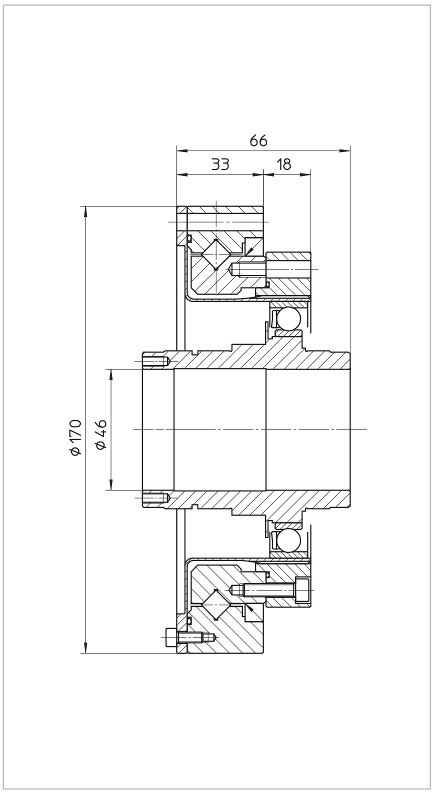

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Table 16.1

	Unit	SHG-45				
Ratio	i [ ]	50	80	100	120	160
Repeatable peak toque	T_R [Nm]	650	918	982	1070	1147
Average torque	T_A [Nm]	345	507	650	806	819
Rated torque	T_N [Nm]	229	407	452	523	523
Momentary peak torque	T_M [Nm]	1235	1651	2041	2288	2483
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	5000				
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	3800				
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	3300/900[1)]				
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	3000/900[1)]				
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm²]	13.8				
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm²]	8.68				
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm²]	13.8				
Weight SHG-2UH	m [kg]	10				
Weight SHG-2SO	m [kg]	6.5				
Weight SHG-2SH	m [kg]	6.9				

[1)]Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

Table 16.2

	Unit	SHG-50			
Ratio	i [ ]	80	100	120	160
Repeatable peak toque	T_R [Nm]	1223	1274	1404	1534
Average torque	T_A [Nm]	675	866	1057	1096
Rated torque	T_N [Nm]	484	611	688	688
Momentary peak torque	T_M [Nm]	1860	2678	2678	3185
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	4500			
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	3500			
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	3000/850[1)]			
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	2500/850[1)]			
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm²]	25.2			
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm²]	12.5			
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm²]	25.2			
Weight SHG-2UH	m [kg]	14.5			
Weight SHG-2SO	m [kg]	9.6			
Weight SHG-2SH	m [kg]	10.2			

[1)] Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

Illustration 17.1 SHG-45-2UH [mm]

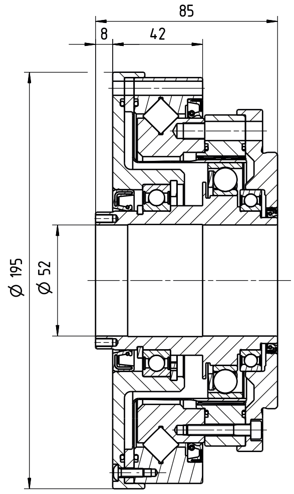

Illustration 17.2 SHG-45-2SO [mm]

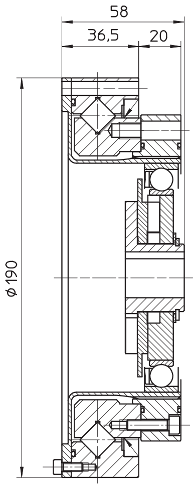

Illustration 17.3 SHG-45-2SH [mm]

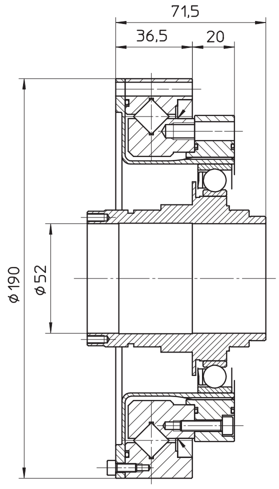

Illustration 17.4 SHG-50-2UH [mm]

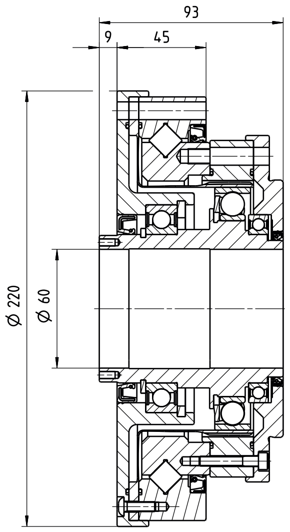

Illustration 17.5 SHG-50-2SO [mm]

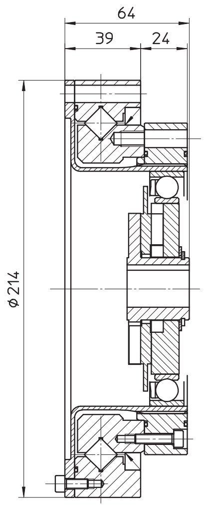

Illustration 17.6 SHG-50-2SH [mm]

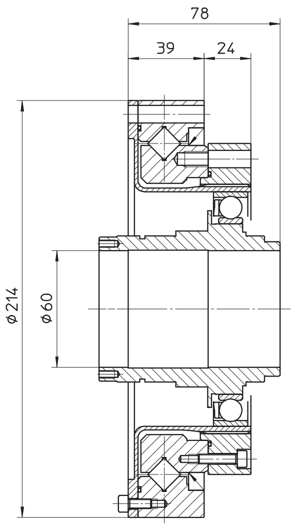

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Table 18.1

	Unit	SHG-58			
Ratio	i [ ]	80	100	120	160
Repeatable peak toque	T_R [Nm]	1924	2067	2236	2392
Average torque	T_A [Nm]	1001	1378	1547	1573
Rated torque	T_N [Nm]	714	905	969	969
Momentary peak torque	T_M [Nm]	3185	4134	4329	4459
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	4000			
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	3000			
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	2700/800[1)]			
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	2200/800[1)]			
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm²]	49.5			
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm²]	27.3			
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm²]	49.5			
Weight SHG-2UH	m [kg]	20			
Weight SHG-2SO	m [kg]	13.5			
Weight SHG-2SH	m [kg]	14.1			

[)] Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

Table 18.2

	Unit	SHG-65			
Ratio	i [ ]	80	100	120	160
Repeatable peak toque	T_R [Nm]	2743	2990	3263	3419
Average torque	T_A [Nm]	1352	1976	2041	2041
Rated torque	T_N [Nm]	969	1236	1236	1236
Momentary peak torque	T_M [Nm]	4836	6175	6175	6175
Maximum input speed (oil lubrication)	$n_{in\ (max)}$ [rpm]	3500			
Maximum input speed (grease lubrication)	$n_{in\ (max)}$ [rpm]	2800			
Average input speed (oil lubrication)	$n_{av\ (max)}$ [rpm]	2400/800[1)]			
Average input speed (grease lubrication)	$n_{av\ (max)}$ [rpm]	1900/800[1)]			
Moment of inertia SHG-2UH	J_{in} [$x10^{-4}$ kgm²]	94.1			
Moment of inertia SHG-2SO	J_{in} [$x10^{-4}$ kgm²]	46.8			
Moment of inertia SHG-2SH	J_{in} [$x10^{-4}$ kgm²]	94.1			
Weight SHG-2UH	m [kg]	28.5			
Weight SHG-2SO	m [kg]	19.5			
Weight SHG-2SH	m [kg]	20.9			

[)] Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.

Illustration 19.1 SHG-58-2UH [mm]

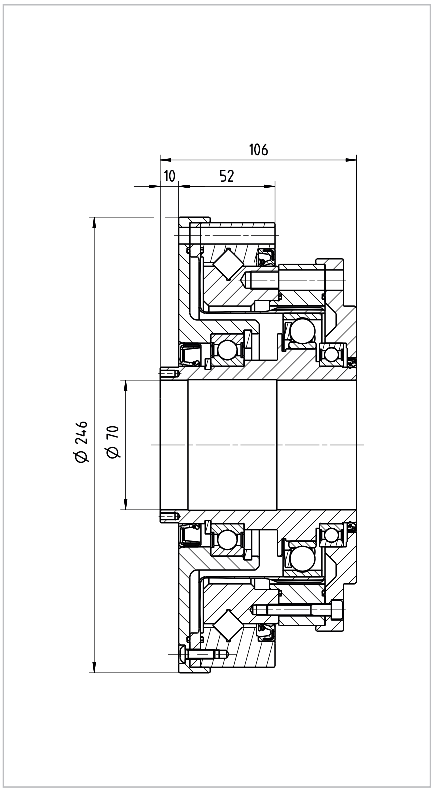


Illustration 19.2 SHG-58-2SO [mm]

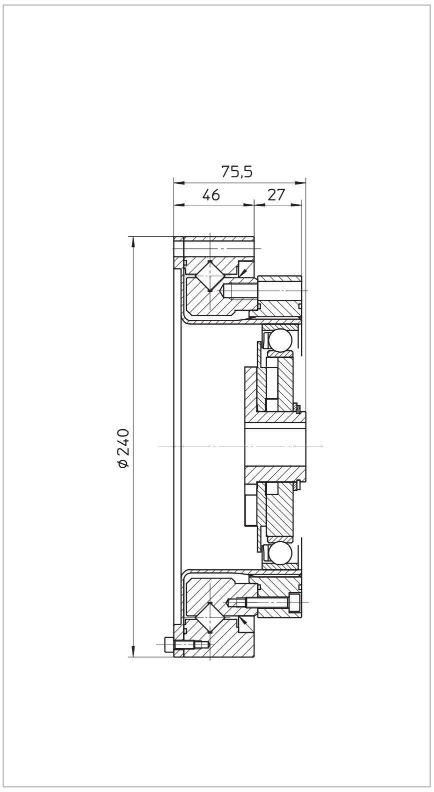


Illustration 19.3 SHG-58-2SH [mm]

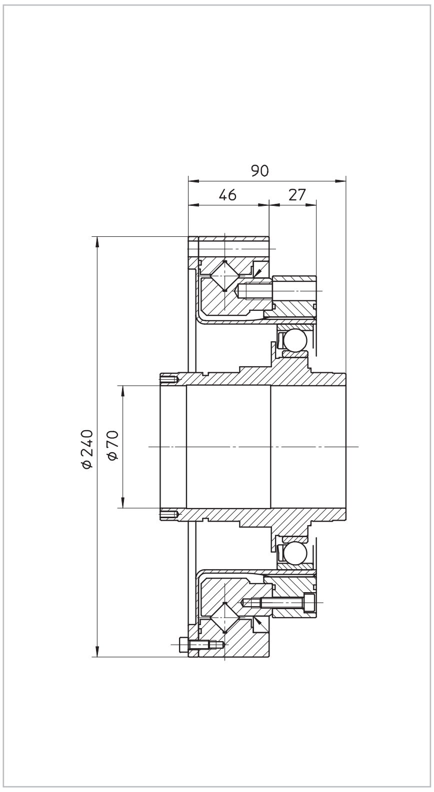


Illustration 19.1 SHG-65-2UH [mm]

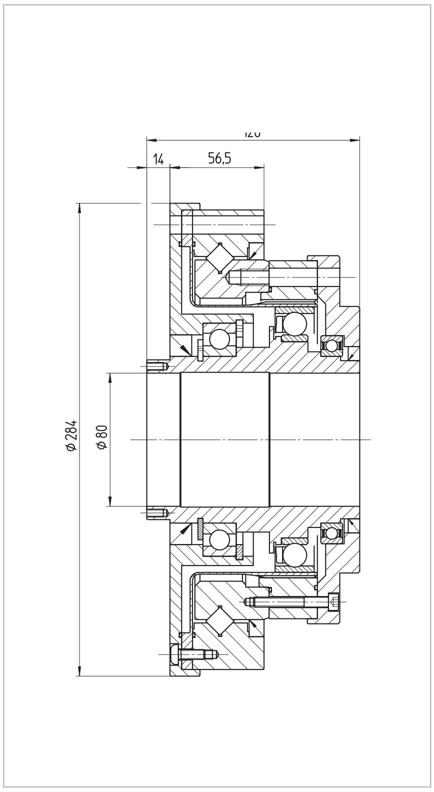


Illustration 19.2 SHG-65-2SO [mm]

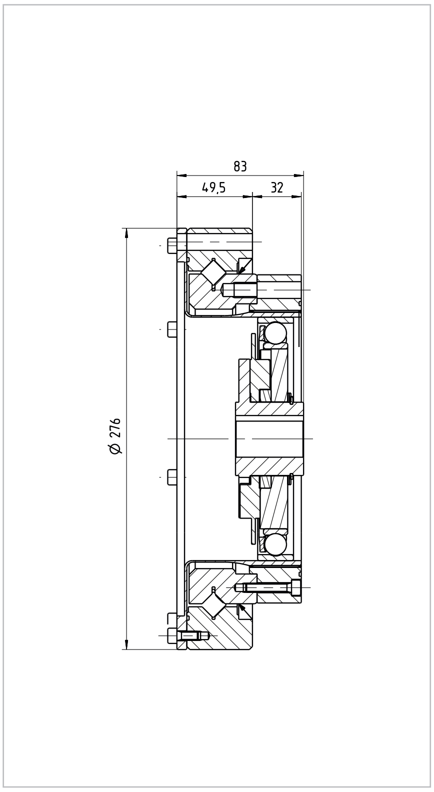
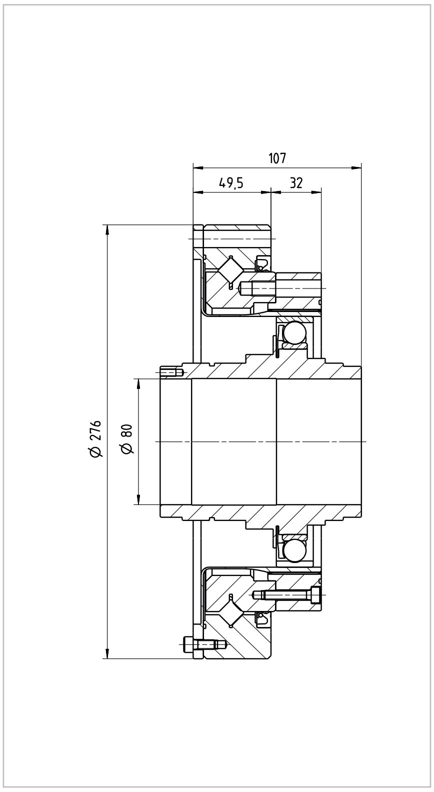


Illustration 19.3 SHG-65-2SH [mm]



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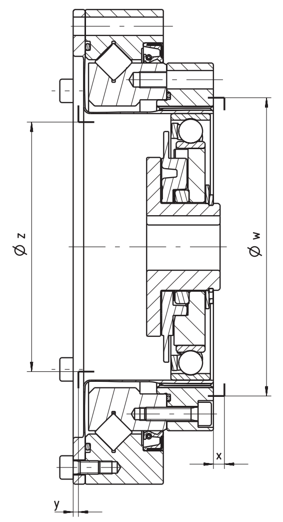
3.3.3 Minimum Housing Dimensions SHG-2SO and SHG-2SH

Table 20.1 [mm]

Size	14	17	20	25	32	40	45	50	58	65
∅W	38	45	53	66	86	106	119	133	154	172
X	1,0	1,0	1,5	1,5	1,5	2,0	2,0	2,0	2,5	2,5
Y	1,7	2,1	2,0	2,0	2,0	2,0	2,3	2,5	2,9	3,5
∅Z	31	38	45	56	73	90	101	113	131	150

Illustration 20.2



3.3.4 Accuracy

Table 20.3 [arcmin]

Size	14	17	≥ 20
Ratio	≥ 50	≥ 50	≥ 50
Transmission accuracy[1]	<1.5	<1.5	<1
Hysteresis loss	<1	<1	<1
Lost Motion	< 1		
Repeatability	< ± 0.1		

[1] Higher accuracy on request

3.3.5 Torsional Stiffness

Table 20.4

Size		14	17	20	25	32	40	45	50	58	65
T_1 [Nm]		2	3.9	7	14	29	54	76	108	168	235
T_2 [Nm]		6.9	12	25	48	108	196	275	382	598	843
i = 50	K_3[x10³ Nm/rad]	5.7	13	23	44	98	180	260	–	–	–
	K_2[x10³ Nm/rad]	4.7	11	18	34	78	140	200	–	–	–
	K_1[x10³ Nm/rad]	3.4	8.1	13	25	54	100	150	–	–	–
i > 50	K_3[x10³ Nm/rad]	7.1	16	29	57	120	230	330	440	710	980
	K_2[x10³ Nm/rad]	6.1	14	25	50	110	200	290	400	610	880
	K_1[x10³ Nm/rad]	4.7	10	16	31	67	130	180	250	400	540

3.3.6 Bearings

Output Bearing

SHG units 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 guaranteeing a long life and constant performance. The integration of an output bearing also serves to reduce subsequent design and production cost, by removing the need for additional output bearings in many applications. However, in some applications the machine element to be driven requires additional bearing support. In this case, please take care to avoid overdetermination of the bearing arrangement. The cross roller bearing of the unit should be used as the fixed bearing, whilst the additional support bearing should be floating, if possible. Table 21.1 lists ratings and important dimensions for the output bearings.

Table 21.1

Size		14	17	20	25	32	40	45	50	58	65
Bearing type 1)		C	C	C	C	C	C	C	C	C	C
Pitch circle ø	d_p [m]	0.050	0.060	0.070	0.085	0.111	0.133	0.154	0.170	0.195	0.218
Abstand 2)	R [m]	0.022	0.024	0.026	0.030	0.036	0.044	0.048	0.053	0.062	0.072
Dynamic load rating	C [N]	5800	10400	14600	21800	38200	43300	77600	81600	87400	133000
Static load rating	C_0 [N]	8600	16300	22000	35800	65400	81600	135000	149000	171000	223000
Permissible dynamic tilting moment 3)	M [Nm]	74	124	187	258	580	849	1127	1487	2180	2740
Permissible static tilting moment 4)	M_0 [Nm]	144	328	515	1070	2425	3623	6949	8505	11159	16200
Tilting moment stiffness 6)	K_B [Nm/arcmin]	25	45	74	114	290	522	749	1020	1550	2155
Permissible axial load 5)	F_a [N]	3044	5468	7687	11504	20119	22750	40858	42973	46017	60000
Permissible radial load 5)	F_r [N]	2039	3664	5150	7708	13480	15243	27375	28792	30831	40000

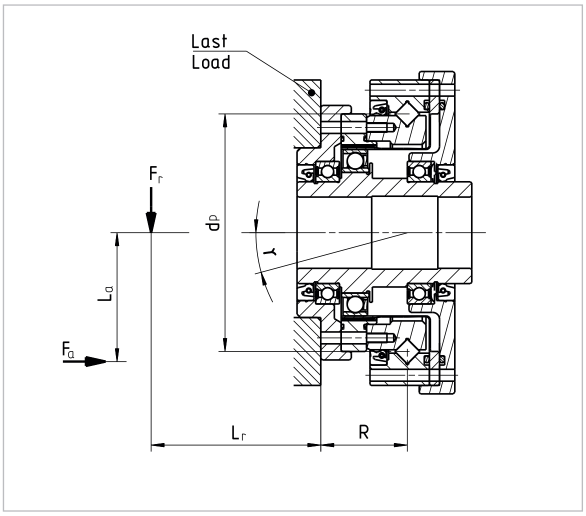
Normally, the gear life is determined by the life of the Wave Generator bearing. Depending on the specific load conditions the output bearing can also be determinant for the unit life.

1) F = Four-point bearing, C = Cross roller bearing
2) See illustration 21.2
3) These values are valid for moving gears. They are not based on the equation for lifetime calculation of the output bearing but on the maximum allowable deflection of the Harmonic Drive® component set. The values indicated in the table must not be exceeded even if the lifetime equation of the bearing permits higher values.
4) These values are valid for gears at a standstill and for a static load safety factor f_s = 1.8 for # 14-20 and 1,5 for # 25-58. For other values of f_s , please refer to capital 4.7.
5) These data are valid for n = 15 rpm and L_{10}=15000h

3) 4) 5) These data are only valid if the following conditions are fulfilled:
For: M, M_0 : $F_a = 0$, $F_r = 0$ | F_a : M = 0; $F_r = 0$ | F_r : M = 0, $F_a = 0$

6) Average value

Illustration 21.2



Output Bearing and Housing Tolerances

In the case of the SHG-2UH Unit the load is connected to the output bearing by means of a flange. Depending on the manner of fastening, either the flange which is connected to the outer ring, or the flange which is connected to the internal ring of the output bearing, can be used as output element (see illustration 22.1 and illustration 22.2). The tolerance values indicated in table 22.3 are the sum of bearing and flange tolerances.

Illustration 22.1

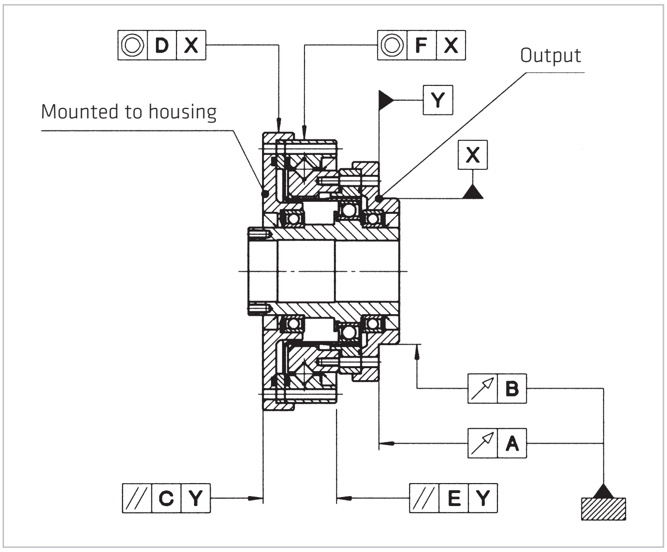


Illustration 22.2

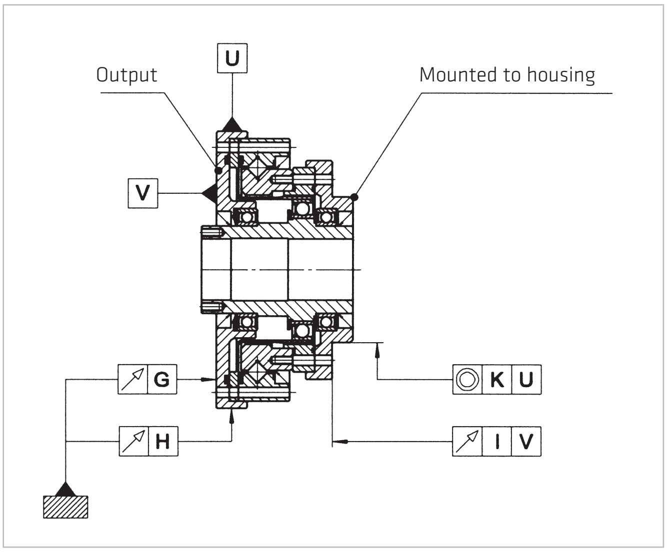


Table 22.3 [mm]

Size	14	17	20	25	32	40	45	50	58	65
A	0.033	0.038	0.040	0.046	0.054	0.057	0.057	0.063	0.063	0.67
B	0.035	0.035	0.039	0.041	0.047	0.050	0.053	0.060	0.063	0.63
C	0.064	0.071	0.079	0.085	0.104	0.111	0.118	0.121	0.121	0.131
D	0.053	0.053	0.059	0.061	0.072	0.075	0.078	0.085	0.088	0.089
E	0.040	0.045	0.051	0.057	0.065	0.071	0.072	0.076	0.076	0.082
F	0.038	0.038	0.047	0.049	0.054	0.060	0.065	0.067	0.070	0.072
G	0.037	0.039	0.046	0.047	0.059	0.063	0.070	0.070	0.070	0.076
H	0.031	0.031	0.038	0.038	0.045	0.048	0.050	0.050	0.050	0.054
I	0.064	0.071	0.079	0.085	0.104	0.111	0.118	0.121	0.121	0.131
K	0.053	0.053	0.059	0.061	0.072	0.075	0.078	0.085	0.088	0.089

Input Bearing SHG-2UH

The hollow shaft incorporated in the SHG-2UH unit is supported by two single row deep groove ball bearings. Illustration 23.2 shows the points of application of force of the maximum permissible radial and axial loads as indicated in illustrations 24.1 and 24.2.
Example: If the hollow shaft of a SHG-40-2UH unit is subjected to an axial load of 500 N, then the maximum permissible radial force will be 570 N, see illustration 24.1 and 24.2.

The maximum values shown are valid for an average input speed of 2000 rpm and a mean bearing life of L50= 35000 h. For SHG-2UH units of size 14 up to 25 the bearing A is pretensioned in axial direction by means of roller bearing compensation washers. If the hollow shaft is subjected to an axial force acting in the negative direction (- Fa, see illustration 23.2) it can be shifted for the value „s" given in table 23.1. For the size 32 up to 58 the bearing A is designed as a fixed bearing.

Table 23.1

Size		14	17	20	25	32	40	45	50	58	65
Bearing A	C [N]	4000	4300	4500	4900	14100	19400	17400	24400	32000	42500
	C_0 [N]	2470	2950	3450	4350	10900	16300	16100	22600	29600	36500
Bearing B	C [N]	4000	4300	4500	4900	5350	11500	11900	12500	18700	19600
	C_0 [N]	2470	2950	3450	4350	5250	10900	12100	13900	20000	21200
Offset	a [mm]	27	29	27	29.5	33	39.5	44	49	56.2	67
Offset	b [mm]	16.5	17.5	15.5	16.5	23.0	27.5	28.5	31.5	36.5	44.5
Max. permissible radial load	F [N]	263	284	303	275	813	1210	1000	1550	2060	2300
Max. axial movement of hollow shaft at axial force = - F_a	s [mm]	1.8	2.8	2.4	3.2	–	–	–	–	–	–

Illustration 23.2

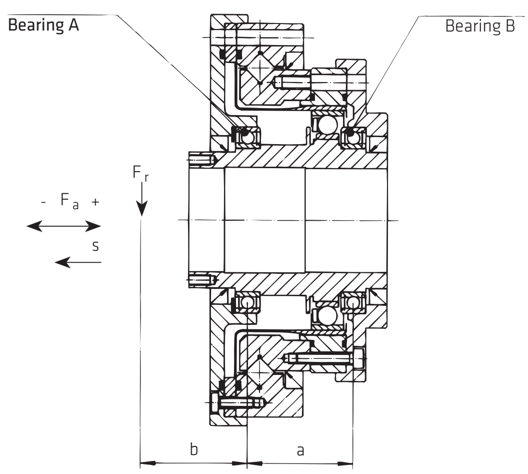


Illustration 24.1

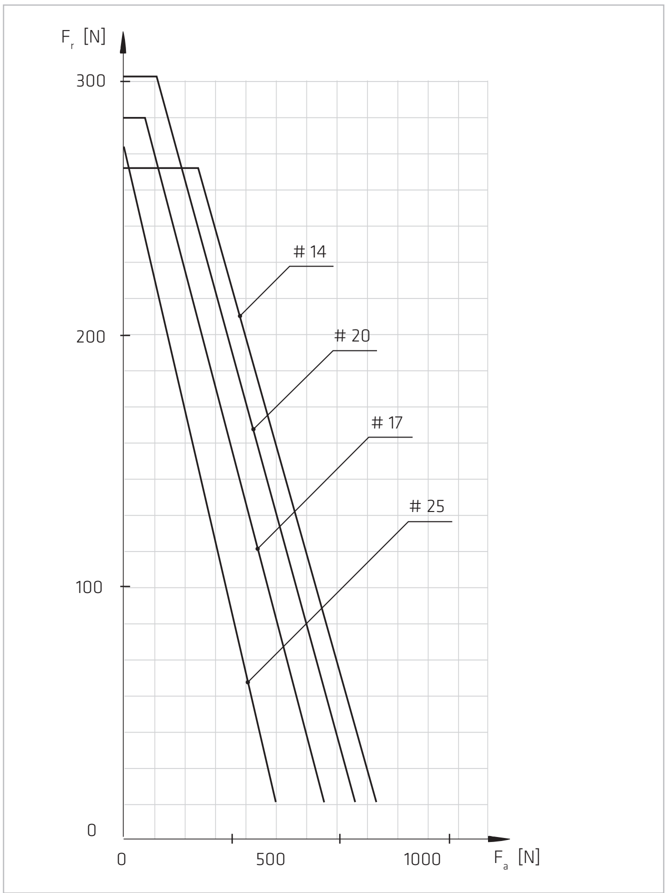
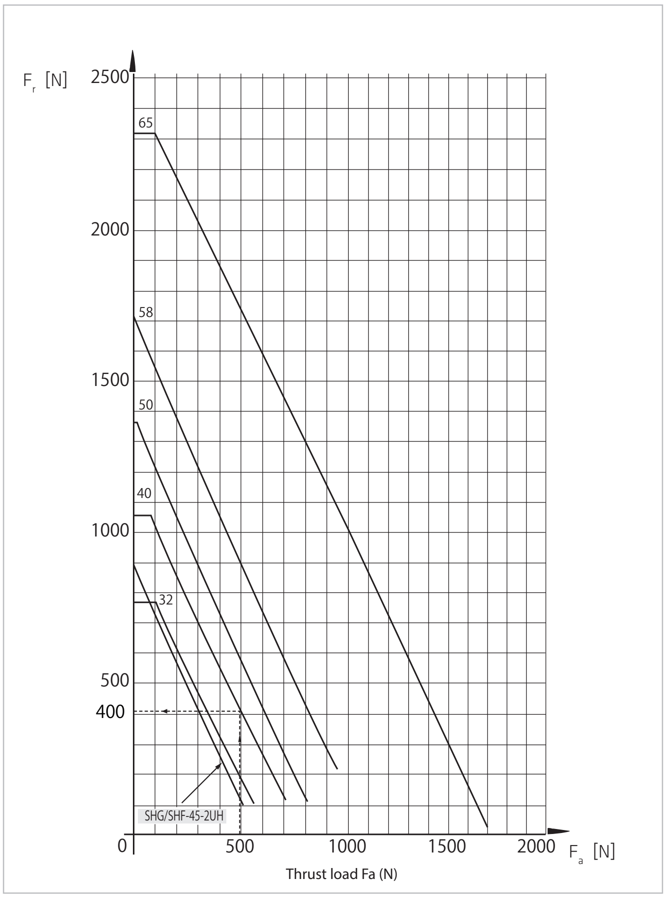


Illustration 24.2



3.3.7. Housing Materials and Surfaces

Materials:
Housing: cast iron and bearing steel.
Adapter flange, if supplied by Harmonic Drive AG: high tensile aluminium or steel.

Surfaces:
Screws: black phosphatized.
Housing: Bright.
Output bearing: Bright bearing steel.

4. Actuator Selection

A variety of different driving arrangements are possible with Harmonic Drive® gears.

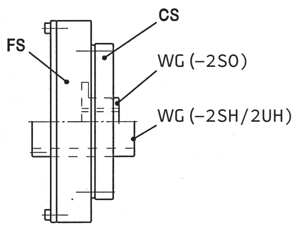
Equation 25.1

$$\text{Ratio } i = \frac{\text{Input speed}}{\text{Output speed}}$$

Overview Harmonic Drive® Products

The three main components of the Harmonic Drive® units, Circular Spline (CS), Flexspline (FS) and Wave Generator (WG) can be seen in the illustration 25.2.

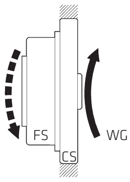
Illustration 25.2



The values for ratios of Harmonic Drive® gears refer to the standard input and output arrangement (example 1 in the table below). Other arrangements are possible, and also shown in the table.

Ratio

1)



Reduction gearing

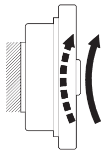
CS	Fixed
WG	Input
FS	Output

Equation 26.1

$$\text{Ratio} = -\frac{i}{1}$$

Input and output rotate in opposite directions.

2)



Reduction gearing

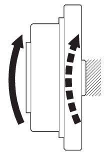
FS	Fixed
WG	Input
CS	Output

Equation 26.2

$$\text{Ratio} = \frac{i+1}{1}$$

Input and output rotate in same direction.

3)



Reduction gearing

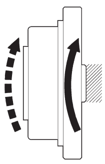
WG	Fixed
FS	Input
CS	Output

Equation 26.3

$$\text{Ratio} = \frac{i+1}{i}$$

Input and output rotate in same direction.

4)



Speed increaser gearing

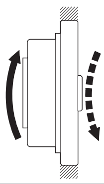
WG	Fixed
CS	Input
FS	Output

Equation 26.4

$$\text{Ratio} = \frac{i}{i+1}$$

Input and output rotate in same direction.

5)



Speed increaser gearing

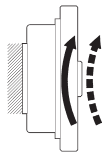
CS	Fixed
FS	Input
WG	Output

Equation 26.5

$$\text{Ratio} = -\frac{1}{i}$$

Input and output rotate in opposite directions.

6)



Speed increaser gearing

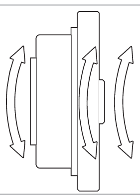
FS	Fixed
CS	Input
WG	Output

Equation 26.6

$$\text{Ratio} = \frac{1}{i+1}$$

Input and output rotate in same direction.

7)



Differential gear

WG	Control input
CS	Main drive input
FS	Main drive output

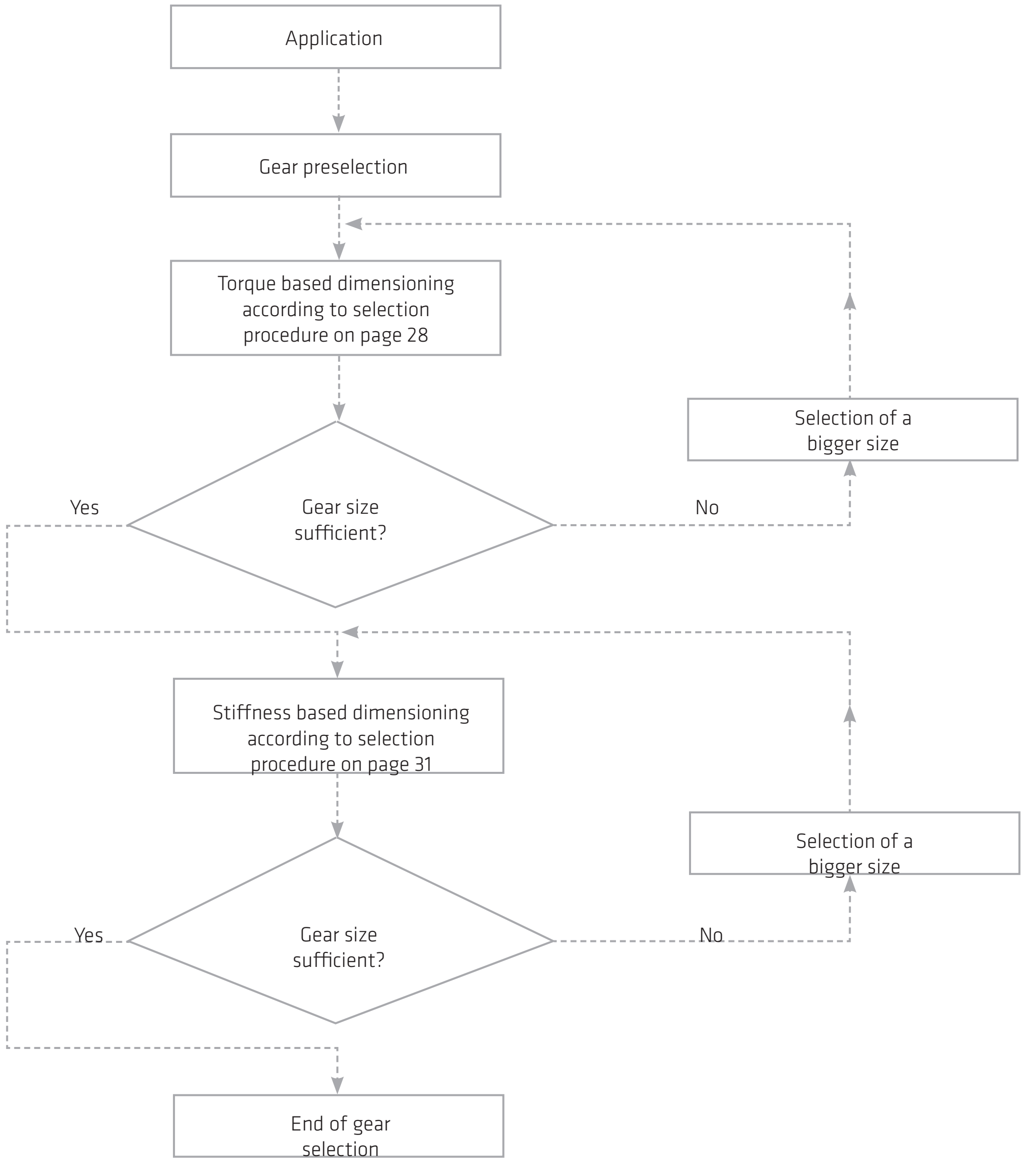
Numerous differential functions can be obtained by combinations of the speed and rotational direction of the three basic elements. Please refer to our broshure “Differential Applications” available to download from our website.

4.1 Selecting Harmonic Drive® Gears

When choosing a gear, both torque as well as stiffness requirements should be take into account. In robot applications, for example, the necessary torque is the more crucial factor for the gear size, while the torsional stiffness is often decisive in machine tool applications. We therefore recommend that you always take both criteria into account according to the following procedures.

ADVICE

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

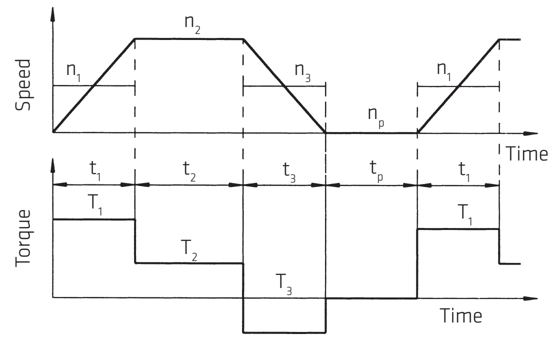


4.1.1 Torque Based Dimensioning

Output Data

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]
at output speed	n_k	[rpm]
and duration	t_k	[s]

Illustration 28.1



Equation 28.2

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

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

Equation 28.3

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

No

Selection of a bigger size

Equation 28.4

Calculation of the average output speed

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

Equation 28.5

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

Equation 28.6

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

Equation 28.7

Permissible average input speed
$n_{in\ av} \leq$ Limit for average input speed
(s. rating table)

Equation 28.8

Load limit 2, T_R

$T_{max} \leq T_R$

Equation 28.9

Load limit 3, T_M

$T_k \leq T_M$

Equation 28.10

Allowable number of momentary peak torques

$$N_{k\ max} = \frac{10^4}{2 \cdot \frac{n_k}{60} \cdot i \cdot t_k} < 10^4$$

Equation 28.11

Operating life

$$L_{50} = L_n{}^* \cdot \frac{\text{Rated input speed}}{n_{in\ av}} \cdot \left(\frac{\text{Rated torque } T_N}{T_{av}}\right)^3$$

Values for L_n see table 30.1

Output Data

T_1 = 400 Nm	t_1 = 0.3 s	n_1 = 7 rpm
T_2 = 320 Nm	t_2 = 3.0 s	n_2 = 14 rpm
T_3 = 200 Nm	t_3 = 0.4 s	n_3 = 7 rpm
T_k = 500 Nm	t_k = 0.15 s	n_k = 14 rpm
	t_p = 0.2 s	n_p = 0 rpm

Ratio i = 120
Life L_{50} = 30000 h (required)

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

$$T_{av} = \sqrt[3]{\frac{7\text{ rpm} \cdot (400\text{ Nm})^3 \cdot 0.3\text{ s} + 14\text{ rpm} \cdot (320\text{ Nm})^3 \cdot 3\text{ s} + 7\text{ rpm} \cdot (200\text{ Nm})^3 \cdot 0.4\text{ s}}{7\text{ rpm} \cdot 0.3\text{ s} + 14\text{ rpm} \cdot 3\text{ s} + 7\text{ rpm} \cdot 0.4\text{ s}}}$$

T_{av} = 319 Nm ≤ T_A = 451 Nm

Selected size
HFUC-40-120-2A-GR

Calculation of the average
output speed

$$n_{out\ av} = \frac{7\text{ rpm} \cdot 0.3\text{ s} + 14\text{ rpm} \cdot 3\text{ s} + 7\text{ rpm} \cdot 0.4\text{ s}}{0.3\text{ s} + 3\text{ s} + 0.4\text{ s} + 0.2\text{ s}} = 12.0\text{ rpm}$$

Average input speed
$n_{in\ av}$ = 120 · 12.0 rpm = 1440 rpm

Permissible maximum input speed
$n_{in\ max}$ = 14 rpm · 120 = 1680 rpm ≤ 4000 rpm

Permissible average input speed
$n_{in\ av}$ = 1440 rpm ≤ 3000 rpm

Load limit 2, T_R

T_{max} = 400 Nm ≤ T_R = 617 Nm

Load limit 3, T_M

T_k = 500 Nm ≤ T_M = 1180 Nm

Allowable number of
momentary peak torques

$$N_{k\ max} = \frac{10^4}{2 \cdot \frac{14 \cdot 120}{60} \cdot 0.15} = 1190 < 10^4$$

Operating life

HFUC-40-120-2A-GR:

$$L_{50} = \frac{35000\text{ h} \cdot 2000\text{ rpm}}{1440\text{ rpm}} \cdot \left(\frac{294\text{ Nm}}{319\text{ Nm}}\right)^3$$

L_{50} = 38054 h > 30000 h

4.1.2 Life of the Wave Generator Bearing

Given that the Harmonic Drive® Gear is rated to provide infinite fatigue life for the Flexspline, the life expectancy is based on the average life of the Wave Generator bearing. The rated torque at the rated speed given in the rating table is based on the mean L_{50} bearing life.

The life expectancy of a component set or an unit operating at an input speed n (rpm) and output torque T (Nm) may be estimated from equation 30.2.

Table 30.1 [h]

Harmonic Drive® series	L_n
CobaltLine, CSG, SHG	50000
HFUC, SHG, CSD, CPU, CSF, SHD	35000
PMG gearbox	15000

Equation 30.2

$$L_{50} = L_n \frac{n_N}{n_{in\ av}} \left(\frac{T_N}{T_{av}}\right)^3$$

Equation 30.3

$$L_{10} \approx \frac{1}{5} \cdot L_{50}$$

n_N = Rated input speed [2000 rpm]
$n_{in\ av}$ = Average input speed [rpm] (equation 28.5)
T_N = Rated output torque at rated speed [Nm]
T_{av} = Average output torque [Nm] (equation 28.2)
L_n = See table 30.1

4.1.3 Stiffness Based Dimensioning

In addition to the “Torque Based Dimensioning” stated on page 28, we recommend that you carry out a selection based on stiffness. For this, the values provided in table 31.1 for the individual resonance frequencies recommended for each application should be taken into account.

Table 31.1 [Hz]

Application	f_n
Slowly rotating turntables, base axes of slow moving welding robots (not laser welding), slowly rotating welding and swinging tables, gantry robot axes	≥ 4
Base axes of revolute robots, hand axes of revolute robots with low requirements regarding dynamic perfomance, tool revolvers, tool magazines, swivelling and positioning axes in medical and measuring devices	≥ 8
Standard applications in general mechanical engineering, tilting axes, palette changers, highly dynamic tool changers, revolvers and magazines, hand axes of robots, scara robots, gantry robots, polishing robots, dynamic welding manipuators, base axes of welding robots (laser welding), swivelling and positioning axes of medical equipment	≥ 15
B/C axes in 5 axis grinding machines, hand axes of welding robots (laser welding), milling heads for plastics machining	≥ 20
C axes in turning machines, milling heads for light metal machining, milling heads for woodworking (chipboards etc.)	≥ 25
Milling heads for woodworking (hardwood etc.)	≥ 30
C axes in turning machines*	≥ 35
Milling heads for metal machining*, B axes in turning milling centers for metal machining	≥ 40
Milling heads for metal machining*, B axes in turning milling centers for metal machining with high requirements regarding surface quality*	≥ 50
Milling heads for metal machining with very high requirements regarding surface quality*	≥ 60

* Depending on the application, a secondary gear stage may be useful. Please contact Harmonic Drive AG for more information..

Resonance Frequency (Gear Output)

The formula

Equation 32.1

$$f_n = \frac{1}{2\pi} \sqrt{\frac{K_1}{J}} \text{ [Hz]}$$

fn = Resonance frequency [Hz]
K1 = Gear torsional stiffness [Nm/rad]
J = Load moment of inertia [kgm2]

allows the calculation of the resonance frequency at the gear output from the given torsional stiffness, K_1, of the Harmonic Drive® gear and the load's moment of inertia. The calculated frequency should correspond with the value provided in table 31.1. The higher the load's moment of inertia, the more influence the application has on the gear selection. If the moment of inertia = 0, the selected application has no numerical influence on the selection result.

Resonance Speed (Gear Input)

The resonance speed nn on the input side (motor side) can be calculated using the formula

$n_n = f_n * 30$ [rpm]

During operation, we recommend that you pass the resonance speed rapidly. This can be achieved by selecting a suitable gear ratio. Another possibility is to select suitable gear stiffness such that the resonance speed lies beyond the required speed range.

Selection Example

HFUC-40-120-2A-GR preselected from "Selection Procedure" on page 29.

Intended application: milling head for woodworking
Moment of inertia at the gear output: 7 kgm^2. Recommended resonance frequency from table 31.1: ≥ 30 Hz.
Resonance frequency using the preselected gear
HFUC-40-120-2A-GR:

$$f_n = \frac{1}{2\pi} \cdot \sqrt{\frac{1.3 \cdot 10^5}{7}} = 22 \text{ [Hz]}$$

According to stiffness based dimensioning, this gear size is too small for the application.
The larger gear HFUC-50-120-2A-GR results in a resonance frequency of:

$$f_n = \frac{1}{2\pi} \cdot \sqrt{\frac{2.5 \cdot 10^5}{7}} = 30 \text{ [Hz]}$$

Based on stiffness based dimensioning, the gear HFUC-50-120-2A-GR is recommended.

The resonance speed at the input (motor) amounts to:
$n_n = 30 * 30 = 900$ [rpm]

Either, this speed should be passed without stopping when accelerating / braking, or it should lie beyond the utilised speed range.

4.2 Calculation of the Torsion Angle

Calculation of the Torsion Angle φ at Torque T:

Equation 33.1

$$T \leq T_1$$

$$\varphi = \frac{T}{K_1}$$

Equation 33.2

$$T_1 < T \leq T_2$$

$$\varphi = \frac{T_1}{K_1} + \frac{T - T_1}{K_2}$$

Equation 33.3

$$T > T_2$$

$$\varphi = \frac{T_1}{K_1} + \frac{T_2 - T_1}{K_2} + \frac{T - T_2}{K_3}$$

φ = Angle [rad]
T1 = Limit torque 1 from Section 3.3.5 [Nm]
T2 = Limit torque 2 from Section 3.3.5 [Nm]
K1 = Torsional stiffness up to the limit torque T1 from Section 3.3.5 [Nm/rad]
K2 = Torsional stiffness up to the limit torque T2 from Section 3.3.5 [Nm/rad]
K3 = Torsional stiffness above the limit torque T2 from Section 3.3.5 [Nm/rad]

Example: HFUC-32-100-2UH

$T = 60$ Nm $K_1 = 6.7 \cdot 10^4$ Nm/rad

$T_1 = 29$ Nm $K_2 = 1.1 \cdot 10^5$ Nm/rad

$T_2 = 108$ Nm $K_3 = 1.2 \cdot 10^5$ Nm/rad

$$\varphi = \frac{29\ \text{Nm}}{6.7 \cdot 10^4\ \text{Nm/rad}} + \frac{60\ \text{Nm} - 29\ \text{Nm}}{11 \cdot 10^4\ \text{Nm/rad}}$$

$$\varphi = 7.15 \cdot 10^{-4}\ \text{rad}$$

$$\varphi = 2.5\ \text{arc min}$$

Equation 33.4

$$\varphi\ [\text{arc min}] = \varphi\ [\text{rad}] \cdot \frac{180 \cdot 60}{\pi}$$

4.3 Accuracy of the Oldham Coupling SHG-2SO

Information concerning the Oldham coupling can be found in section 5.7.2.

In the region of tooth engagement Harmonic Drive® gears have no backlash. If an Oldham coupling is used for the compensation of eccentricity errors of the motor shaft, a small backlash in the range of a few seconds of arc can occur at the output shaft, as listed in table 33.5.

Table 33.5 [arcsec]

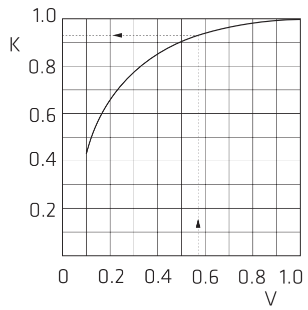
Sizes		**14**	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**	**65**
Ratio	50	36	20	17	17	14	14	12	–	–	–
	80	23	13	11	11	9	9	8	8	6	6
	100	18	10	9	9	7	7	6	6	5	5
	120	–	8	8	8	6	6	5	5	4	4
	160	–	–	6	6	5	5	4	4	3	3

4.4 Efficiency Versus Load

Efficiency for Harmonic Drive® gears varies depending on the output torque. The efficiency curves are for gears operating at rated output torque. Efficiency for a gear operating at a load below the rated torque may be estimated using a compensation curve and equation as shown on the next page.

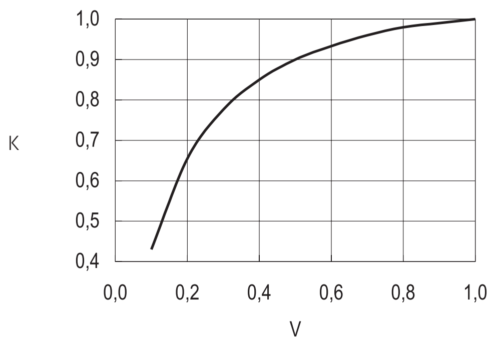
4.4.1 Efficiency Calculations SHG-2SO and SHG-2SH Units

Table 34.1

Calculation Procedure	Example
	Efficiency of HFUC-20-80-2A-GR with input speed n=1000 rpm output torque T=19.6 Nm at 20° C ambient temperature. Lubrication: Oil
The efficiency may be determined using the efficiency graphs.	From matching chart η = 78 %
Calculate the torque factor V. $V = \frac{T_{av}}{T_N}$ [Equation 34.2] With: T_{av} = Average torque T_N = Rated torque at rated speed	T_{av} = 19.6 Nm T_N = 34.0 Nm $V = \frac{19.6\ Nm}{34.0\ Nm} = 0.57$
K depending on gear type and V, see illustration 34.4	
Calculation of total efficiency η_L $\eta_L = K \cdot (\eta_R + \eta_e)$ [Equation 34.3]	with: K = Correction factor from illustration 35.1 K = 1; for $T > T_N$ η_R = Efficiency at rated torque, see 35.4 η_e = Correction value to reflect the influence of the rotary shaft seals at the input side, see illustration 34.4

Calculating Factor K

Illustration 34.4



4.4.2 Efficiency Calculations SHG-2UH

Calculation of torque factor V

Equation 35.1

$$V = \frac{T}{T_N}$$

with:
T = Actual torque
T_N = Rated torque at rated speed

Correction factor/value SHG-2UH

Illustration 35.2

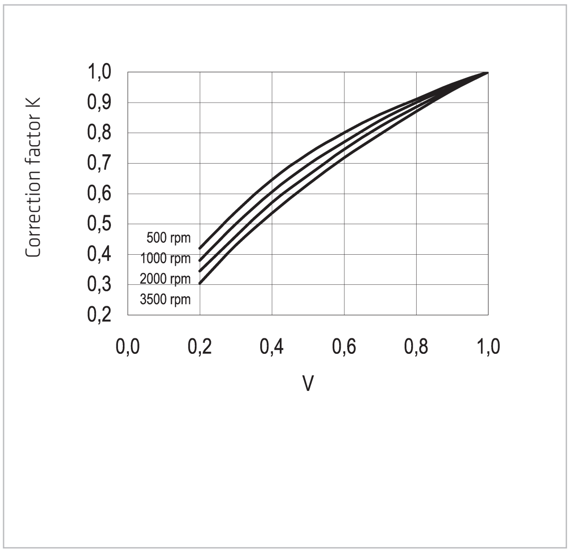
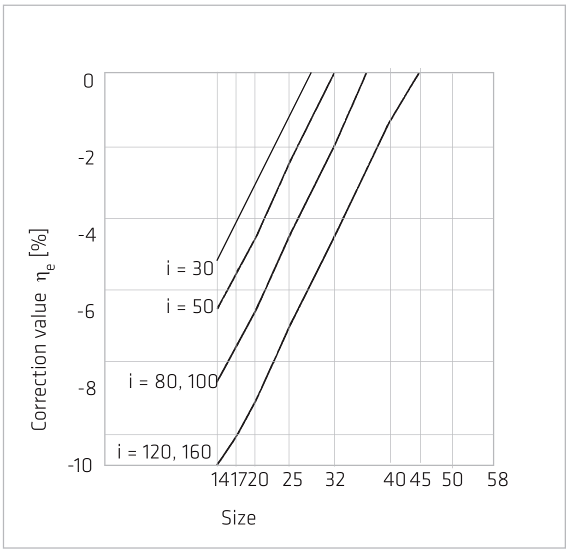


Illustration 35.3



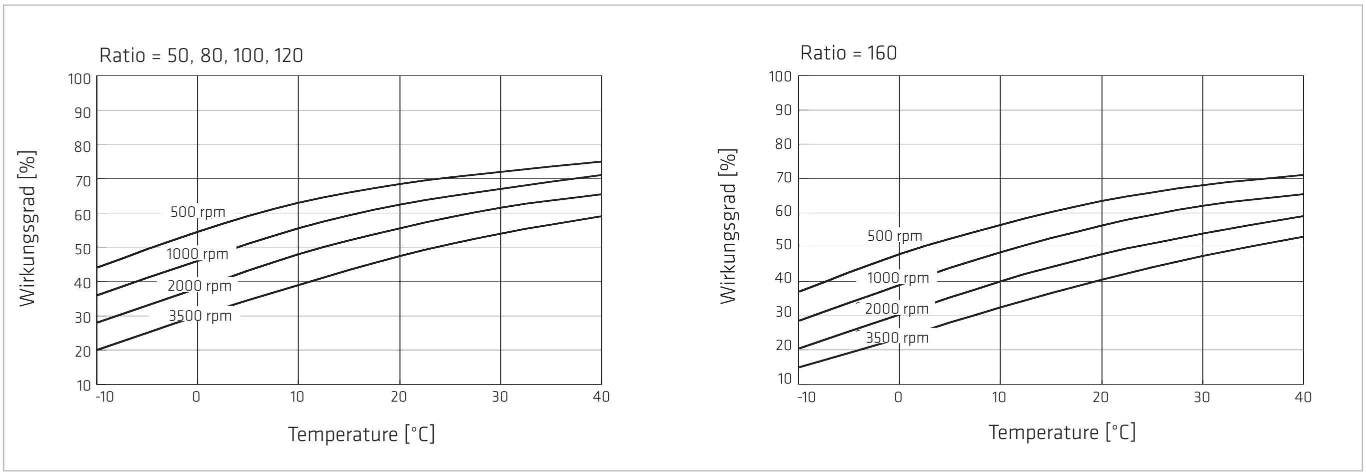
4.4.3 Efficiency Tables

Grease Tables

Efficiency for Grease Lubrication at Rated Torque
Harmonic Drive® Grease

SHG-2UH

Illustration 35.4



4.5 No Load Starting, Back Driving and Running Torque

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.

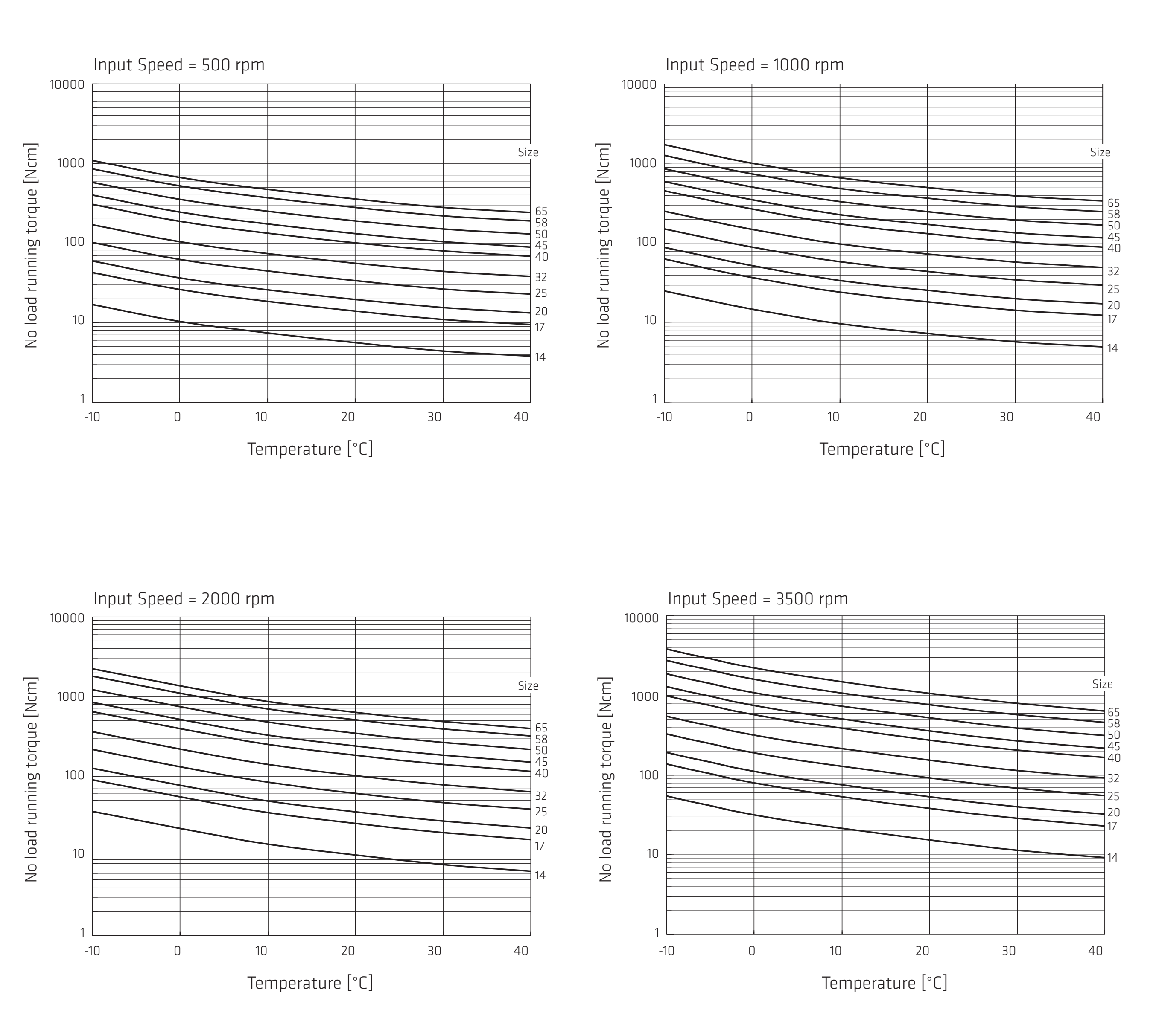
No Load Starting Torque
The no load starting torque is the quasistatic torque required to commence rotation of the input element (high speed side) with no load applied to the output element (low speed side).

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.

4.5.1 No Load Running Torque

No Load Running Torque SHG-2UH

Illustration 36.1



Compensation Values For No Load Running Torque SHG-2UH

When using gears with ratios other than i ≠ 100, please apply the compensation values from the table to the values taken from the curves .

Table 37.1 [Ncm]

Ratio	Size									
	14	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**	**65**
50	1.1	1.8	2.6	4.2	8.0	13.3	18.2	–	–	–
80	0.2	0.4	0.5	0.8	1.5	2.4	3.3	4.3	6.2	8.1
120	–	-0.2	-04	-0.6	-1.1	-1.7	-2.4	-3.1	-4.4	-5.8
160	–	–	-0.8	-1.3	-2.5	-4.0	-5.5	-7.2	-10.3	-13.7

4.5.2 No Load Starting Torque

No Load Starting Torque SHG-2UH

Table 37.2 [Ncm]

Ratio	Size									
	14	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**	**65**
50	8.8	27	36	56	85	136	165	–	–	–
80	7.5	25	33	50	74	117	138	179	244	314
100	6.9	24	32	49	72	112	131	171	231	297
120	–	24	31	48	68	110	126	165	223	287
160	–	–	31	47	67	105	122	156	213	276

4.5.3 No Load Back Driving Torque

No Load Back Driving Torque SHG-2UH

Table 37.1 [Ncm]

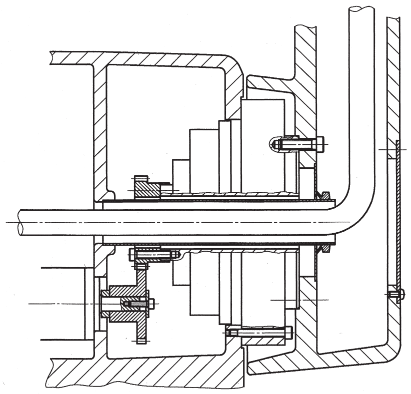
Ratio	Size									
	14	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**	**65**
50	5.3	16	22	34	51	82	**99**	–	–	–
80	7.2	24	31	48	70	112	133	172	234	301
100	8.2	29	38	59	86	134	158	205	278	356
120	–	34	45	69	97	158	182	237	322	413
160	–	–	59	90	128	201	233	299	408	530

4.6 Continuous Operation SHG-2UH

The friction of the rotary shaft seals at the input side can result in an increased temperature of the hollow shaft units during operation. Therefore the defined "Limit for average input speed" of these units is reduced. For continuous operation at rated speed the max. operating times specified in table 38.2 should not be exceeded.

Alternatively a design according to illustration 38.1 can be used. This application example shows the removal of the rotary shaft seals at the (fast running) input side. For this design, the operating time is not limited. The removal of one or both rotary shaft seals at the input element should only be carried out if other measures have been undertaken to prevent the leakage of grease or oil, or if a leakage can be ruled out due to the installation position.

Illustration 38.1



Max. Permissible Operating Time At Continuous Operation

Table 38.2 [min]

Operating time	Sizes									
	14	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**	**65**
at no load	90	90	90	60	45	40	35	30	20	15
at rated torque	60	60	60	45	35	30	25	20	15	10

The data mentioned in table 38.2 are valid for:

- Ambient temperature: 25 °C
- Input speed: 2000 rpm
- Max. lubrication temperature: 80 °C
- Mounting of the unit on a plate with the following dimensions:
  Height of plate: 330 mm
  Thickness of plate: 15 mm for sizes: 15 mm for sizes ≤ 32
  30 mm for sizes ≥ 40
- Plate material:: Steel
- An additional output flange is not mounted.

4.7 Output Bearing Operating Life

The operating life of the output bearing can be calculated using equation 39.1.

Equation 39.1

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

with:

L_{10} [h] = Operating life

n_{av} [rpm] = Average output speed (equation 39.2)

C [N] = Dynamic load rating see section 3.3.6

P_C [N] = Dynamic equivalent load (equation 40.1)

f_W = Operating factor (table 39.3)

B = Bearing type (table 39.4)

Average Output Speed

Equation 39.2

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

Table 39.3

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

Table 39.4

Bearing type	**B**
Cross roller bearings	10/3
Four point contact bearings	3

Dynamic Equivalent Load

Equation 40.1

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

with:

F_{rav} [N]	=	Radial force (equation 40.2)	x	=	Radial load factor (table 40.4)
F_{aav} [N]	=	Axial force (equation 40.3)	y	=	Axial load factor (table 40.4)
d_p [m]	=	Pitch circle (see section 3.3.5)	M	=	Tilting moment

Equation 40.2

$$F_{rav} = \left(\frac{|n_1| \cdot t_1 \cdot (|F_{r1}|)^B + |n_2| \cdot t_2 \cdot (|F_{r2}|)^B + \ldots + |n_n| \cdot t_n \cdot (|F_{rn}|)^B}{|n_1| \cdot t_1 + |n_2| \cdot t_2 + \ldots + |n_n| \cdot t_n} \right)^{1/B}$$

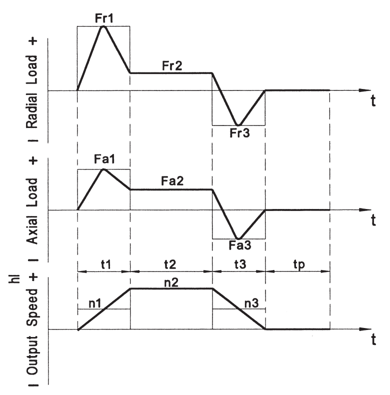
Equation 40.3

$$F_{aav} = \left(\frac{|n_1| \cdot t_1 \cdot (|F_{a1}|)^B + |n_2| \cdot t_2 \cdot (|F_{a2}|)^B + \ldots + |n_n| \cdot t_n \cdot (|F_{an}|)^B}{|n_1| \cdot t_1 + |n_2| \cdot t_2 + \ldots + |n_n| \cdot t_n} \right)^{1/B}$$

Table 40.4

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

Illustration 40.5



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

4.7.1 Output Bearing at oscillating motion

Life for Oscillating Motion
The operating life at oscillating motion can be calculated using equation 42.1

Equation 41.1

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

with:

L_{OC} [h]	=	Operating life for oscillating motion
n_1 [cpm]	=	Number of oscillations/minute*
C [N]	=	Dynamic load rating, see table “Output Bearing” in the appropriate product chapter (table 21.1)
P_C [N]	=	Dynamic equivalent load (equation 40.1)
φ [deg]	=	Oscillating angle
f_W	=	Operating factor (table 39.3)

* 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 41.2

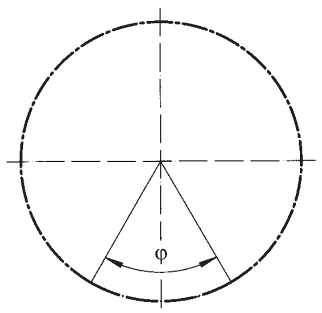


Tabelle 41.3

Lagertyp	B
Kreuzrollenlager	10/3
Vierpunktlager	3

4.8 Permissible Static Tilting Moment

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

Equation 42.1

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

and so

Equation 42.2

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

f_s = Static load safety factor

(f_s = 1.5 ... 3) (table 42.3)

C_0 = Static load rating

F_r = F_a = 0

x_0 = 1

y_0 = 0.44

P_0 = Static equivalent load (equation 40.1)

d_p = Pitch circle diameter of the output bearing (section 3.3.6)

M = Moment acting

M_0 = Allowable static overturning moment

Table 42.3

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

4.9 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 42.4:

Equation 42.4

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

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 (table 21.1)

4.10 Lubrication

Ratings and Lubricants
Harmonic Drive® products achieve the specified ratings and characteristics in the standard ambient temperature range (0° C to 40° C) when they are used with the lubricants named in the catalogue. Harmonic Drive AG can guarantee for the data specified in the catalogue only if a Harmonic Drive® grease or a mineral oil qualified for the specific product used. Lubricants and lubricant quantities other than recommended by Harmonic Drive AG should be qualified by means of prototype tests, as necessary.

The warranty becomes void when lubricants that have not been recommended in the Harmonic Drive® catalogue or that have not been approved in writing for the specific application are used.

4.10.1 Grease Lubrication

Application of Harmonic Drive® Lubricating Grease
Depending on product, size and if necessary ratio, the matching Harmonic Drive® grease should be selected.

Caution!
The Harmonic Drive® high performance greases 4BNo.2 and Flexolub-A1 have relatively low viscosities during operation. Therefore the design must be oil-tight. Because of the special characteristics of this grease, a small base oil leakage at the oil seals can not completely be ruled out.

Table 43.1

<table>
<tr><th rowspan="3">Grease</th><th colspan="15">Ratio ≥ 50</th></tr>
<tr><th colspan="15">Size</th></tr>
<tr><th>8</th><th>11</th><th>14</th><th>17</th><th>20</th><th>25</th><th>32</th><th>40</th><th>45</th><th>50</th><th>58</th><th>65</th><th>80</th><th>90</th><th>100</th></tr>
<tr><td>Flexolub A1</td><td colspan="2">–</td><td colspan="13">Standard for CPU and CobaltLine</td></tr>
<tr><td>SK-1A</td><td colspan="4">–</td><td colspan="11">Standard</td></tr>
<tr><td>SK-2</td><td colspan="4">Standard</td><td colspan="11">–</td></tr>
<tr><td>4BNo.2</td><td colspan="2">–</td><td colspan="13">For heavy duty operation*</td></tr>
</table>

Table 43.2

<table>
<tr><th rowspan="3">Grease</th><th colspan="7">Ratio = 30</th></tr>
<tr><th colspan="7">Size</th></tr>
<tr><th>8</th><th>11</th><th>14</th><th>17</th><th>20</th><th>25</th><th>32</th></tr>
<tr><td>Flexolub A1</td><td colspan="2">–</td><td colspan="5">Standard for CPU</td></tr>
<tr><td>SK-1A</td><td colspan="4">–</td><td colspan="3">Standard</td></tr>
<tr><td>SK-2</td><td colspan="4">Standard</td><td colspan="3">–</td></tr>
<tr><td>4BNo.2</td><td colspan="4">–</td><td colspan="3">For heavy duty operation*</td></tr>
</table>

Notes:
* = recommended for heavy duty operation or at operating temperatures ranging from -10° C to +110° C
– = not approved

Table 44.1 gives some important information regarding Harmonic Drive® lubricating greases.

Table 44.1

Type	Harmonic Drive® lubricating greases			
	Standard		Special	
	SK-1A	SK-2	Flexolub A1	4BNo.2
Operating temperature range	0° C … +80° C	0° C … +80° C	-40° C … +120° C	-10° C … +110° C
Base oil	Mineral oil	Mineral oil	PAO / Ester oil	Synthetic oil
Thickener	Lithium soap	Lithium soap	Lithium soap	Urea
Consistency class (NLGI)	2	2	1	1-2
Base oil viscosity (40° C; 100° C)	37; 5,9 mm^2/St	37; 5,9 mm^2/St	25; 5,2 mm^2/St	50; 12 mm^2/St
Drop point	197° C	198° C	180° C	247° C
Colour	yellow	green	magenta	pale yellow
Max. storage time in hermetically sealed container	5 years			
Ease of sealing (safety against grease- or base oil leakage at the oil seals)	+	+	+	+/-

Notes:
+ = Good
+/– = May be critical depending on design / mounting position / application, please contact Harmonic Drive AG

Safety data sheets and technical data sheets for the Harmonic Drive® lubricants are available from Harmonic Drive AG.

Precautions for using Harmonic Grease 4BNo.2

Harmonic grease 4BNo.2 has fluid characteristics (thickness, shear characteristics etc.) suited to Harmonic Drive® gears. The following procedures can be utilised to improve the lubricant life:

1) apply the grease to the required areas before operation.
2) remove any abrasion particles after the running-in period.
3) re-grease the contact areas.

Precautions

1) When greasing:
The consistency of Harmonic grease 4BNo.2 when stored in the container is higher than during operation. However, please note that the consistency varies depending on the storage period.
Before greasing please mix the grease to soften the consistency.

2) Aging (running-in):
The aging process before the fully loading the gears softens the grease. More effective grease performance can be realised when the grease flows around the required contact areas of the Harmonic Drive® gear.

Therefore the following aging method is recommended:
• Keep the internal operating temperature below 80°C. Do not allow a steep increase in temperature during the aging process.
• Limit the input speed to between 1000 and 3000 rpm. Lower speeds are more effective. Select an input speed as close to 1000 rpm as possible.
• The time required for aging is 20 minutes or longer.
• Keep the output rotation angle as large as possible during the aging process.

Contact our offices if you have any questions about handling Harmonic grease 4BNo.2.

Special Operating Demands

Table 45.1 shows examples of lubricants for special operating demands. In individual cases other lubricants may be recommendable, and special limit values may have to be considered for product calculations at extended operating temperatures. Please ask Harmonic Drive AG for more information.

Table 45.1

Lubricants for special operating demands			
Application	Type	Manufacturer, Designation	Operating temperature range [1]
Broadband temperature range	Grease	Harmonic Drive®, Flexolub-A1	-40° C ... +120° C [3]
Low temperature	Grease Oil	Harmonic Drive®, Flexolub-M0	-50° C ... +120° C [2][5]
High temperature	Grease Oil	Mobil, Mobil Grease 28 Mobil, Mobil SHC 626	-55° C ... +160° C [2] -15° C ... +140 °C [2]
Food-/pharmaceutical industry	Grease	Bechem, Berulub FG-H 2 SL	-40° C ... +120 °C [2][4]

Notes:

[1] Operating temperature = Lubricant temperature
[2] User specific prototype tests recommended
[3] Applicability confirmed for all Harmonic Drive® catalogue products with cup type Flexspline for size 14 and up. 1 kg bundles available at HDAG
[4] NSF-H1 certification. Applicability confirmed for HFUC-XX, CPU-XX, SHG-XX, CPL-XX, CHA-XX with i=100 at full usage of the catalogue performance data. Please consult Harmonic Drive AG for i>100 applications. For food/ pharmaceutical compatibility, grease change is necessary for output- and support bearings, if used. 400 g bundles available at Harmonic Drive AG.
[5] Recommended for applications requiring best possible efficiency at low temperatures. Not suitable for high output torque.

4.10.2 Oil Lubrication

Harmonic Drive® units with oil lubrication are customer specific solutions. Oil quantity and change interval are specified individually.

Table 45.2

Shared lubricating oils				
Manufacturer	Klüber	Mobil	Castrol	Shell
Designation	Syntheso D 68 EP	Mobilgear 600 XP 68	Optigear BM 68	Omala S2 G 68

Please note the information in section 5.5.5.

4.11 Axial Forces at the Wave Generator SHG-2SO and SHG-2SH

When a Harmonic Drive® Gear is used as a speed reducer (torque input via Wave Generator), the deflection of the Flexspline leads to an axial force acting on the Wave Generator. This axial force acts in the direction of the Flexspline diaphragm.
When the Harmonic Drive® Component Set is used as a speed accelerating gear (reverse operation, e.g. when braking), the axial force acts in the opposite direction. In any case the axial force must be absorbed by the input shaft (motor shaft).
The Wave Generator thus needs to be fixed on the input shaft in the axial direction. In closed Harmonic Drive® units and gearboxes the axial force is absorbed internally.

Illustration 46.1

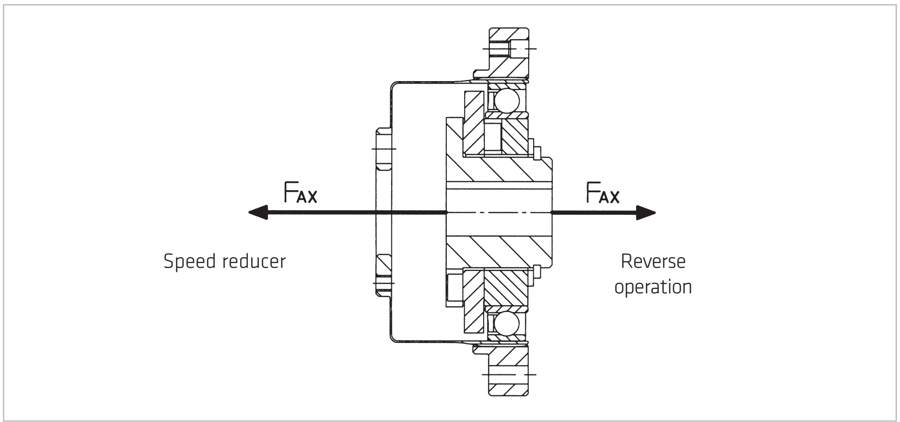


Table 46.2

Ratio		
30	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 32°$	[Equation 46.3]
50	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 30° + 2\mu PF$	[Equation 46.4]
80...160	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 20° + 2\mu PF$	[Equation 46.5]

with:

F_{AX} = Axial force [N]
D = (Size) · 0.00254 [m]
T = Torque at the output [Nm]
μ = 0.07 Coefficient of friction
2μPF = Additional force (only CSD) [N]

Example

Size 32 (CSD-32-50)
Output torque = 200 Nm
Coefficient of friction μ = 0.07

$$F_{AX} = 2 \cdot \frac{200 \text{ Nm}}{(32 \cdot 0.00254) \text{ m}} \cdot 0.07 \cdot \tan 30° + 16$$

F_{AX} = 215 N

Table 46.6

Sizes	14	17	20	25	32	40	50
2μPF [N] for CSD and SHD	2.1	4.1	5.6	9.8	16	24	39

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.

Gears with Oil Lubrication
Harmonic Drive® Units with oil lubrication are generally customer-specific solutions. Please follow the notes given on the confirmation drawing. The oil temperature during operation must not exceed 90° C. Oil must be filled into the unit by the customer as the standard delivery does not include any oil lubricant.

Oil Quantity
The values specified in the confirmation drawing include the valid oil quantities to fill in. The oil quantity defined on the confirmation drawing must be obeyed in any case. Too much oil results in excessive heat production and early wear due to the thermal destruction of the oil. If the oil level is too low, this may lead to early wear as a result of lubricant deficiency.

5.3 Assembly Information

ADVICE

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

5.4 Recommended Tolerances for Assembly SHG-2SO and SHG-2SH

In order for the full features of Harmonic Drive® Units to be exploited fully, it is essential that the tolerances according to table 48.2 are observed for the input assembly.

Illustration 48.1

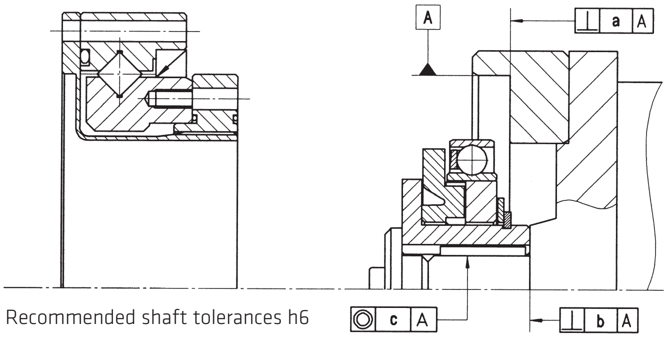


Table 48.2 [mm]

Size	14	17	20	25	32	40	45	50	58	65
a	0.011	0.015	0.017	0.024	0.026	0.026	0.027	0.028	0.031	0.034
b	0.017	0.020	0.020	0.024	0.024	0.032	0.032	0.032	0.032	0.032
	(0.008)	(0.010)	(0.010)	(0.012)	(0.012)	(0.012)	(0.013)	(0.015)	(0.015)	(0.015)
c	0.030	0.034	0.044	0.047	0.050	0.063	0.065	0.066	0.068	0.070
	(0.016)	(0.018)	(0.019)	(0.022)	(0.022)	(0.024)	(0.027)	(0.030)	(0.033)	(0.035)

The values in brackets are the recommended tolerances for component sets featuring a Wave Generator without Oldham coupling. The Oldham coupling serves to compensate for eccentricity of the input shaft and is available in the standard version. For the direct mounting of a Wave Generator without Oldham coupling (optional) on a motor shaft, the shaft tolerances should fulfill the DIN 42955 R standard.

5.5 Lubrication SHG-2UH

Harmonic Drive® Units are delivered ready for immediate installation. They are supplied with lifetime lubricant which is a high performance grease that meets the specific requirements of the Harmonic Drive® gears. It guarantees constant accuracy of the gears for their whole life. A re-lubrication of the Units is not necessary.

5.5.1 Grease Lubrication SHG-2SO and SHG-2SH

We recommend the use of Harmonic Drive® greases which have been specially developed.
When using these special greases continuous operation is permissible.

5.5.2 Amount of Grease SHG-2SO and SHG-2SH

Standard Units are prepared for grease lubrication. If no special arrangements are made the specially developed high performance grease SK-1A (for sizes 20 to 65) and SK-2 (for size 14 and 17) are used. If any other grease is used this will be indicated on the customer drawing. High performance 4BNo. 2 grease with improved characteristics is also available for these products. On delivery, Flexspline and Circular Spline teeth are lubricated ready for use. Before mounting, the Wave Generator bearing and the inner part of the Flexspline must be greased. It may be necessary to place an additional amount of grease on the front face of the Wave Generator (see illustration 50.2).

Illustration 49.1 shows the areas requiring grease.

Illustration 49.1

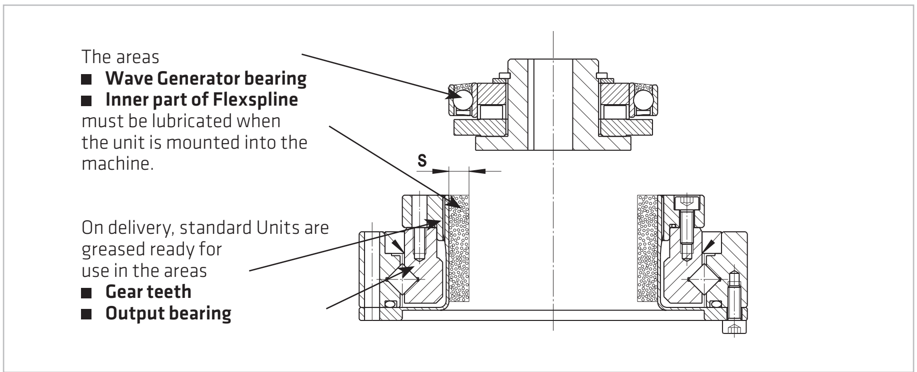
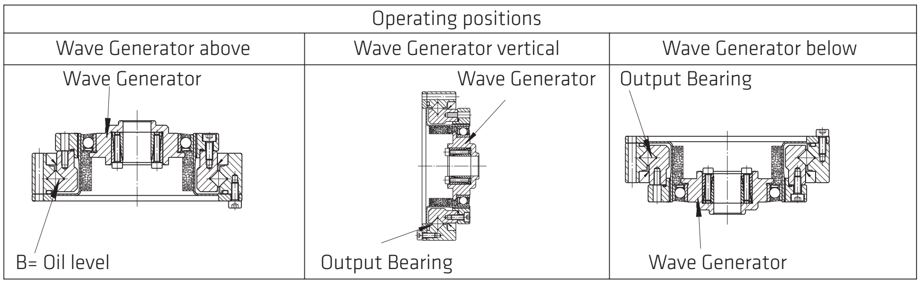


Table 49.2

Size		14	17	20	25	32	40	45	50	58	65
Dimensions S (s. illustration 49.1) [mm]		3	4	5	6	8	10	11	12	14	16
Total weight ca. [g]	Horizontal use	5.8	11	18	32	64	120	185	235	385	494
	Wave Generator mainly vertical and below	7.5	13	19	37	74	130	200	255	400	530
	Wave Generator mainly vertical and above	8.7	15	22	42	84	150	230	290	480	630

The following operating positions “Wave Generator above” or “Wave Generator below” refer to the position of the Wave Generator in relative to the output bearing of the Unit, see illustration 51.1.

Illustration 50.1

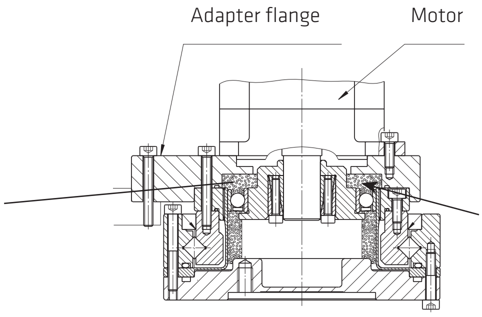


5.5.3 Additional Grease Package

The required grease quantity is dependent on the operating position. If the unit is mainly operated with Wave Generator above, additional grease must be supplied above the Wave Generator, see illustration 50.1 and table 49.2

Illustration 50.2

If the units are used mainly with Wave Generator above, then additional grease lubrication is necessary. In this case about 60% of the available space in the adaptor flange must be filled with grease.

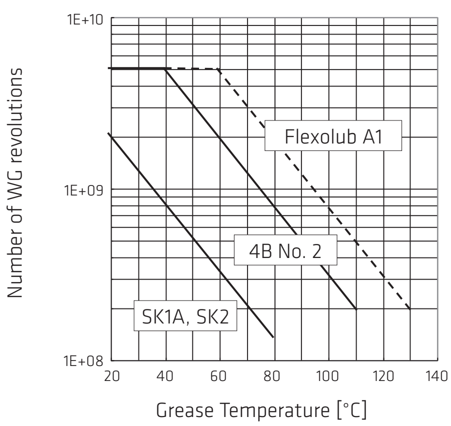


5.5.4 Grease Change

To change the grease the component set should be completely disassembled and cleaned before regreasing. Fresh grease should be applied generously to the inside of the Flexspline, the Wave Generator bearing, the Oldham coupling and the teeth of the Circular Spline and Flexspline.

In illustration 50.3, the grease change interval depending on the grease temperature is given. The number of allowable revolutions of the input shaft which represents the grease change interval can be estimated as shown in the example. This means, that for a temperature of SK-1A or SK-2 grease of 40° C a change should take place after approx. 8.5 x 10^8 revolutions of the input shaft. All grease change data refers to rated speed and rated torque.

Illustration 50.3



Equation 50.4

$$L_{GT} = L_{GTn} \cdot \left(\frac{T_N}{T_{av}}\right)^3$$

L_{GT} = Number of Wave Generator revolutions until grease change

L_{GTn} = see diagram

T_N = Rated torque

T_{av} = Average torque

5.5.5 Oil Lubrication

Harmonic Drive® Units with oil lubrication are generally customer-specific solutions. Please follow the notes given on the confirmation drawing and refer to page 54 for allowed oil types. The oil temperature during operation must not exceed 90° C. The minimum requirement is mineral oil CLP 68 (ISO VG 68) according to DIN 51517 T3. Oil must be filled into the unit by the customer as the standard delivery does not include any oil lubricant.

The values specified in the confirmation drawing include the required oil quantities. The oil quantity defined on the confirmation drawing must be obeyed in any case. Too much oil results in excessive heat production and early wear due to the thermal destruction of the oil. If the oil level is too low, this may lead to early wear as a result of lubricant deficiency.

The first oil change should be performed after about 100 hours of operation. Subsequent change intervals depending on the load, but should be carried out in a period of about 1000 hours.

To change the oil, the old oil must be completely drained and new oil introduced. The mixture of lubricants with different specifications is to be avoided. See table 45.2 for additional information.

5.6 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 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.

5.7 Mounting SHG-2SO and SHG-2SH Units

The following explanations refer to SHG-2SO series units, having a Wave Generator with Oldham Coupling or a Solid Wave Generator.

The assembly of the SHG-2SH series units with hollow shaft is not described explicitly in this manual. Please contact Harmonic Drive AG if necessary.

The assembling method of the gear depends strongly on the design details. Thus, this assembly manual only provides general guidelines. The assembly procedure may differ from those described herein in exceptional cases.

If the described assembling sequence cannot be observed, please ask Harmonic Drive® whether in the concrete case another sequence is permissible.

The assembly must take place without the use of undue force. The assembly instructions of the machine manufacturer should be referred to. Unless otherwise noted, all screws must be tightened crosswise in 3 steps to the prescribed torque.

Screws that have been tightened on delivery must not be released. On delivery, Flexspline and Circular Spline of SHG-2SO and SHG-2SH Units are pre-assembled only by a few screws. Therefore the full output bearing and torque load can only be applied after the unit has been attached completely to the machine frame and the load. Therefore we recommend the user to connect the unit to the machine housing and load (please take care of the dead weight) before initiating/ applying any radial and/ or axial forces.

5.7.1 Motor Assembly SHG-2SO

Assembly of the adaptor flange to the motor

For the planning of the assembly sequence it may be helpful to know the max. diameter of the Wave Generator, see illustration 53.1. In table 53.2 the diameters of the Wave Generator main axes are indicated.

Illustration 53.1

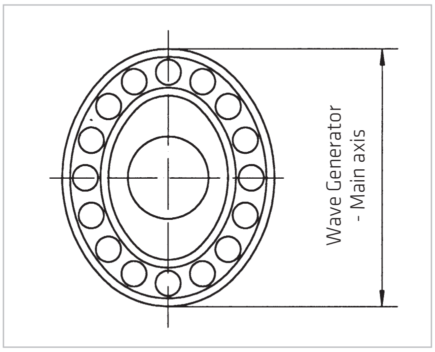
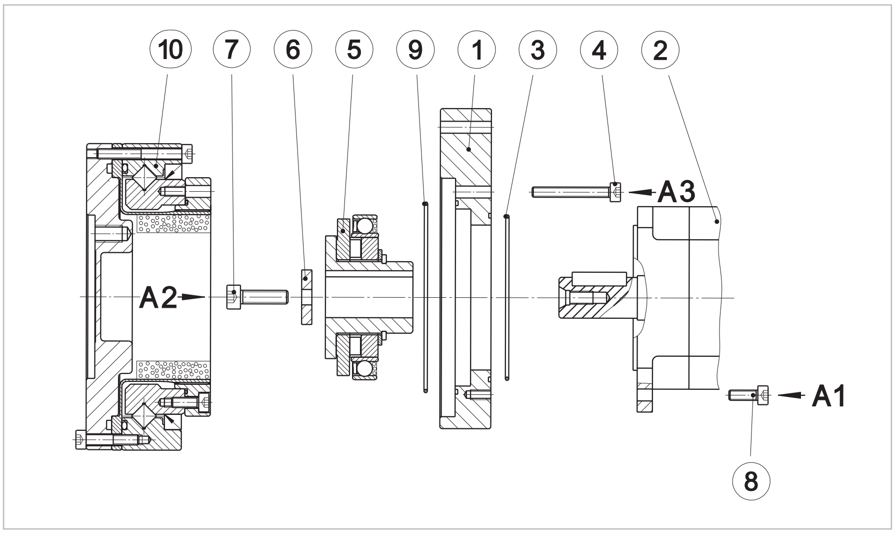


Table 53.2

Size	14	17	20	25	32	40	45	50	58	65
ca. ∅ Wave Generator - Main axis	36	43	50	63	82	100	114	125	146	164

Connect the adaptor flange (1) to the motor (2) by means of the screws (8). Apply sealing to the motor flange, if necessary.

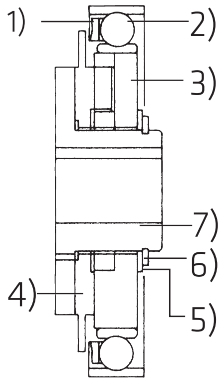
Illustration 53.3



5.7.2 Wave Generator Components SHG-2SO

Illustration 54.1 shows a standard Wave Generator with Oldham Coupling.

Illustration 54.1



1) Ball Separator
2) Wave Generator bearing
3) Wave Generator plug
4) Insert
5) Thrust washers
6) Snap ring
7) Wave Generator hub

5.7.3 Mounting the Wave Generator (WG) to the Motor Shaft

The axial position of the Wave Generator in the gearbox is critical for the correct operation of the unit. Please check the correct position of the Wave Generator against the confirmation drawing.

- Push the greased Wave Generator onto the motor shaft according to the assembly dimension given in the confirmation drawing. If there is no assembly value given, the Wave Generator must be moved until it reaches the shaft collar.

- Insert the plug into the bore of the Wave Generator hub and tighten with the screw. When a clamping element is used, tighten its screws in five steps to the torque given in the confirmation drawing. Final control of the assembly. Some types of clamping elements can move axially during tightening. Adjust as appropriate.

5.7.4 Check before Assembly of the Wave Generator (WG)

- Final check of position of the Wave Generator. For some clamping elements an axial movement may occur during tightening. Please take account of this effect when positioning the Wave Generator on the shaft.

- Check whether the WG is lubricated. When the gear is oil lubricated, fill in the prescribed oil quantity.

5.7.5 Assembly of the Wave Generator (WG) into the Flexspline (FS)

When the Wave Generator is assembled into the Flexspline please consider that the parts must not be tilt during assembly. By parallel assemby it is ensured that the teeth of Flexspline and Circular Spline mesh symmetrically.

Alternatively the assembly can be executed during slowly rotation of the input shaft ($n < 10$ rpm). This method eases the assembly.

5.7.6 Assembly Control SHG-2SO and SHG-2SH

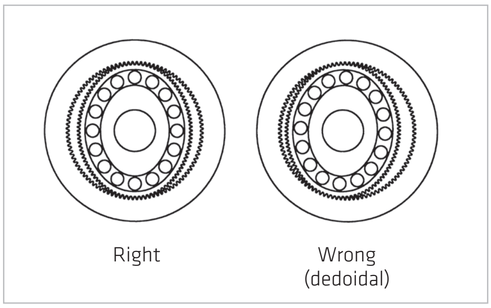
Very rarely, an eccentric tooth mesh, called dedoidal, may occur.
The correct assembly can be checked as follow:

- Check the running behaviour by rotating the input shaft (in case of types with input shaft).
  Alternatively you may rotate the output flange.
  If you notice torque variations these may be caused by eccentric tooth mesh.

- Check the running behaviour and the motor current while the motor is rotating.
  Strong fluctuations in the motor current and/or an excessive no-load current
  may be the result of an eccentric tooth mesh.

In case of a dedoidal assembly you can avoid permanent damage to the gear if the wrong installation is recognized by means of the above mentioned inspection. The problem can be solved by disassembling the gear followed by a new assembly.

Illustration 55.1



5.7.7 Assembly of the Output Flange

In the case of these Units the load is connected to the output bearing by means of a flange. Depending on the manner of fastening, either the flange which is connected to the outer ring, or the flange which is connected to the internal ring of the output bearing, can be used as output element. The tolerance values indicated in table 48.2 are the sum of bearing and flange tolerances, valid for standard Units. On request Units with optimized flange tolerances are available.

Table 56.1

Size		**14**	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**	**65**
Number of Bolts		8	16	16	16	16	16	12	16	12	16
Bolt Size		M3	M3	M3	M4	M5	M6	M8	M8	M10	M10
Bolt pitch diameter	[mm]	44	54	62	77	100	122	140	254	178	195
Tightening Torque	[Nm]	2.0	2.0	2.0	4.5	9.0	15.3	37.0	37.0	74.0	89
Torque transmitting capacity [1)]	[Nm]	90	176	206	431	902	1558	2440	3587	4910	8658

5.7.8 Assembly of the Housing Flange

Table 56.2

Size		**14**	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**	**65**
Number of Bolts		8	12	12	12	12	12	18	12	16	16
Bolt Size		M3	M3	M3	M4	M5	M6	M6	M8	M10	M10
Bolt pitch diameter	[mm]	64	74	84	102	132	158	180	200	226	258
Tightening Torque	[Nm]	2.0	2.0	2.0	4.5	9.0	15.3	15.3	37.0	37.0	74
Torque transmitting capacity [1)]	[Nm]	108	186	206	431	892	1509	2578	3489	5263	9546

* Friction coefficient μ = 0.15; 12.9 quality screws

Housing and output flange is to be assembled as per tables 56.1 and 56.2

5.7.9 Installation of the Input Shaft SHG-2UH und SHG-2SH

Table 56.3

Size		**14**	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**	**65**
Number of Bolts		3	3	6	6	6	6	6	6	8	6
Bolt Size		M3	M3	M3	M3	M3	M4	M4	M4	M4	M5
Tightening Torque	[Nm]	2.1	2.1	2.1	2.1	2.1	4.0	4.0	4.0	4.0	9.0

6. Decommissioning and Disposal

The gears, servo actuators and motors from Harmonic Drive AG contain lubricants for bearings and gears as well as electronic components and printed circuit boards. Since lubricants (greases and oils) are considered hazardous substances in accordance with health and safety regulations, it is necessary to dispose of the products correctly. Please ask for safety data sheet where necessary.

7. Glossary

7.1 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]

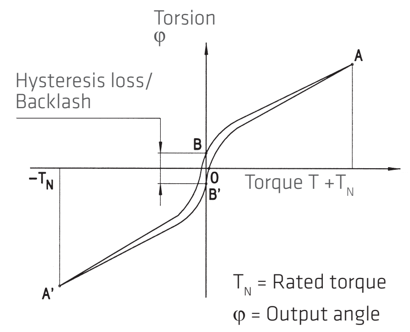
Maximum permissible average gear input speed for oil lubrication.

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 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_{Br} [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.

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 the 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 the 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.

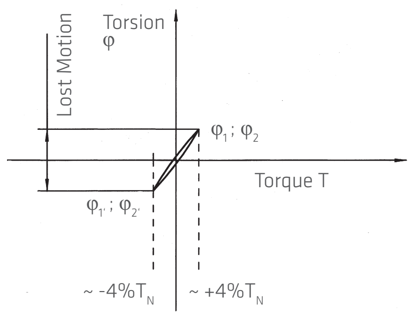
Inductance (L-L) L_{L-L} [mH]

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 current I_{max} [A]

The maximum current is the maximum current that can be applied for a short period.

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 possible diameter of the axial hollow shaft.

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

Maximum allowable input speed with grease lubrication.

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

Maximum allowable 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 calculated average speed is within the permissible continuous operation 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 parameterised 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 calculated average torque is within the permissible continuous operation 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 to a minimum and under no circumstances should the collision 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 the load.

Pitch circle diameter d_p [mm]

Pitch circle diameter of the output bearing rolling elements.

Protection 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], Mechanical

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

[rpm]

Product series	n_N
CobaltLine®, HFUC, HFUS, CSF, CSG, CSD, SHG, SHD	2000
PMG size 5	4500
PMG size 8 to 14	3500
HPG, HPGP, HPN	3000

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], Mechanical

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.

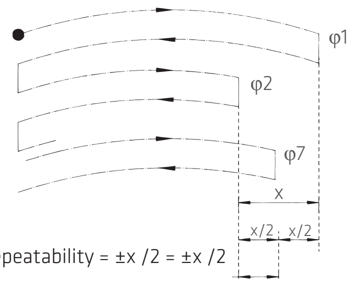
Ratio i [ ]

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

Note for Harmonic Drive® Gears: The standard version has the Wave Generator as the input element, the Flexspline as the output element and the Circular Spline is fixed to the housing. Since the direction of rotation of the input (Wave Generator) is opposite to the output (Flexspline), a negative ratio should be used for calculations in which the direction of rotation is to 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 the iron 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]

Describes the relationship between the tilting angle of the output bearing and an applied moment load.

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

Quotient of stall torque and stall current.

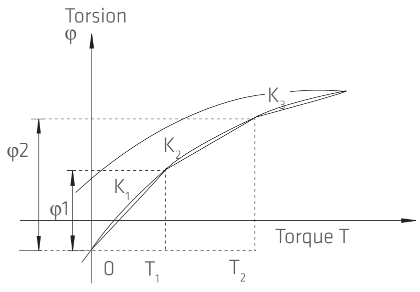
Torque constant (output) k_{Tout} [Nm/A_{rms}]

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 with the Wave Generator blocked. The torsional stiffness K_3 describes the stiffness above a defined reference torque where the stiffness is almost linear.

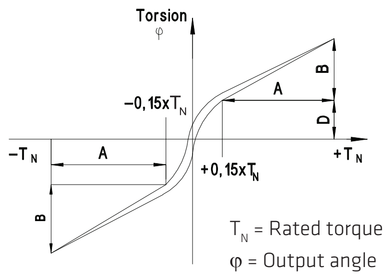
The value given for the torsional stiffness K_3 is an average that has been determined during numerous tests. The limit torques T_1 and T_2 and calculation example for the total torsional angle can be found in sections 3 and 4 of this documentation.



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]

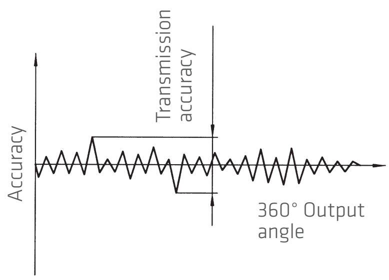
The amount of elastic rotation at the output for a given torque and blocked input shaft. The torsional rigidity of the Harmonic Planetary gear describes the rotation of the gear above a reference torque of 15% of the rated torque. In this area the torsional stiffness is almost linear.



T_N = Rated torque
φ = Output angle

Transmission accuracy [arcmin]

The transmission accuracy of the gear represents the 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 the theoretical and actual output rotation angles.



Weight m [kg]

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

7.2 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

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