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

Harmonic Drive AG

Contents

1. General

About this documentation

This document contains safety instructions, technical data and operation rules for servo actuators and servo motors 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 servo actuators and servo motors from Harmonic Drive AG with servo drives, we advise you to obtain the relevant documents for each device.

Your feedback

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

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1.1 Description of Safety Alert Symbols

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

1.2 Disclaimer and Copyright

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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. Specially designed models may differ in technical detail. If in doubt, we recommend to contact the manufacturer, giving the type designation and serial number for clarification.

2.1 Hazards

⚠ DANGER

Electric servo actuators and motors have dangerous live and rotating parts. All work during connection, operation, repair and disposal must be carried out by qualified personnel as described in the standards EN 50110-1 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.

⚠ ATTENTION

The surface temperature of products exceed 55 degrees Celsius. The hot surfaces should not be touched.

ADVICE

Cables must not come into direct contact with hot surfaces.

⚠ DANGER

Electric, magnetic and electromagnetic fields are dangerous, in particular for persons with heart pacemaker, implants or similiar. Vulnerable individuals must not be in the close proximity of the product.

⚠ DANGER

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

⚠ DANGER

Danger of injury due to improper handling of batteries.

Observing of the battery safety rules:
- do not insert batteries in reverse. Observe the + and - marks on the battery and on the electrical device
- do not short circuit
- do not recharge
- do not open or deform
- do not expose to fire, water or high temperature
- do not leave discharged batteries in the electrical device
- keep batteries out of reach of children. In case of ingestion of a battery, seek medical assistance promptly.

⚠ WARNING

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

⚠ ATTENTION

Use suitable lifting equipment to move and lift products with a weight > 20 kg.

INFORMATION

Special versions of products may differ in the specification from the standard. Further applicable data from data sheets, catalogues and offers of the special version have to be considered.

2.2 Intended Purpose

Harmonic Drive® Products are intended for industrial or commercial applications.

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 prediction, temperature range, etc).

Before commissioning of plants and machinery including Harmonic Drive® Products, the compliance with the Machinery Directive must be established.

2.3 Non Intended Purpose

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

2.4   Use in Special Application Areas

The use of the products in one of the following application areas requires a risk assessment and approval by
Harmonic Drive AG.

• 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
• Household devices
• Medical equipment
• Devices which interact directly with the human body
• Machines or equipment for transporting or lifting people
• Special devices for use in annual markets or leisure parks

2.5   Declaration of Conformity

2.5.1   Gears

Harmonic Drive® Gears are components for installation in machines as defined by the Machinery Directive.
Commissioning is prohibited until the end product conforms 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 end product conforms to the
Machinery Directive.

2.5.2   Servo Actuators and Motors

The Harmonic Drive® Servo Actuators and Motors described in the engineering data comply with the Low Voltage Directive.
In accordance with the Machinery Directive, Harmonic Drive® Servo Actuators and Motors are electrical equipment
for the use within certain voltage limits as covered by the Low Voltage Directive and thus excluded from the scope of the
Machinery Directive. Commissioning is prohibited until the final product conforms to the Machinery Directive.

According to the EMC directive Harmonic Drive® Servo Actuators and Motors are inherently benign equipment, unable to
generate electromagnetic disturbance or to be affected by such disturbance.

The conformity to the EU directives of equipment, plant and machinery in which Harmonic Drive® Servo Actuators and Motors
are installed must be provided by the user before taking the device into operation.

Equipment, plant and machinery with inverter driven motors must satisfy the protection requirements of the EMC directive.
It is the responsibility of the user to ensure that the installation is carried out correctly.

3. Technical Description

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 repeated 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 10.1

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		
	65		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 10.2

Version	
Ordering code	Description
2UH	Unit with hollow shaft
2SO	Simplicity Unit for motor assembly
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 11.1

	Symbol [Unit]	SHG-14		
Ratio	i [ ]	50	80	100
Repeated 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} [$\cdot 10^{-4}$ kgm^2]	0.091		
Moment of inertia SHG-2SO	J_{in} [$\cdot 10^{-4}$ kgm^2]	0.033		
Moment of inertia SHG-2SH	J_{in} [$\cdot 10^{-4}$ 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 11.2

	Symbol [Unit]	SHG-17			
Ratio	i [ ]	50	80	100	120
Repeated 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} [$\cdot 10^{-4}$ kgm^2]	0.193			
Moment of inertia SHG-2SO	J_{in} [$\cdot 10^{-4}$ kgm^2]	0.079			
Moment of inertia SHG-2SH	J_{in} [$\cdot 10^{-4}$ 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 12.1   SHG-14-2UH   [mm]
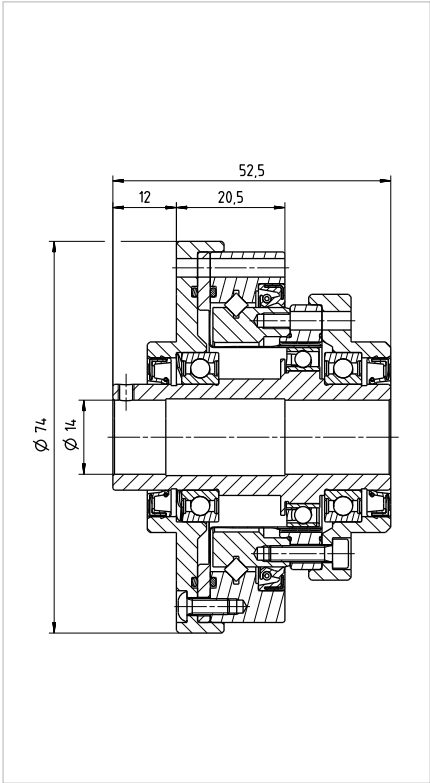
Illustration 12.2   SHG-14-2SO   [mm]
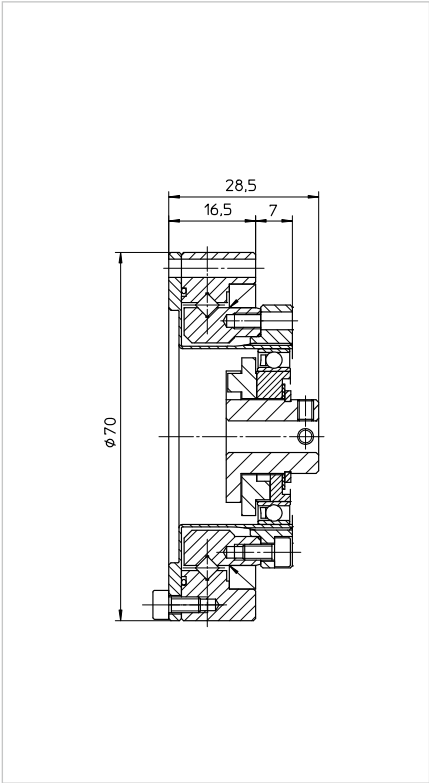
Illustration 12.3   SHG-14-2SH   [mm]
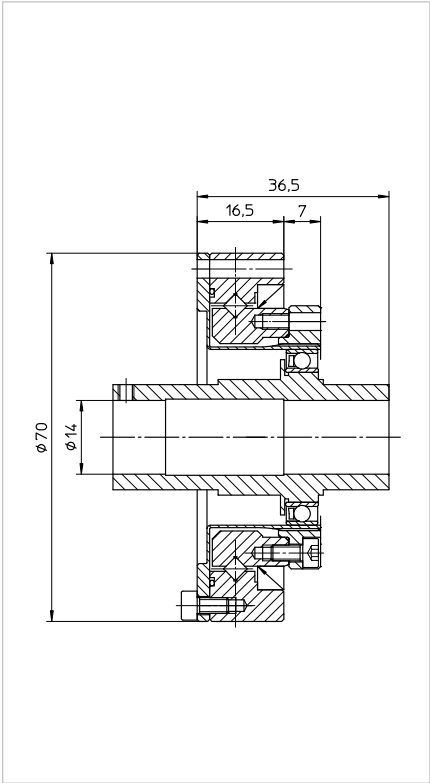
Illustration 12.4   SHG-17-2UH   [mm]
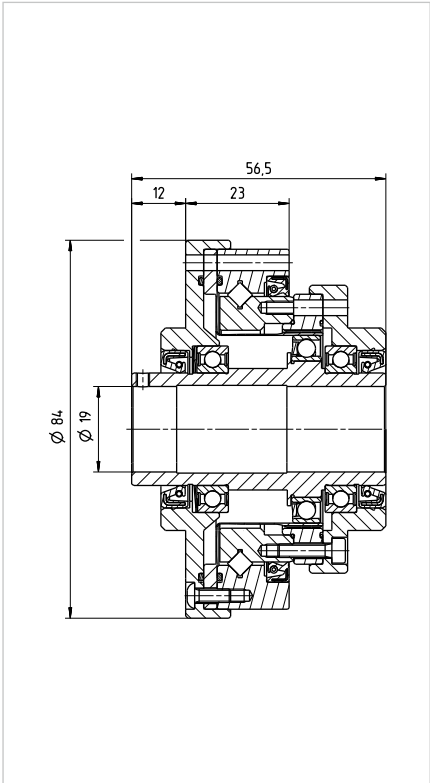
Illustration 12.5   SHG-17-2SO   [mm]
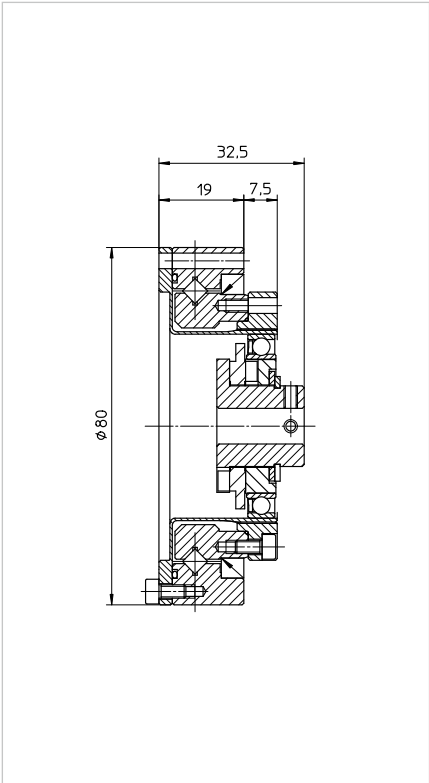
Illustration 12.6   SHG-17-2SH   [mm]
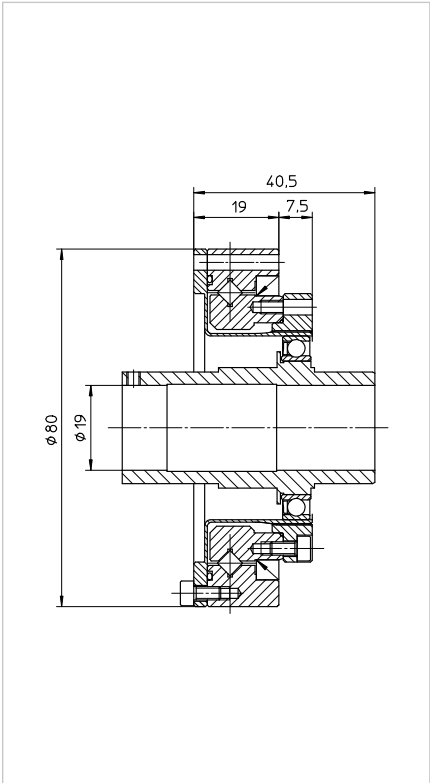
Table 13.1

	Symbol [Unit]	SHG-20				
Ratio	i [ ]	50	80	100	120	160
Repeated 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} [· 10^{-4} kgm²]	0.404				
Moment of inertia SHG-2SO	J_{in} [· 10^{-4} kgm²]	0.193				
Moment of inertia SHG-2SH	J_{in} [· 10^{-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 13.2

	Symbol [Unit]	SHG-25				
Ratio	i [ ]	50	80	100	120	160
Repeated 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} [· 10^{-4} kgm²]	1.07				
Moment of inertia SHG-2SO	J_{in} [· 10^{-4} kgm²]	0.413				
Moment of inertia SHG-2SH	J_{in} [· 10^{-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 14.1   SHG-20-2UH   [mm]

51,5
5
25
Ø 95
Ø 21

Illustration 14.2   SHG-20-2SO   [mm]

33,5
20,5
8,5
Ø 90
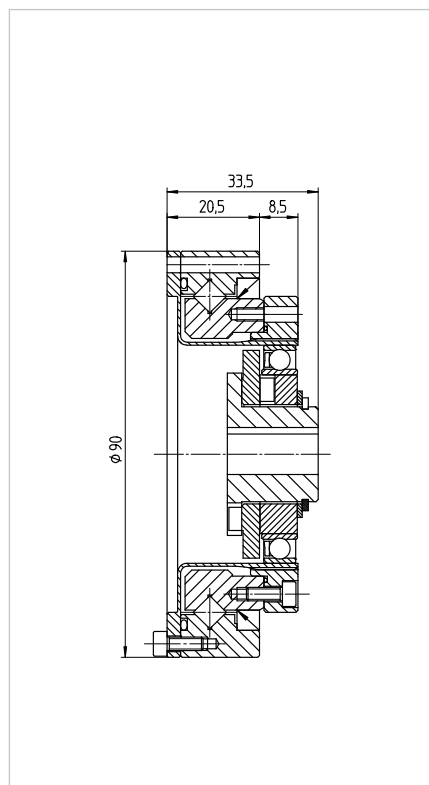
Illustration 14.3   SHG-20-2SH   [mm]

42
20,5
8,5
Ø 90
Ø 21
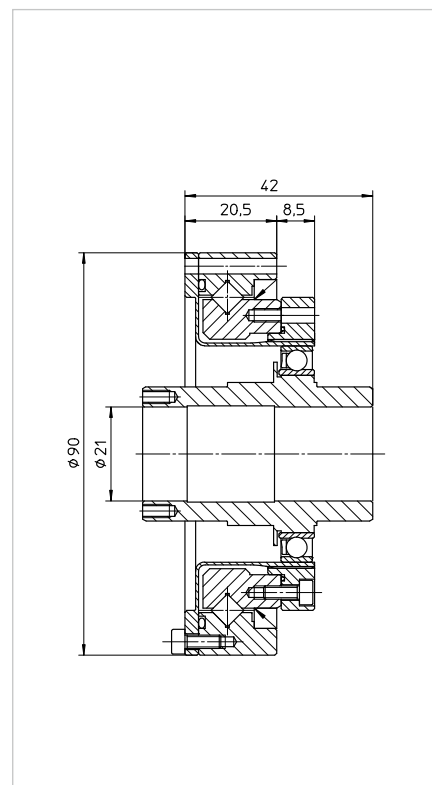
Illustration 14.4   SHG-25-2UH   [mm]

55,5
6
26
Ø 115
Ø 29

Illustration 14.5   SHG-25-2SO   [mm]

37
22
12
Ø 110

Illustration 14.6   SHG-25-2SH   [mm]

45,5
22
12
Ø 110
Ø 29

Table 15.1

	Symbol [Unit]	SHG-32				
Ratio	i [ ]	50	80	100	120	160
Repeated 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} [· 10^{-4} kgm²]	2.85				
Moment of inertia SHG-2SO	J_{in} [· 10^{-4} kgm²]	1.69				
Moment of inertia SHG-2SH	J_{in} [· 10^{-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 15.2

	Symbol [Unit]	SHG-40				
Ratio	i [ ]	50	80	100	120	160
Repeated 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} [· 10^{-4} kgm²]	9.28				
Moment of inertia SHG-2SO	J_{in} [· 10^{-4} kgm²]	4.50				
Moment of inertia SHG-2SH	J_{in} [· 10^{-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 16.1 SHG-32-2UH [mm]

Illustration 16.2 SHG-32-2SO [mm]

Illustration 16.3 SHG-32-2SH [mm]

Illustration 16.4 SHG-40-2UH [mm]
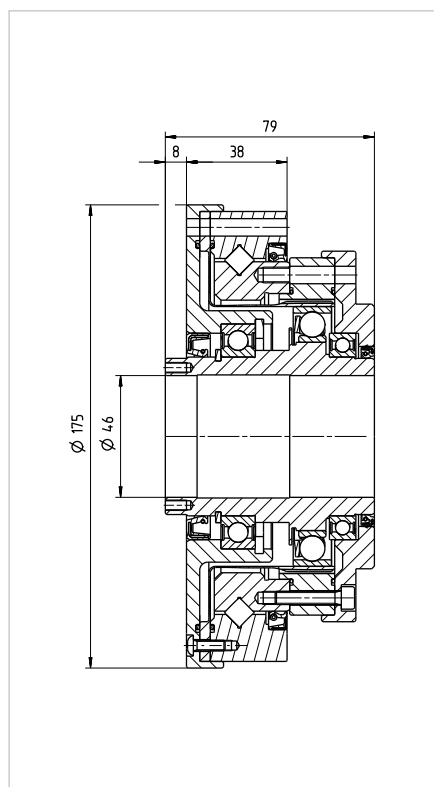
Illustration 16.5 SHG-40-2SO [mm]
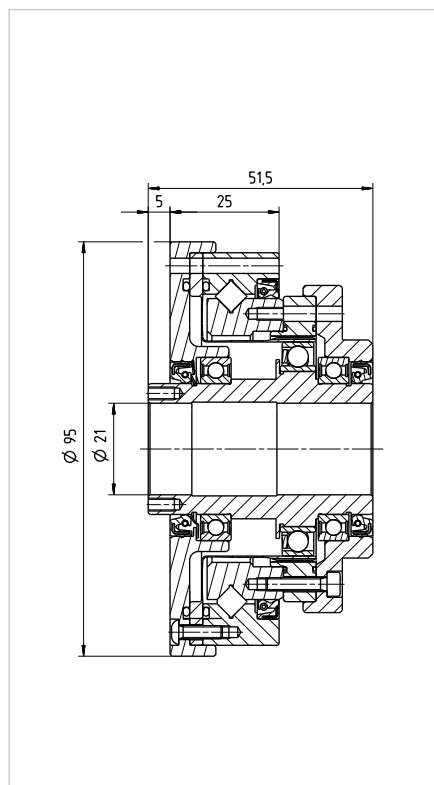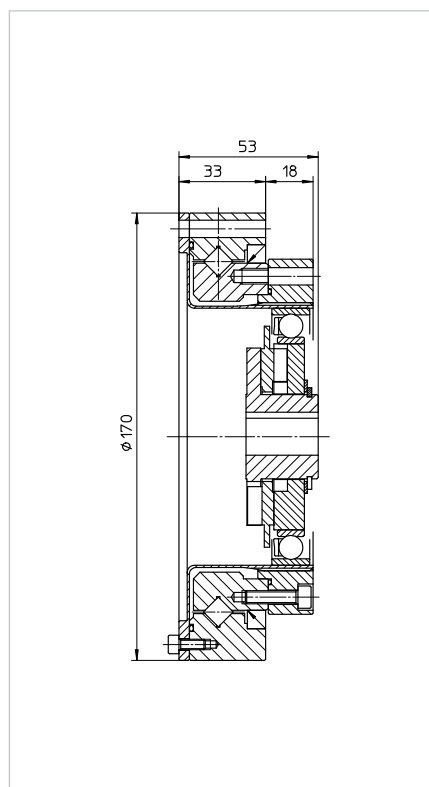

Illustration 16.6 SHG-40-2SH [mm]
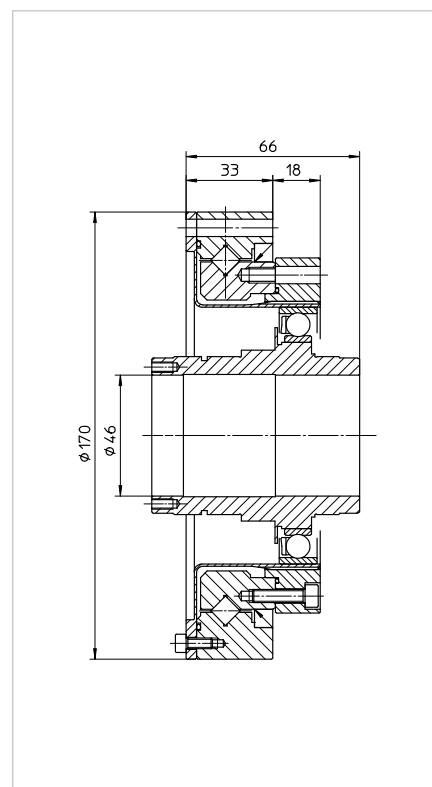
Table 17.1

	Symbol [Unit]	SHG-45				
Ratio	i [ ]	50	80	100	120	160
Repeated 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} [· 10^{-4} kgm²]	13.8				
Moment of inertia SHG-2SO	J_{in} [· 10^{-4} kgm²]	8.68				
Moment of inertia SHG-2SH	J_{in} [· 10^{-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 17.2

	Symbol [Unit]	SHG-50			
Ratio	i [ ]	80	100	120	160
Repeated 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} [· 10^{-4} kgm²]	25.2			
Moment of inertia SHG-2SO	J_{in} [· 10^{-4} kgm²]	12.5			
Moment of inertia SHG-2SH	J_{in} [· 10^{-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 18.1   SHG-45-2UH   [mm]
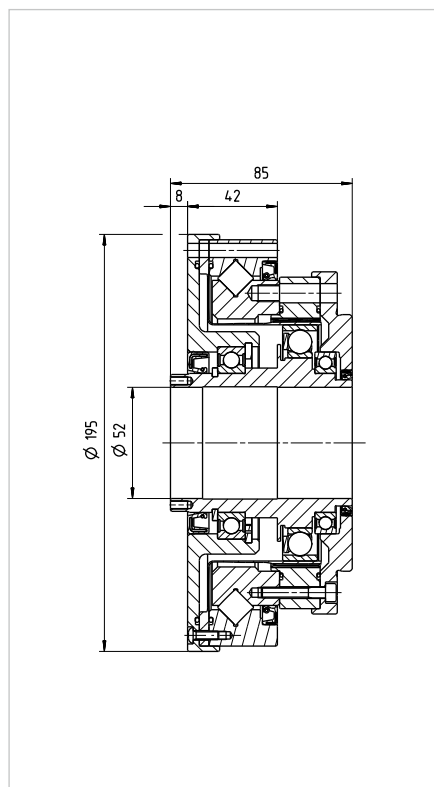
Illustration 18.2   SHG-45-2SO   [mm]
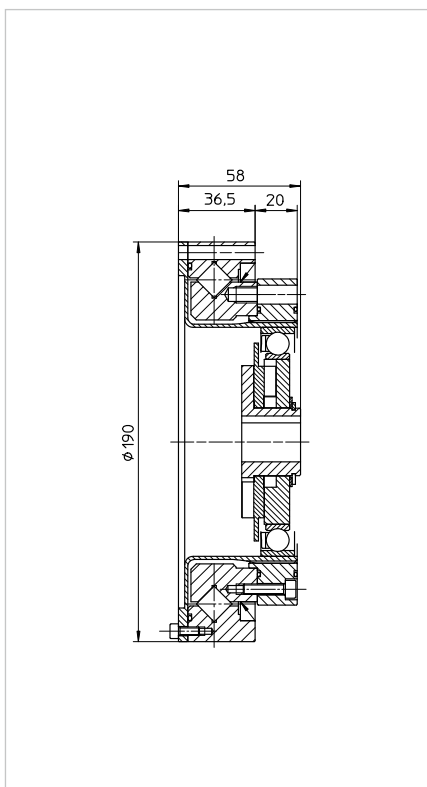
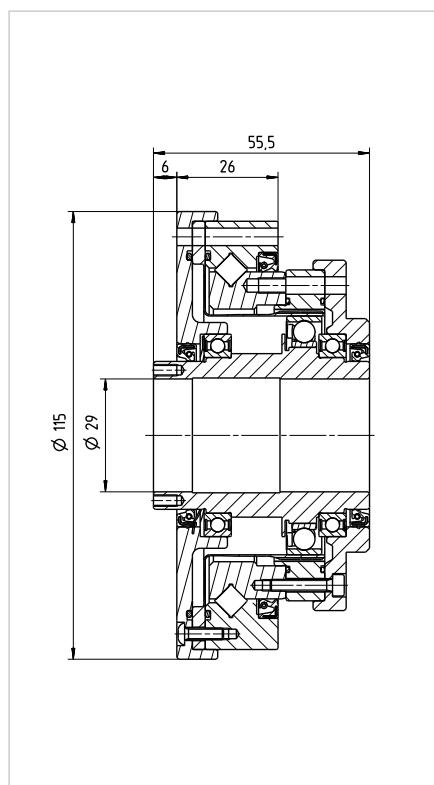Illustration 18.3   SHG-45-2SH   [mm]
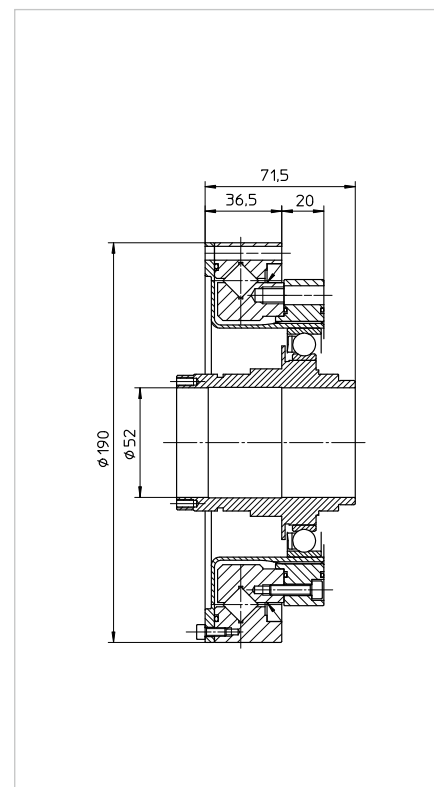
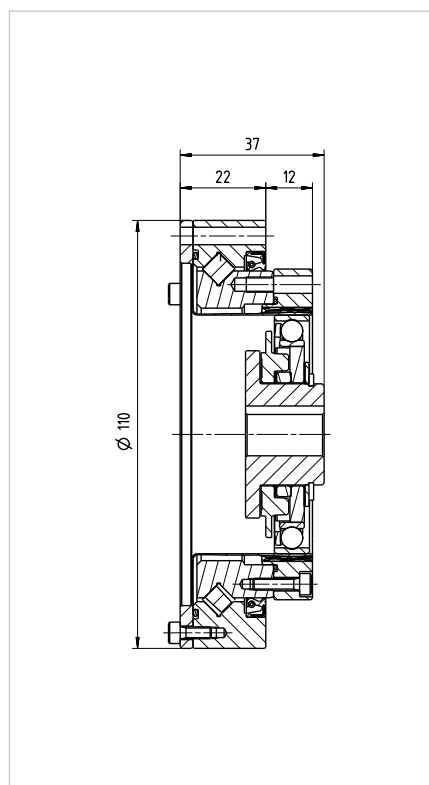Illustration 18.4   SHG-50-2UH   [mm]
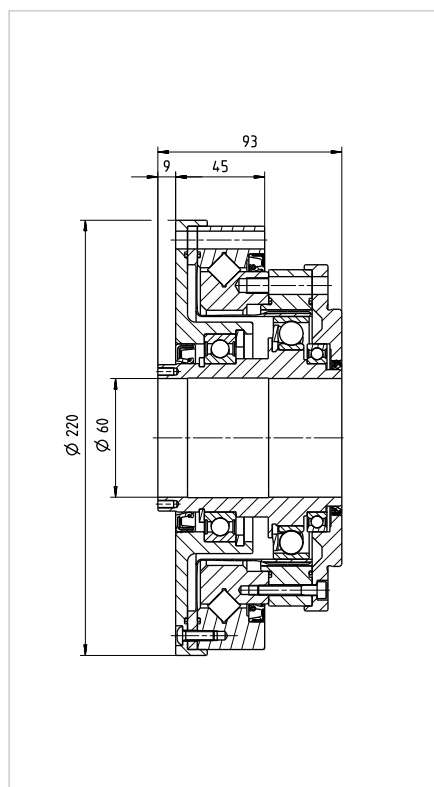
Illustration 18.5   SHG-50-2SO   [mm]
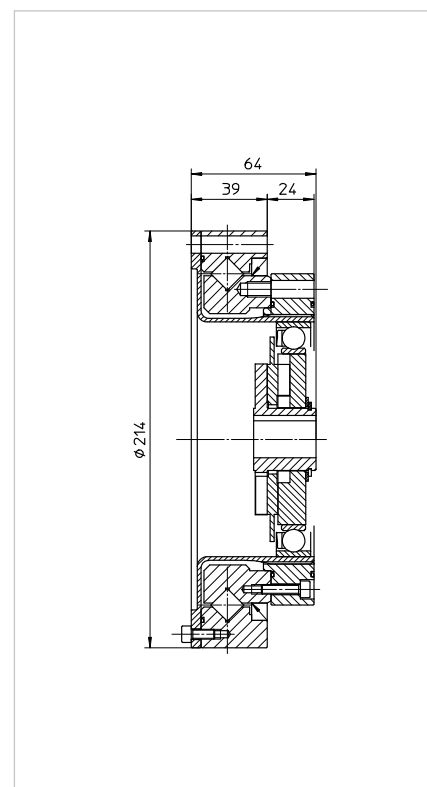
Illustration 18.6   SHG-50-2SH   [mm]
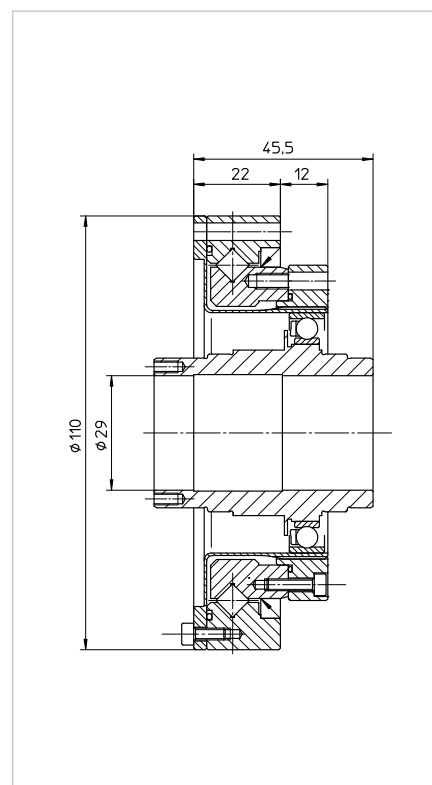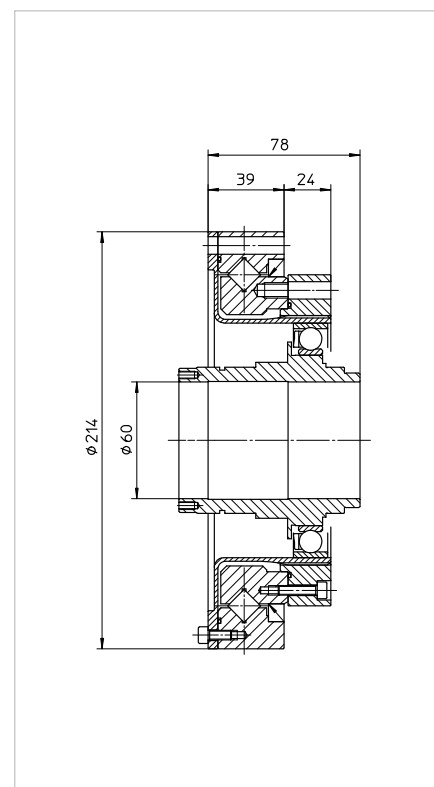
Table 19.1

	Symbol [Unit]	SHG-58			
Ratio	i [ ]	80	100	120	160
Repeated 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} [· 10^{-4} kgm²]	49.5			
Moment of inertia SHG-2SO	J_{in} [· 10^{-4} kgm²]	27.3			
Moment of inertia SHG-2SH	J_{in} [· 10^{-4} kgm²]	49.5			
Weight SHG-2UH	m [kg]	20			
Weight SHG-2SO	m [kg]	13.5			
Weight SHG-2SH	m [kg]	14.1			

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

Table 19.2

	Symbol [Unit]	SHG-65			
Ratio	i [ ]	80	100	120	160
Repeated 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} [· 10^{-4} kgm²]	94.1			
Moment of inertia SHG-2SO	J_{in} [· 10^{-4} kgm²]	46.8			
Moment of inertia SHG-2SH	J_{in} [· 10^{-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			

[1]) Valid for SHG-2UH and SHG-2SH when radial shaft seals are used on the hollow shaft.
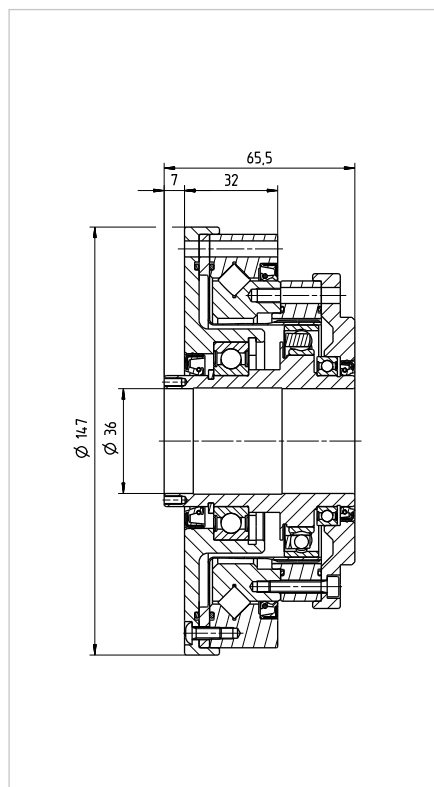
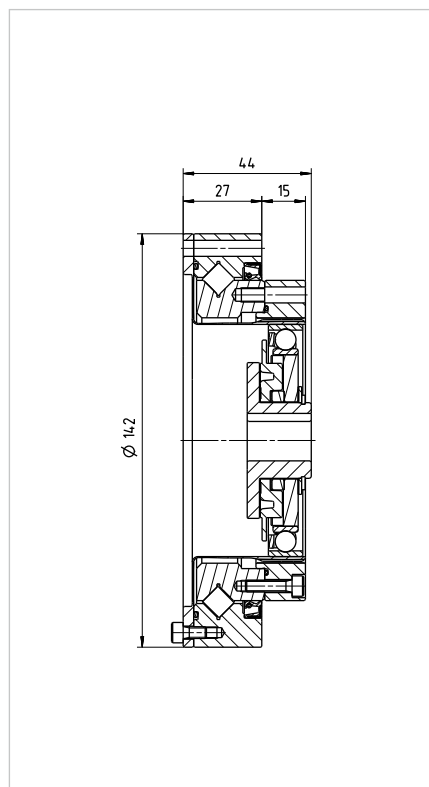Illustration 20.1 SHG-58-2UH [mm]   Illustration 20.2 SHG-58-2SO [mm]   Illustration 20.3 SHG-58-2SH [mm]
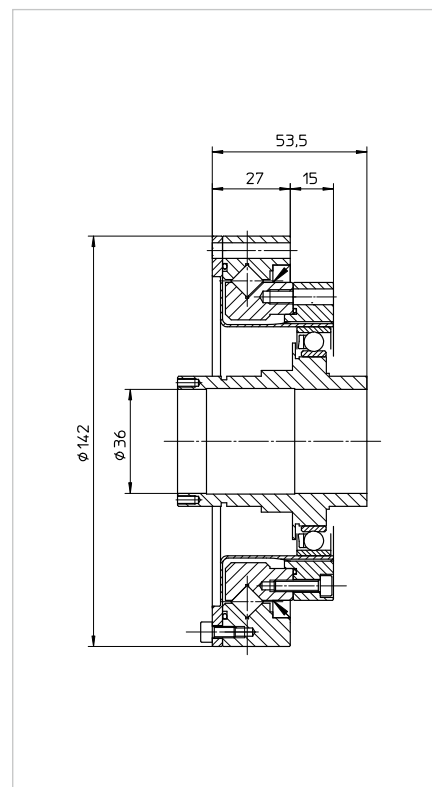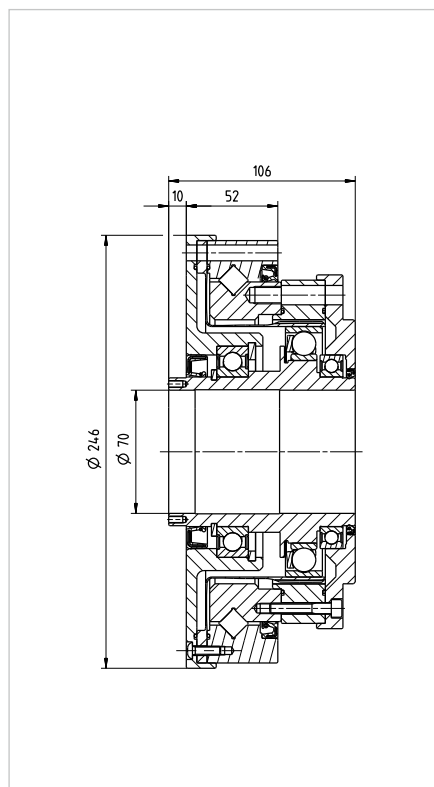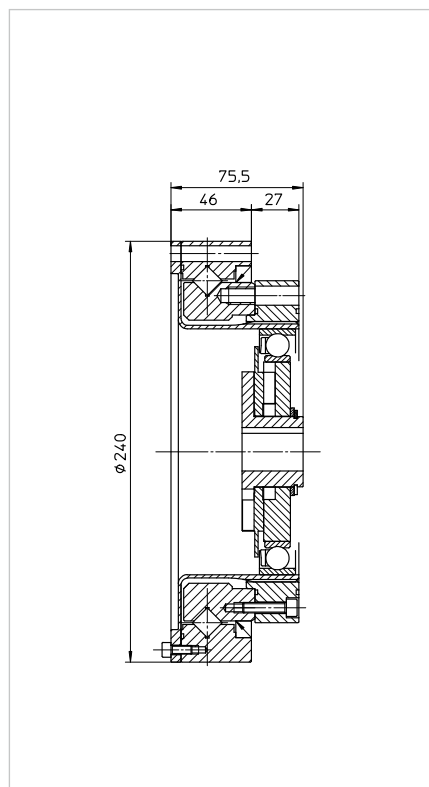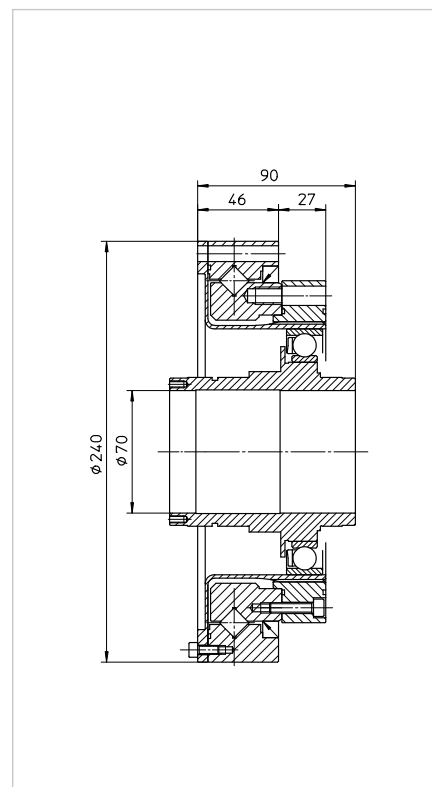
Illustration 20.4 SHG-65-2UH [mm]   Illustration 20.5 SHG-65-2SO [mm]   Illustration 20.6 SHG-65-2SH [mm]
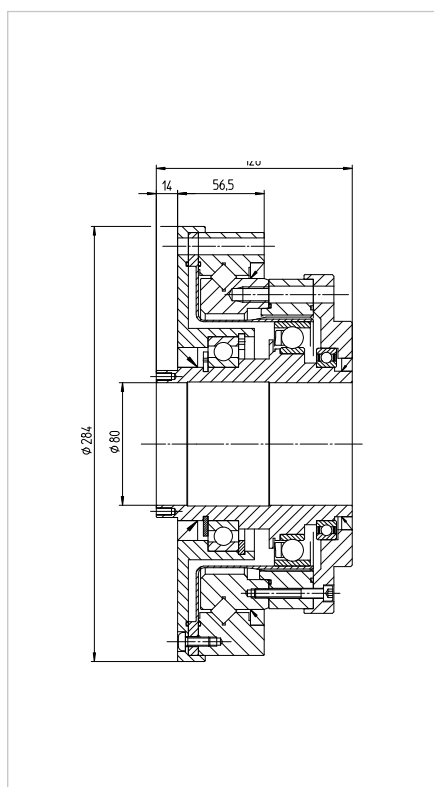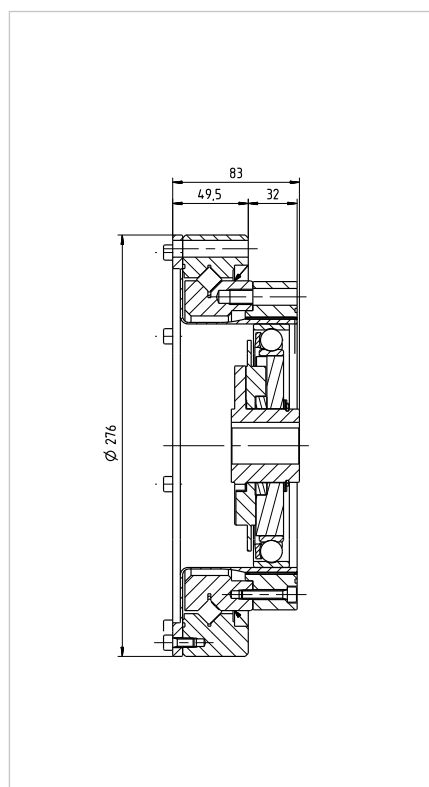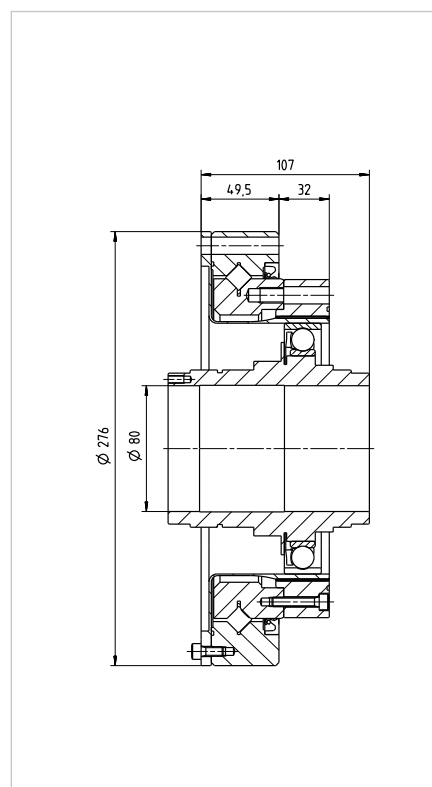
3.3.3 Minimum Housing Dimensions SHG-2SO and SHG-2SH

Table 21.1

Size	Unit	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-65
∅ w	[mm]	38	45	53	66	86	106	119	133	154	172
x	[mm]	1.0	1.0	1.5	1.5	1.5	2.0	2.0	2.0	2.5	2.5
y	[mm]	1.7	2.1	2.0	2.0	2.0	2.0	2.3	2.5	2.9	3.5
∅ z	[mm]	31	38	45	56	73	90	101	113	131	150

Illustration 21.2
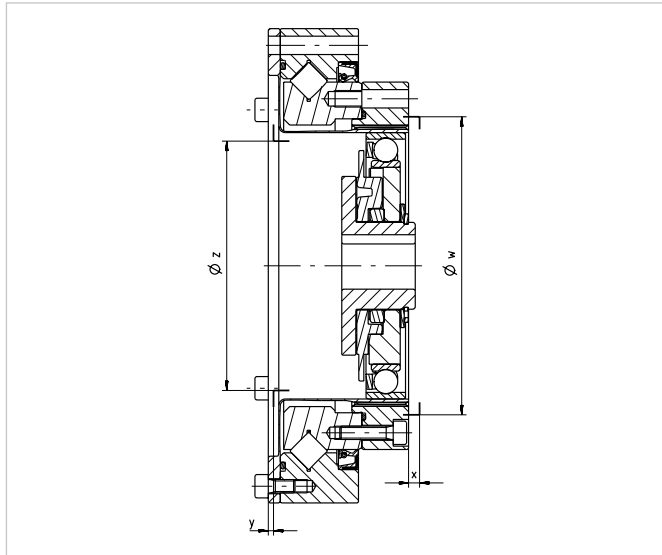
3.3.4 Accuracy

Table 21.3

	Symbol [Unit]	SHG-14		SHG-17		SHG-20	
Ratio	i [ ]	≥ 50	≥ 80	≥ 50	≥ 80	≥ 50	≥ 80
Transmission accuracy	[arcmin]	< 1,5		< 1,5		< 1	
Repeatability	[arcmin]	< ±0,1		< ±0,1		< ±0,1	
Hysteresis loss	[arcmin]	< 2	< 1	< 2	< 1	< 2	< 1
Lost Motion	[arcmin]	< 1		< 1		< 1	

Table 21.4

	Symbol [Unit]	SHG-25		SHG-32		SHG-40	
Ratio	i [ ]	≥ 50	≥ 80	≥ 50	≥ 80	≥ 50	≥ 80
Transmission accuracy	[arcmin]	< 1		< 1		< 1	
Repeatability	[arcmin]	< ±0,1		< ±0,1		< ±0,1	
Hysteresis loss	[arcmin]	< 2	< 1	< 2	< 1	< 2	< 1
Lost Motion	[arcmin]	< 1		< 1		< 1	

Table 21.5

	Symbol [Unit]	SHG-45		SHG-50	SHG-58	SHG-65
Ratio	i [ ]	≥ 50	≥ 80	≥ 80	≥ 80	≥ 80
Transmission accuracy	[arcmin]	< 1		< 1	< 1	< 1
Repeatability	[arcmin]	< ±0,1		< ±0,1	< ±0,1	< ±0,1
Hysteresis loss	[arcmin]	< 2	< 1	< 1	< 1	< 1
Lost Motion	[arcmin]	< 1		< 1	< 1	< 1

3.3.5 Torsional Stiffness

Table 22.1

	Symbol [Unit]	SHG-14		SHG-17		SHG-20	
Limit torque	T_1 [Nm]	2		3.9		7	
	T_2 [Nm]	6.9		12		25	
Ratio	i [ ]	**50**	**≥ 80**	**50**	**≥ 80**	**50**	**≥ 80**
Torsional Stiffness	K_3 [· 10^3 Nm/rad]	5.7	7.1	13	16	23	29
	K_2 [· 10^3 Nm/rad]	4.7	6.1	11	14	18	25
	K_1 [· 10^3 Nm/rad]	3.4	4.7	8.1	10	13	16

Table 22.2

	Symbol [Unit]	SHG-25		SHG-32		SHG-40	
Limit torque	T_1 [Nm]	14		29		54	
	T_2 [Nm]	48		108		196	
Ratio	i [ ]	**50**	**≥ 80**	**50**	**≥ 80**	**50**	**≥ 80**
Torsional Stiffness	K_3 [· 10^3 Nm/rad]	44	57	98	120	180	230
	K_2 [· 10^3 Nm/rad]	34	50	78	110	140	200
	K_1 [· 10^3 Nm/rad]	25	31	54	67	100	130

Table 22.3

	Symbol [Unit]	SHG-45		SHG-50	SHG-58	SHG-65
Limit torque	T_1 [Nm]	76		108	168	235
	T_2 [Nm]	275		382	598	843
Ratio	i [ ]	**50**	**≥ 80**	**≥ 80**	**≥ 80**	**≥ 80**
Torsional Stiffness	K_3 [· 10^3 Nm/rad]	260	330	440	710	980
	K_2 [· 10^3 Nm/rad]	200	290	400	610	880
	K_1 [· 10^3 Nm/rad]	150	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 23.1 lists ratings and important dimensions for the output bearings.

Table 23.1

	Symbol [Unit]	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG- 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
Offset[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	130000
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	73	114	291	521	748	1021	1545	2155
Permissible axial load[5]	F_a [N]	3050	5469	7678	11464	20088	22770	40808	42911	45961	68364
Permissible radial load[5]	F_r [N]	2044	3664	5144	7681	13459	15256	27341	28751	30794	45804

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 23.2
[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 sizes 14 ... 20 and 1,5 for sizes 25 ... 58. For other values of f_s, please refer to chapter 4.7.
[5]   These data are valid for f_w = 1.3, n = 15 rpm and L_{10} = 15000 h
[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 23.2
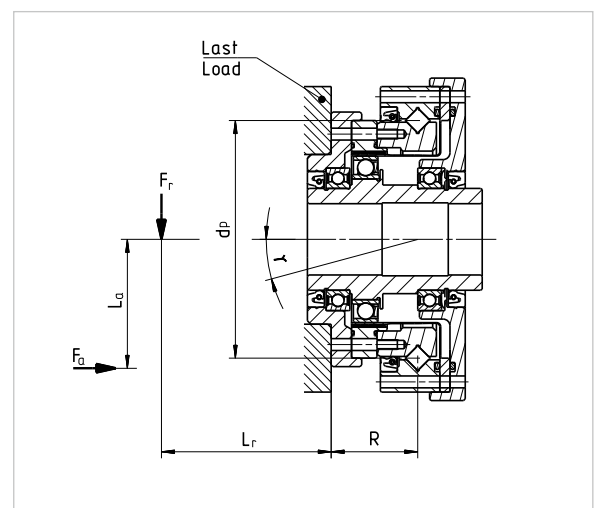
Output Bearing and Housing Tolerances

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 24.1 and illustration 24.2). The tolerance values indicated in table 24.3 are the sum of bearing and flange tolerances.

Illustration 24.1
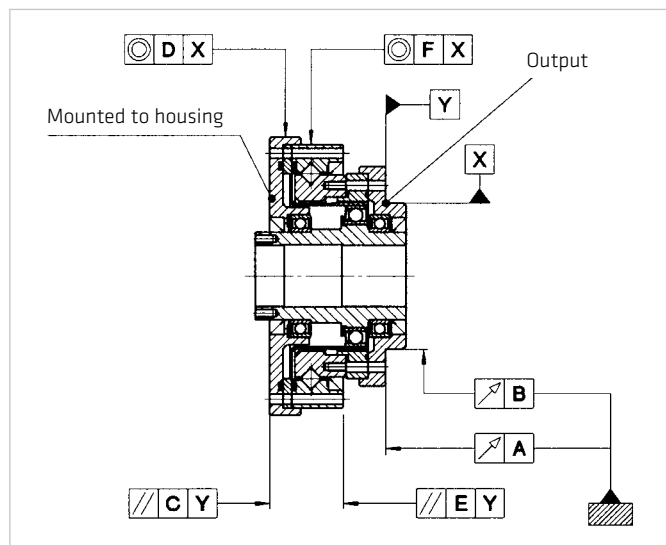
Illustration 24.2
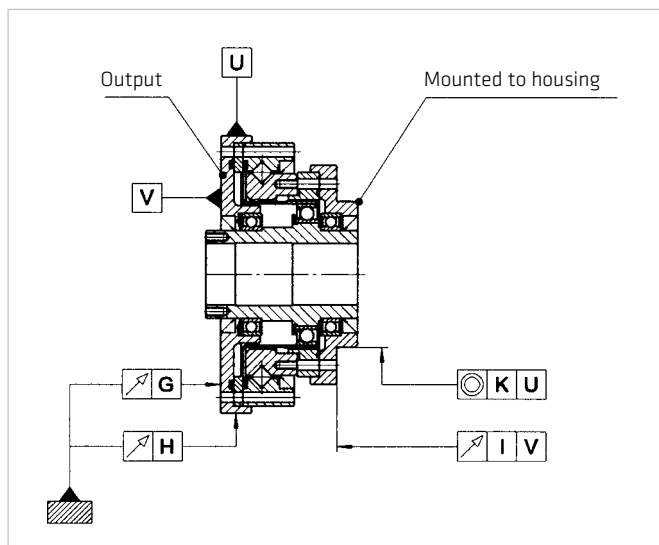
Table 24.3

Symbol [Unit]	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG- 65
A [mm]	0.033	0.038	0.040	0.046	0.054	0.057	0.057	0.063	0.063	0.67
B [mm]	0.035	0.035	0.039	0.041	0.047	0.050	0.053	0.060	0.063	0.63
C [mm]	0.064	0.071	0.079	0.085	0.104	0.111	0.118	0.121	0.121	0.131
D [mm]	0.053	0.053	0.059	0.061	0.072	0.075	0.078	0.085	0.088	0.089
E [mm]	0.040	0.045	0.051	0.057	0.065	0.071	0.072	0.076	0.076	0.082
F [mm]	0.038	0.038	0.047	0.049	0.054	0.060	0.065	0.067	0.070	0.072
G [mm]	0.037	0.039	0.046	0.047	0.059	0.063	0.070	0.070	0.070	0.076
H [mm]	0.031	0.031	0.038	0.038	0.045	0.048	0.050	0.050	0.050	0.054
I [mm]	0.064	0.071	0.079	0.085	0.104	0.111	0.118	0.121	0.121	0.131
K [mm]	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 25.2 shows the points of application of force of the maximum permissible radial and axial loads as indicated in illustrations 26.1 and 26.2.
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 420 N, see illustration 26.2.

The maximum values shown are valid for an average input speed of 2000 rpm and a mean bearing life of L_{50} = 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 (-F_a, see illustration 25.2) it can be shifted by the value „s" given in table 25.1. For the size 32 up to 58 the bearing A is designed as a fixed bearing.

Table 25.1

	Symbol [Unit]	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG- 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 25.2
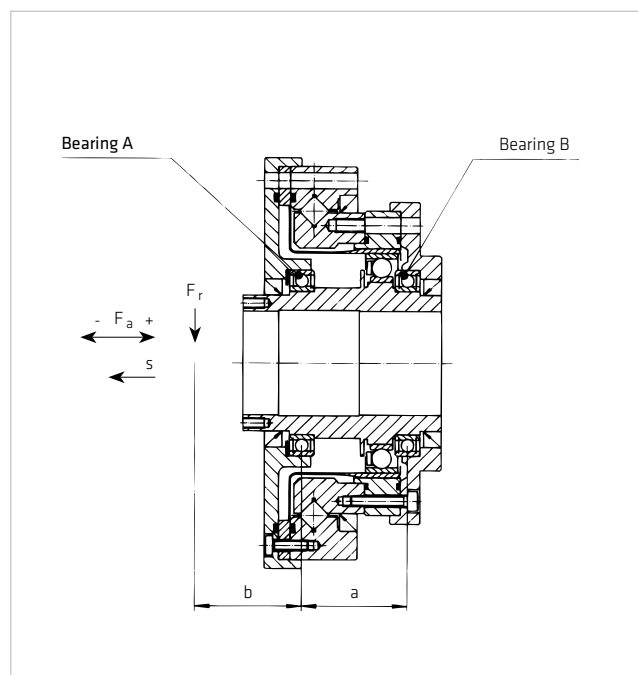
Illustration 26.1
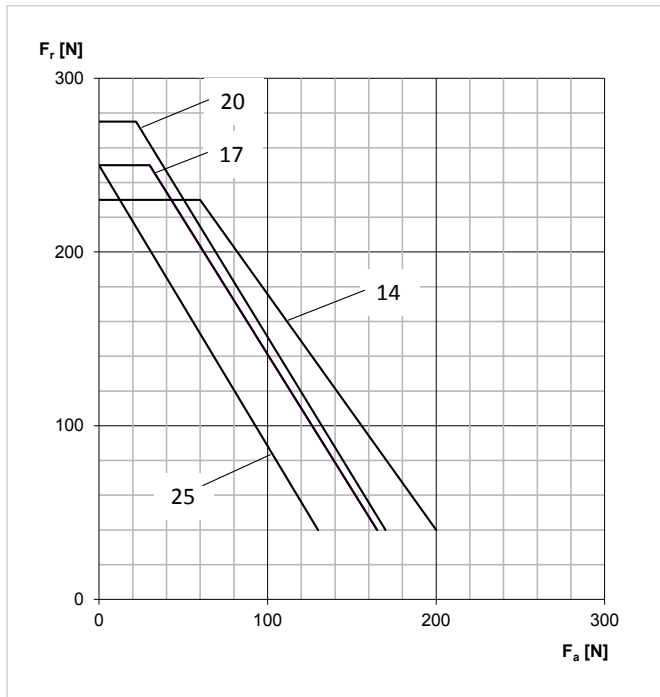
Illustration 26.2
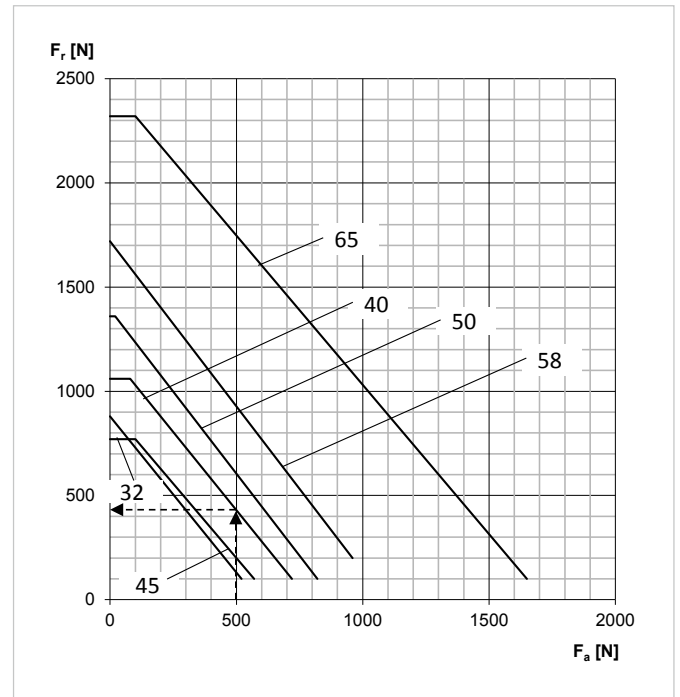
3.3.7. Housing Materials and Surfaces

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: corrosion protected (optional: browned).

4. Actuator Selection

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

Equation 27.1

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

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 27.2.

Illustration 27.2
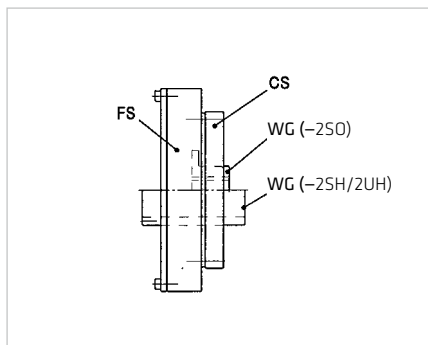
The values for ratios of Harmonic Drive® Gears refer to the standard drive arrangement (example 1 in the table below). Other arrangements are possible, and also shown in the table.

Ratio

1)
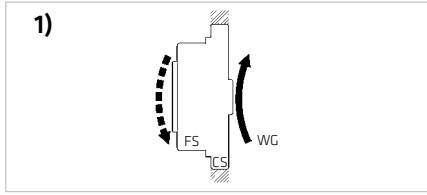
Reduction gearing
- CS   Fixed
- WG   Input
- FS   Output

Equation 28.1

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

Input and output rotate in opposite directions.

2)
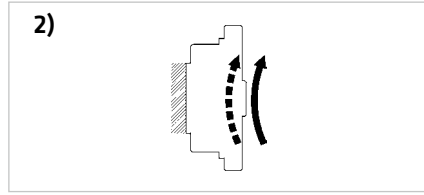
Reduction gearing
- FS   Fixed
- WG   Input
- CS   Output

Equation 28.2

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

Input and output rotate in same direction.

3)
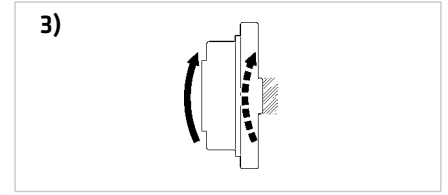
Reduction gearing
- WG   Fixed
- FS   Input
- CS   Output

Equation 28.3

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

Input and output rotate in same direction.

4)
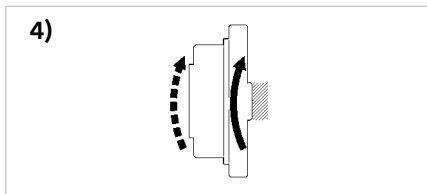
Speed increaser gearing
- WG   Fixed
- CS   Input
- FS   Output

Equation 28.4

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

Input and output rotate in same direction.

5)
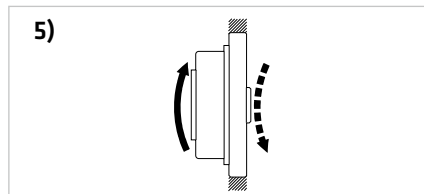
Speed increaser gearing
- CS   Fixed
- FS   Input
- WG   Output

Equation 28.5

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

Input and output rotate in opposite directions.

6)
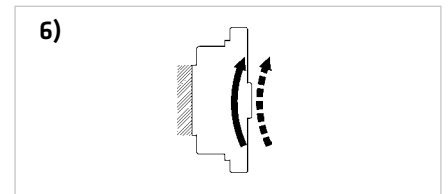
Speed increaser gearing
- FS   Fixed
- CS   Input
- WG   Output

Equation 28.6

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

Input and output rotate in same direction.

7)
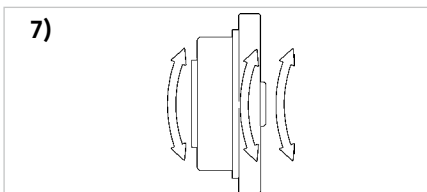
Differential gear
- WG   Control input
- CS   Main drive input
- FS   Main drive output

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 taken 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.

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

```
                    ┌──────────────────────┐
                    │     Application      │
                    └──────────────────────┘
                                │
                    ┌──────────────────────┐
                    │  Preselection gear   │
                    └──────────────────────┘
                                │
                    ┌──────────────────────┐
                    │ Torque based         │
                    │ dimensioning         │
                    │ according to selection│
                    │ procedure on page 30 │
                    └──────────────────────┘
                                │                   ┌──────────────────┐
                                │                   │  Selection of a  │
                                │                   │   bigger size    │
                                │                   └──────────────────┘
                         Gear size
                   Yes   sufficient?   No
                                │
                    ┌──────────────────────┐
                    │ Stiffness based      │
                    │ dimensioning         │
                    │ according to selection│
                    │ procedure on page 33 │
                    └──────────────────────┘
                                │                   ┌──────────────────┐
                                │                   │  Selection of a  │
                                │                   │   bigger size    │
                                │                   └──────────────────┘
                         Gear size
                   Yes   sufficient?   No
                                │
                    ┌──────────────────────┐
                    │    End of gear       │
                    │    selection         │
                    └──────────────────────┘
```
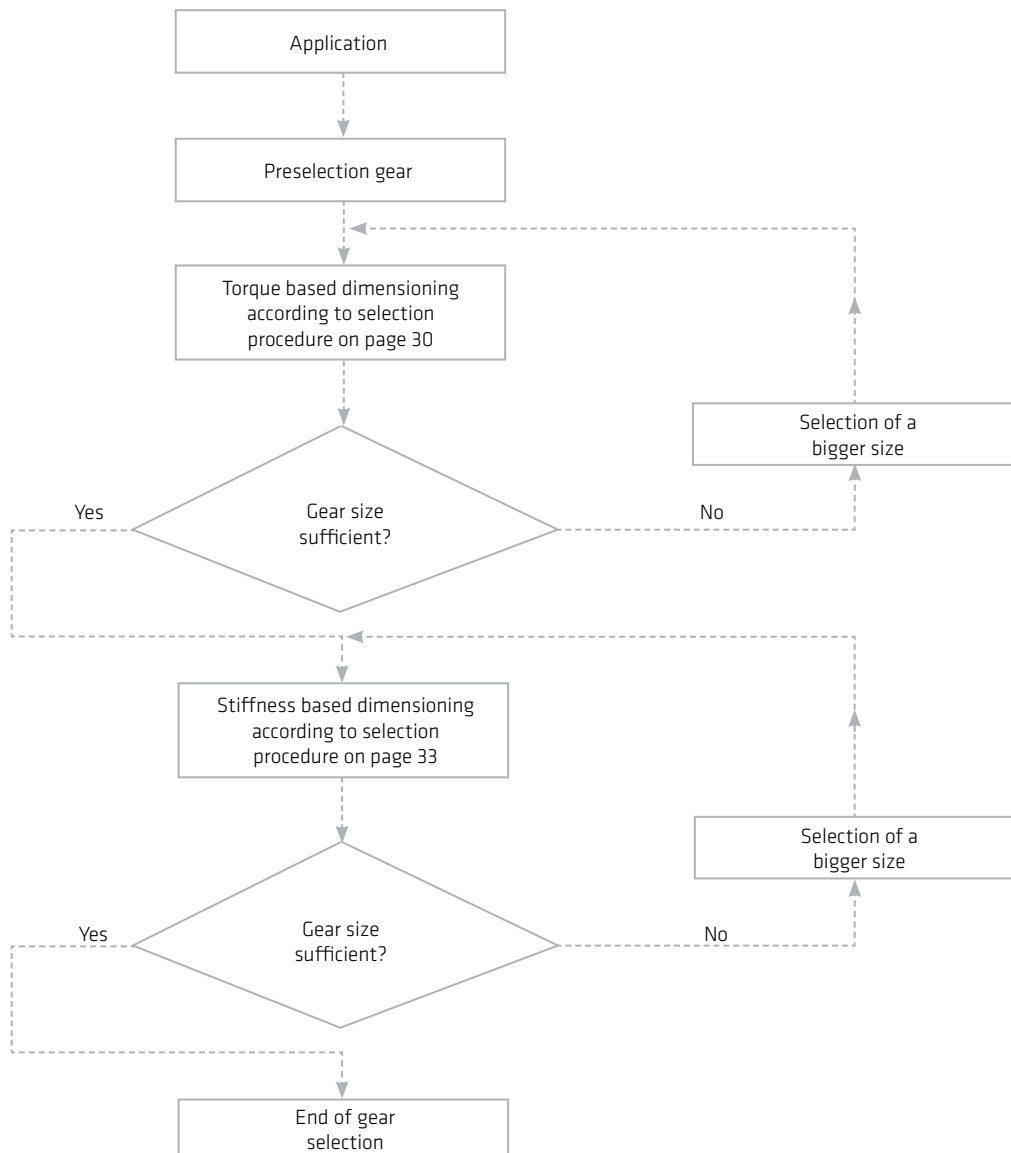
4.1.1   Torque Based Dimensioning

Output Data

Torques	$T_1 \dots T_n$	[Nm]	
during the load phases	$t_1 \dots t_n$	[s]	
during the pause time	t_p	[s]	
and output speeds	$n_1 \dots n_n$	[rpm]	
Emergency stop/momentary peak torque	T_k	[Nm]	
at output speed	n_k	[rpm]	
and duration	t_k	[s]	

Illustration 30.1
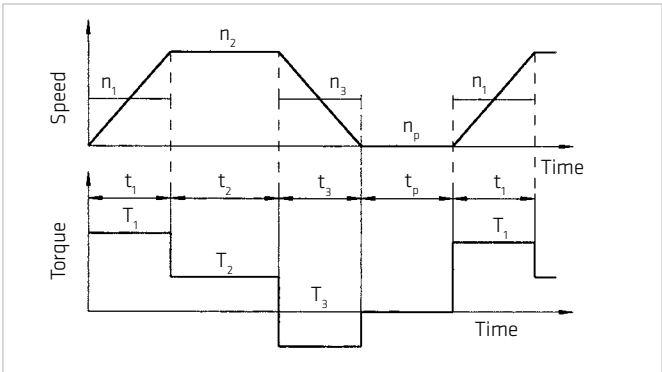
Equation 30.2

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

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

Equation 30.3

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

No → Selection of a bigger size

Equation 30.4

Calculation of the average output speed

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

Equation 30.5

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

Equation 30.6

Permissible maximum input speed

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

Equation 30.7

Permissible average input speed
$n_{in\ av} \le$ Limit for average input speed
(see rating table)

Equation 30.8

Load limit 2, T_R

$T_{max} \le T_R$

Equation 30.9

Load limit 3, T_M

$T_k \le T_M$

Equation 30.10

Allowable number of momentary peak torques

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

Equation 30.11

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 32.1

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

The life expectancy of a Harmonic Drive® Strain Wave Gear 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 nominal service life L_n of the Wave Generator Bearing.

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 32.2.

Table 32.1

Harmonic Drive® Series	Einheit	L_n
CobaltLine®, CSG, SHG	h	50000
HFUC, SHG, CSD, CPU, CSF, SHD	h	35000
PMG Gearbox	h	15000

Equation 32.2

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

Equation 32.3

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

n_N = Rated input speed [2000 rpm]
$n_{in\ av}$ = Average input speed [rpm] (equation 30.5)
T_N = Rated output torque at rated speed [Nm]
T_{av} = Average output torque [Nm] (equation 30.2)
L_n = nominal service life of the Wave Generator Bearing, see table 32.1

4.1.3 Stiffness Based Dimensioning

In addition to the "Torque Based Dimensioning" stated on page 30, we recommend that you carry out a selection based on stiffness. For this, the values provided in table 33.1 for the individual resonance frequencies recommended for each application should be taken into account.

Table 33.1 [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 articulated robots, hand axes of articulated 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..

Selection Example: Stiffness Based Dimensioning

Resonance Frequency (Gear Output)

The formula

Equation 34.1

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

f_n = Resonance frequency [Hz]
K_1 = Gear torsional stiffness [Nm/rad]
J = Load moment of inertia [kgm^2]

allows the calculation of the resonance frequency at the gear output, from the given the 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 33.1. The higher the load's moment of inertia, the higher is the influence of the type of application 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 n_n on the input side (motor side) can be calculated using the formula

$$n_n = f_n \cdot 30 \ [rpm]$$

During operation, we recommend passing the resonance speed quickly. This can be achieved by selecting a suitable gear ratio. Another possibility the selection of a 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 31.

Intended application: milling head for woodworking
Moment of inertia at the gear output: 7 kgm^2. Recommended resonance frequency from table 33.1: ≥ 30 Hz.
Resonance frequency using the preselected gear
HFUC-40-120-2A-GR:

$$f_n = \frac{1}{2\pi}\cdot\sqrt{\frac{1.3\cdot10^5}{7}} = 22 \ [Hz]$$

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:

$$f_n = \frac{1}{2\pi}\cdot\sqrt{\frac{2.5\cdot10^5}{7}} = 30 \ [Hz]$$

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

The calculated resonance speed at the input (motor) is:
$n_n = 30 \cdot 30 = 900 \ [rpm]$

Either, this speed should be passed quickly during acceleration and deceleration 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 35.1

$$T \leq T_1$$

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

Equation 35.2

$$T_1 < T \leq T_2$$

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

Equation 35.3

$$T > T_2$$

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

φ = Angle [rad]
T_1 = Limit torque 1 from section 3.3.5 [Nm]
T_2 = Limit torque 2 from section 3.3.5 [Nm]
K_1 = Torsional stiffness up to the limit torque T_1 from section 3.3.5 [Nm/rad]
K_2 = Torsional stiffness up to the limit torque T_2 from section 3.3.5 [Nm/rad]
K_3 = Torsional stiffness above the limit torque T_2 from section 3.3.5 [Nm/rad]

Example: HFUC-32-100-2UH

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

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

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

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

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

$$\varphi = 2.5 \text{ arcmin}$$

Equation 35.4

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

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 arcsec can occur at the output shaft, as listed in table 35.5.

Table 35.5

Ratio	Unit	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-65
50	[arcsec]	36	20	17	17	14	14	12	–	–	–
80	[arcsec]	23	13	11	11	9	9	8	8	6	6
100	[arcsec]	18	10	9	9	7	7	6	6	5	5
120	[arcsec]	–	8	8	8	6	6	5	5	4	4
160	[arcsec]	–	–	6	6	5	5	4	4	3	3

4.4 Efficiency Calculation SHG-2UH

The efficiency of Harmonic Drive® Gears varies depending on the following conditions
• Ratio
• Input speed
• Load torque
• Temperature
• Lubrication condition (type of lubricant and the quantity)

The efficiency curves are valid for gears operating at rated output torque. The efficiency of 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. The efficiency of the Simplicity Units SHG-2SO and SHG-2SH strongly depends on the integration into the application, like sealing concept, bearing concept etc. Please contact the Harmonic Drive AG for further support.

4.4.1   Efficiency Calculation Scheme

Table 36.1

Calculation Procedure	Example
	Efficiency of SHG-20-80-2UH with input speed n = 1000 rpm output torque T = 35 Nm at 20 °C ambient temperature. Lubrication: Harmonic Drive® Grease
The efficiency may be determined using the efficiency graphs.	See illustration 38.4 η_R = 63 %
Calculate the torque factor V. $$V = \frac{T_{av}}{T_N} \qquad \text{[Equation 36.2]}$$ With: T_{av} = Average torque T_N = Rated torque at rated speed	$$V = \frac{35 \text{ Nm}}{44 \text{ Nm}} = 0.8$$ T_{av} = 35 Nm T_N = 44 Nm
Determination of the correction factor K depending on the gear type and the torque factor V, see example in illustration 38.2.	K = 0.9
Determination of correction value η_e, see illustration 38.3	η_e = -6.6 %
Calculation of the total efficiency η_L $$\eta_L = K \cdot (\eta_R + \eta_e) \qquad \text{[Equation 36.3]}$$	η_L = 0.9 · (62 % - 6.6 %) = 50 %

4.4.2   Efficiency Correction factor

The efficiency of a Harmonic Drive® Strain Wave Gear depends on the load torque. When the load torque is lower than the rated torque, the efficiency value decreases. The correction factor K can be determined with illustration 36.2. When the load torque is higher than the rated torque, the correction factor is K = 1.

Calculation of torque factor V

Equation 37.1

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

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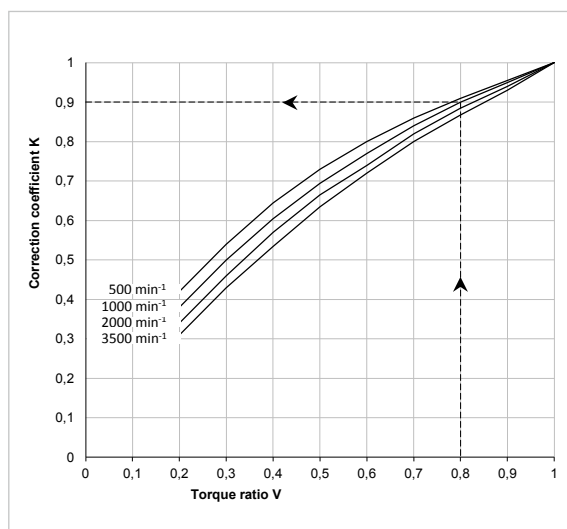T = Actual torque
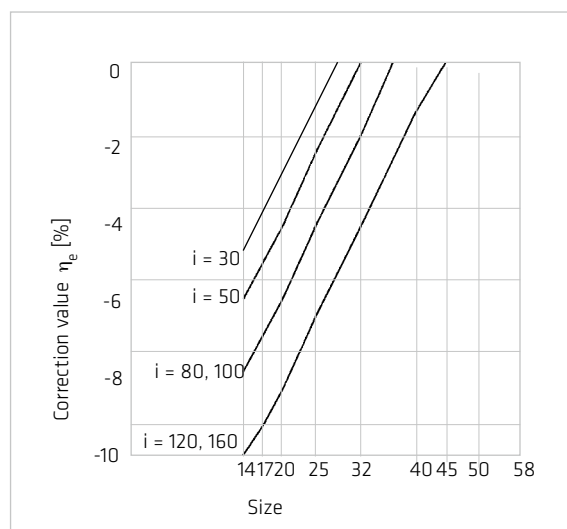T_N = Rated torque at rated speed

Illustration 37.2

4.4.3   Efficiency Correction Value

The SHG-2UH Series Unit is equipped with two support bearings and two shaft seals running on the hollow shaft, having an large impact on the gear's efficiency. The impact depends on the gear size and ratio and is considered by the correction value η_e.

Illustration 37.3

4.4.4 Efficiency Tables

The following illustrations show the efficiency of the SHG-2UH Series Unit at rated torque and lubrication with Harmonic Drive® Grease.

SHG-2UH

Illustration 38.4
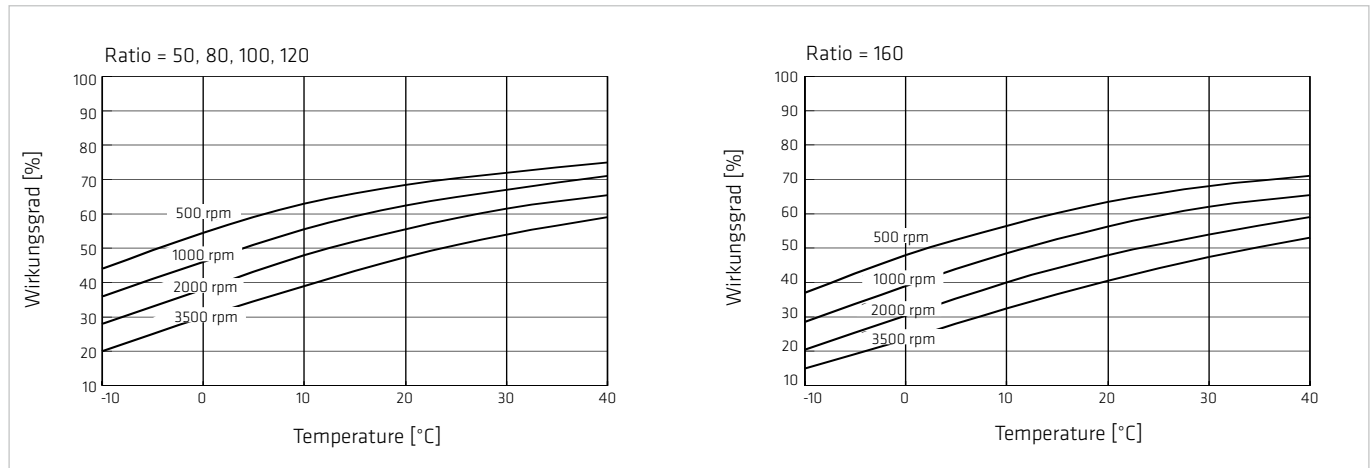
Remarks on Efficiency

The SHG-2UH Series Units are equipped with two rotary shaft seals at the hollow shaft as standard. The friction of the rotary shaft has a considerable influence on the efficiency of these units because the seals are mounted on the fast running input side and seal on the relatively large diameter of the hollow shaft.

If there is insufficient heat dissipation during operation (e. g. the unit is not connected to the machine housing and the load) the unit may reach a high temperature within a few minutes. This may result in overpressure which may have a negative impact on the pre-load of the rotary shaft seal. In this case the efficiency of the unit may be lower than the value given in the catalogue.

Cleaning the area of the seals with compressed air may also result in an unacceptable overpressure within the unit.

When the unit is equipped with standard seals, the over-pressure on the seals can be released by lifting up one of the sealing lips with a soft tool (e. g. by means of a toothpick on the outside of the sealing lip near the shaft. Be careful not to damage the sealing lip!). If special seals are used, we ask you to contact Harmonic Drive AG.

4.5 No Load Torque values SHG-2UH

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. The diagrams are valid for: Harmonic Drive® Grease, standard grease amount according to this engineering data and ratio i = 100.

For other ratios the compensation values have to be applied. When oil lubrication is used please contact Harmonic Drive AG.

4.5.1 No Load Running Torque

No Load Running Torque SHG-2UH

Illustration 39.1
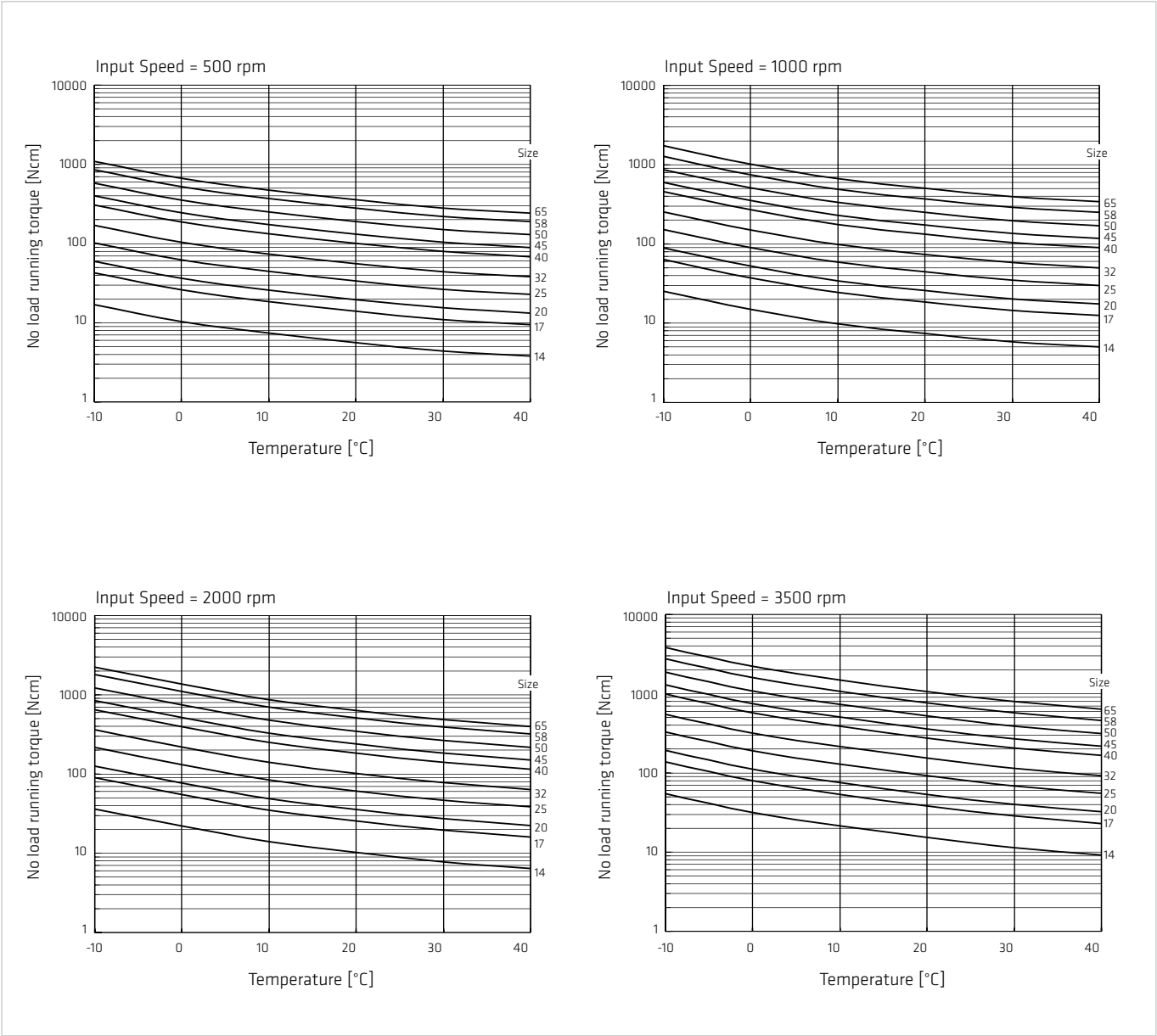
Compensation Values For No Load Running Torque SHG-2UH

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 40.1

Ratio	Unit	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-65
50	[Ncm]	1.1	1.8	2.6	4.2	8.0	13.3	18.2	–	–	–
80	[Ncm]	0.2	0.4	0.5	0.8	1.5	2.4	3.3	4.3	6.2	8.1
120	[Ncm]	–	-0.2	-04	-0.6	-1.1	-1.7	-2.4	-3.1	-4.4	-5.8
160	[Ncm]	–	–	-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 40.2

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

4.5.3   No Load Back Driving Torque

No Load Back Driving Torque SHG-2UH

Table 40.3

Ratio	Unit	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-65
50	[Nm]	5.3	16	22	34	51	82	99	–	–	–
80	[Nm]	7.2	24	31	48	70	112	133	172	234	301
100	[Nm]	8.2	29	38	59	86	134	158	205	278	356
120	[Nm]	–	34	45	69	97	158	182	237	322	413
160	[Nm]	–	–	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 41.2 should not be exceeded.

Alternatively a design according to illustration 41.1 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 41.1
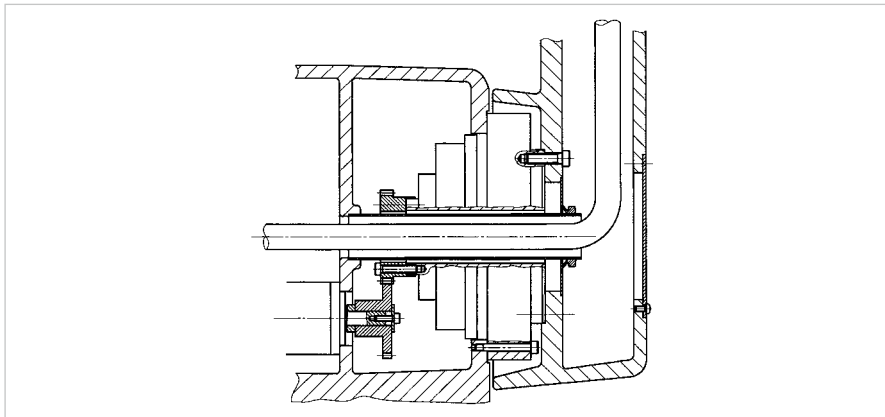
Max. Permissible Operating Time At Continuous Operation

Table 41.2

Operating time	Unit	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-65
At no load	[min]	90	90	90	60	45	40	35	30	20	15
At rated torque	[min]	60	60	60	45	35	30	25	20	15	10

The data mentioned in table 41.2 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 42.1.

Equation 42.1

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

with:

L_{10} [h]	=	Operating life
n_{av} [rpm]	=	Average output speed (equation 42.2)
C [N]	=	Dynamic load rating see section 3.3.6
P_C [N]	=	Dynamic equivalent load (equation 43.1)
f_w	=	Operating factor (table 42.3)
B	=	Bearing type (table 42.4)

Average Output Speed

Equation 42.2

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

Table 42.3

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 42.4

Bearing type	B
Cross roller bearings	$\frac{10}{3}$
Four point contact bearings	3

Dynamic Equivalent Load

Equation 43.1

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

with:

F_{rav} [N]	=	Radial force (equation 43.2)	x	=	Radial load factor (table 43.4)
F_{aav} [N]	=	Axial force (equation 43.3)	y	=	Axial load factor (table 43.4)
d_p [m]	=	Pitch circle (see section 3.3.5)	M	=	Tilting moment

Equation 43.2

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

Equation 43.3

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

Table 43.4

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

Illustration 43.5
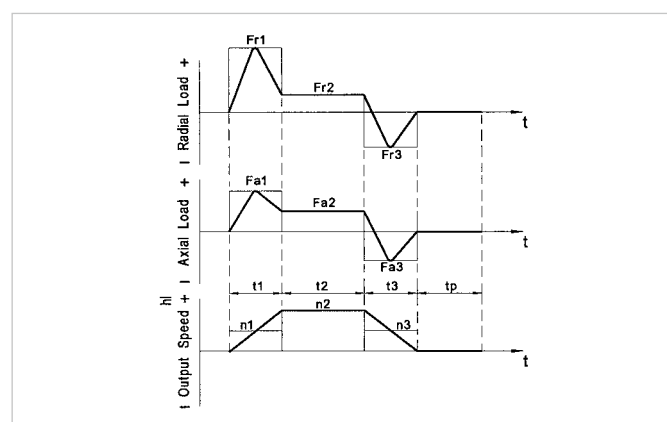
Please note:
F_{rx} = represents the maximum radial force.
F_{ax} = represents the maximum axial force.
t_p = represents the pause time between cycles.

4.7.1   Output Bearing at Oscillating Motion

Life for Oscillating Motion

The operating life at oscillating motion can be calculated using equation 44.1

Equation 44.1

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

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 23.1)
P_C [N]	=	Dynamic equivalent load (equation 43.1)
φ [°]	=	Oscillating angle
f_w	=	Operating factor (table 42.3)

* 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 44.2
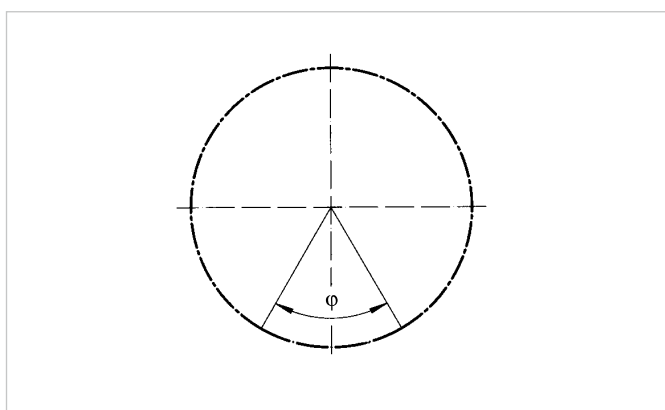
Tabelle 44.3

Bearing type	B
Cross roller bearing	$\frac{10}{3}$
Four point contact bearing	3

4.8 Permissible Static Tilting Moment

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

Equation 45.1

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

 and so

Equation 45.2

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

f_s = Static load safety factor

   ($f_s = 1.5 \dots 3$) (table 45.3)

C_0 = Static load rating

F_r = $F_a = 0$

x_0 = 1

y_0 = 0.44

P_0 = Static equivalent load (equation 43.1)

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

M = Moment acting

M_0 = Allowable static overturning moment

Table 45.3

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 45.4:

Equation 45.4

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

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 23.1)

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® Grease

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

Caution!

The Harmonic Drive® Greases 4B No.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 46.1

Grease	Ratio ≥ 50														
	Size														
	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
Flexolub®-A1	–	Standard for CPU and CobaltLine®													
SK-1A	–			Standard											
SK-2	Standard			–											
4B No.2	–	For heavy duty operation*													

Table 46.2

Grease	Ratio = 30						
	Size						
	8	11	14	17	20	25	32
Flexolub®-A1	–		Standard for CPU				
SK-1A	–				Standard		
SK-2	Standard				–		
4B No.2	–				For heavy duty operation*		

Notes:

* = recommended for heavy duty operation or at operating temperatures ranging from -10 °C to +110 °C

– = not approved

Table 47.1 gives some important information regarding Harmonic Drive® Greases.

Table 47.1

| Type | Harmonic Drive® Greases | | | |
| | Standard | | Special | |
	SK-1A	SK-2	Flexolub®-A1	4B No.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 mm²/St	37; 5.9 mm²/St	25; 5.2 mm²/St	50; 12 mm²/St
Drop point	197 °C	198 °C	180 °C	247 °C
Colour	yellow	green	pale yellow	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® Greases are available from Harmonic Drive AG.

Precautions for using Harmonic Drive® Grease 4B No.2

Harmonic Drive® Grease 4B No.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 Drive® Grease 4B No.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 Drive® Grease 4B No.2.

Special Operating Demands

Table 48.1 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 48.1

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. 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 48.2

Approved 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 (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 supported 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 with support bearings the axial force is absorbed internally.
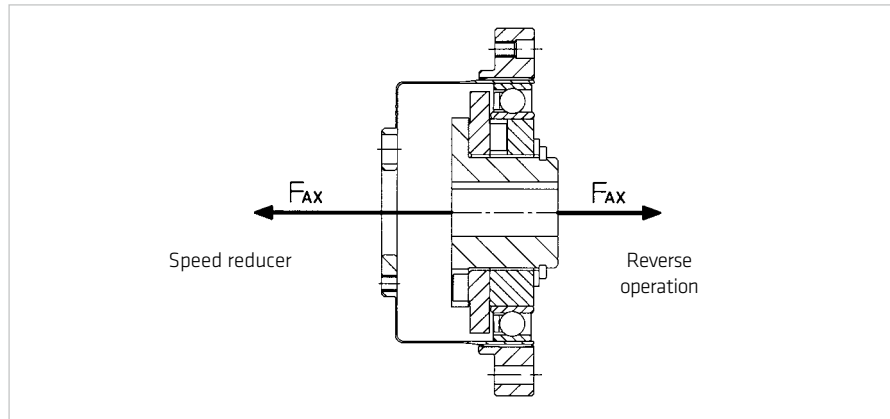
Illustration 49.1

Table 49.2

Ratio		
30	$F_{AX} = 2 \cdot \dfrac{T}{D} \cdot \mu \cdot \tan 32°$	[Equation 49.3]
50	$F_{AX} = 2 \cdot \dfrac{T}{D} \cdot \mu \cdot \tan 30° + 2\mu PF$	[Equation 49.4]
80 ... 160	$F_{AX} = 2 \cdot \dfrac{T}{D} \cdot \mu \cdot \tan 20° + 2\mu PF$	[Equation 49.5]

with:

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

Example

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

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

F_{AX} = 215 N

Table 49.6

	Unit	14	17	20	25	32	40	50
2µPF for CSD and SHD	[N]	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
• SHG-2UH
These units are supplied with a lifetime lubrication as standard.

• SHG-2SO und SHG-2SH
These units are supplied without lifetime lubrication. Before commissioning of the unit an initial lubrication has to be applied by the customer. A recommendation for the lubricant type can be found at chapter 4.10.1 and the recommended amount of grease at chapter 5.5.2.

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 to use the full performance of Harmonic Drive® Units, it is essential that the tolerances according to table 51.2 are observed for the input assembly.
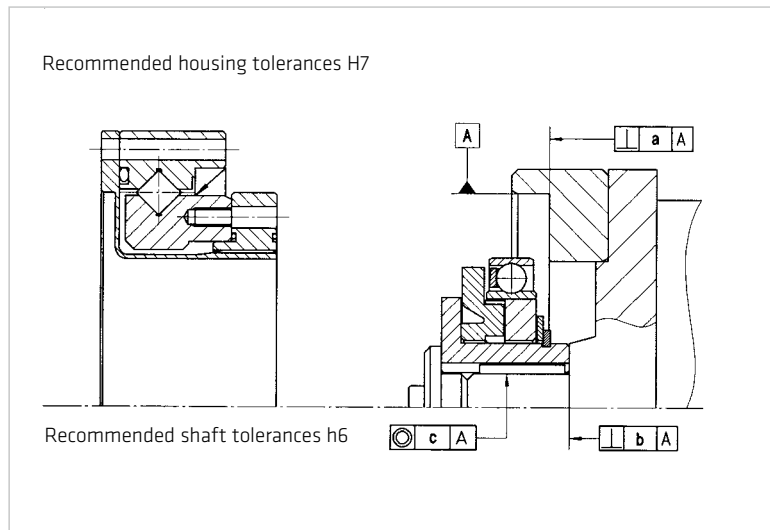
Illustration 51.1

Recommended housing tolerances H7

Recommended shaft tolerances h6

Table 51.2

	Unit	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-65
a	[mm]	0.011	0.015	0.017	0.024	0.026	0.026	0.027	0.028	0.031	0.034
b	[mm]	0.017	0.020	0.020	0.024	0.024	0.032	0.032	0.032	0.032	0.032
	[mm]	(0.008)	(0.010)	(0.010)	(0.012)	(0.012)	(0.012)	(0.013)	(0.015)	(0.015)	(0.015)
c	[mm]	0.030	0.034	0.044	0.047	0.050	0.063	0.065	0.066	0.068	0.070
	[mm]	(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 (Solid Wave Generator) on a motor shaft, the shaft tolerances should fulfill the DIN 42955 R standard.

5.5 Lubrication

5.5.1 Grease lubrication SHG-2UH

Harmonic Drive® SHG-2UH 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 based on strain wave gear principle. It guarantees constant accuracy of the gears for their whole life. A re-lubrication of the Units is not necessary.

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

These units are delivered without lifetime lubrication. Before commissioning of the unit an initial lubrication has to be applied by the customer. A recommendation for the lubricant type can be found at chapter 4.10.1. If any other grease is used this will be indicated on the customer drawing. On delivery of SHG-2SO and -2SH Units as standard, 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 53.1).

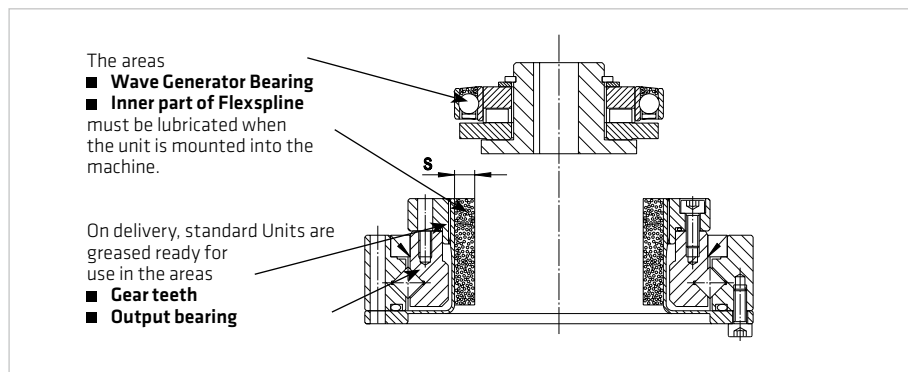Illustration 52.1 shows the areas requiring grease.

Illustration 52.1

Table 52.2

	Symbol [Unit]	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-65
Dimension (Illustration 52.3)	s [mm]	3	4	5	6	8	10	11	12	14	16
Standard amount of grease	[g]	5,8	11	18	32	64	120	185	235	385	495
	[cm³]	6,4	12	20	35	70	132	203	258	423	544
Additionally required grease quantity for operation with Wave Generator above	[g]	3,1	4	4	10	20	30	45	55	95	135
	[cm³]	3,4	4	4	11	22	33	49	60	104	148

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 52.3.
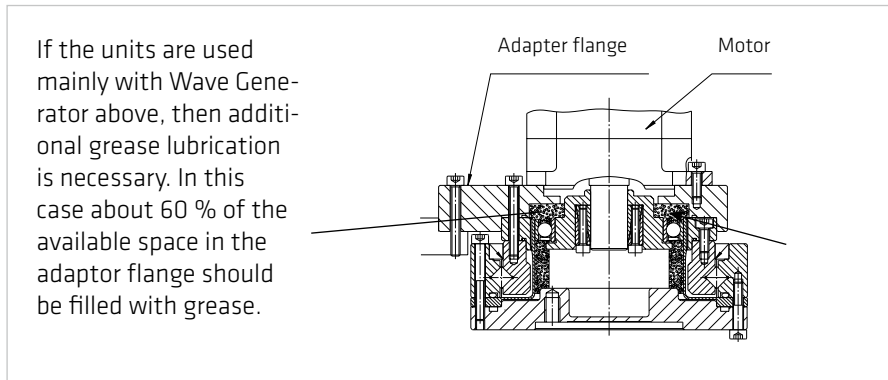
Illustration 52.3
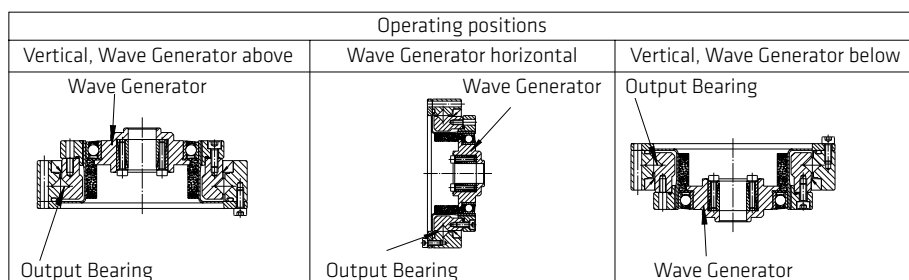
5.5.3   Additional Grease Package

The required grease quantity is depending 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 52.3 and table 52.2.

Illustration 53.1

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 should be filled with grease.

Adapter flange   Motor

5.5.4   Grease Change

If the strain wave gear is operated at regular operating conditions (average environmental temperatures ≤ 40 °C, average application loads ≤ rated torque and rated speed), the initial lubrication is sufficient for the lifetime of the gear. Abrasion of the sliding parts of a strain wave gear is influenced by the grease condition. Grease performance changes by temperature and deteriorates rapidly as the temperature rises. Therefore a replacement of the grease may become necessary depending on the operating conditions.

In illustration 53.2, the grease change interval depending on the grease temperature is given. This chart is valid for a gear loaded with rated torque and rated speed. If the application's average torque is higher than the rated torque, the grease change interval can be determined with equation 53.3. This means, that for a temperature of Harmonic Drive® Grease SK-1A or SK-2 of 40 °C a change should take place after approx. $8.5 \cdot 10^8$ revolutions of the input shaft.

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

Illustration 53.2
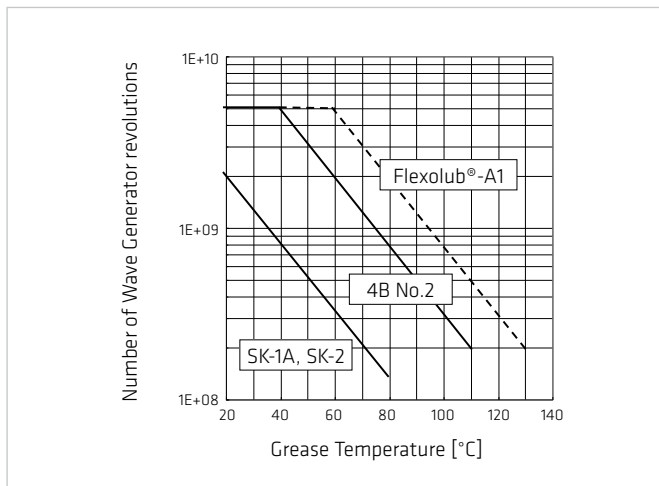
Equation 53.3

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

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

L_{GTn} = see diagram

T_N = Rated torque

T_{av} = Average torque of the application

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 chapter 4.10.2 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 confirmation drawing includes 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 the lack of lubricant.

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. Recommended oil types can be found in table 49.2. The mixture of lubricants with different specifications is to be avoided.

5.6   Assembly Preparation

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 518
- 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
- Loxeal 55-03

This adhesive ensures that the screw is fixed and also provides a good sealing effect and 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

Adhesive applicable 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 Assembly of 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 AG whether in the concrete case another sequence is permissible.

The assembly must be carried out without the use of excessive 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.

Pre-assembled screws 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 to connect the unit to the machine housing and load (please take care of the dead weight) before applying any radial or axial forces.

5.7.1   Motor Assembly SHG-2SO

Assembly of the adapter 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 56.1. In table 56.2 the diameters of the Wave Generator main axes are indicated.
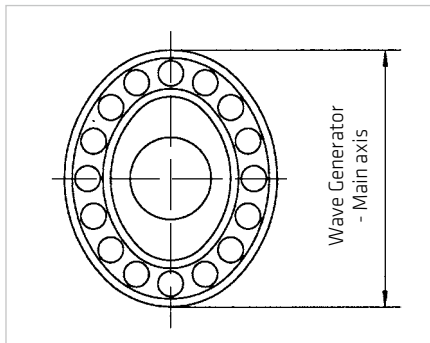
Illustration 56.1

Table 56.2

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

Installation steps (see Illustration 57.3):

1) Mount the adapter flange (1) to the motor (2) using the screws (8).
2) Mount the Wave Generator (5) to the motor shaft.
3) Mount the adapter flange - motor subassembly to the unit (10).
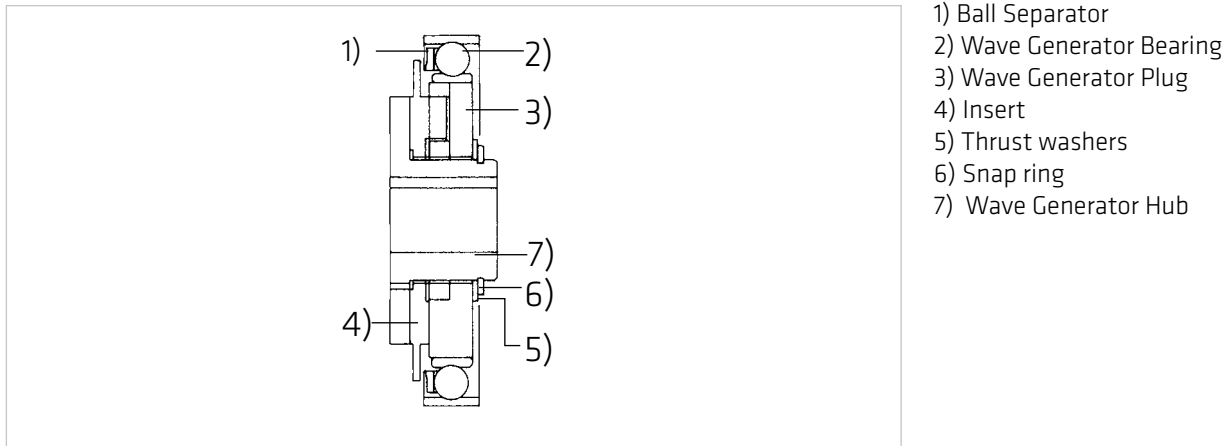
Illustration 56.3
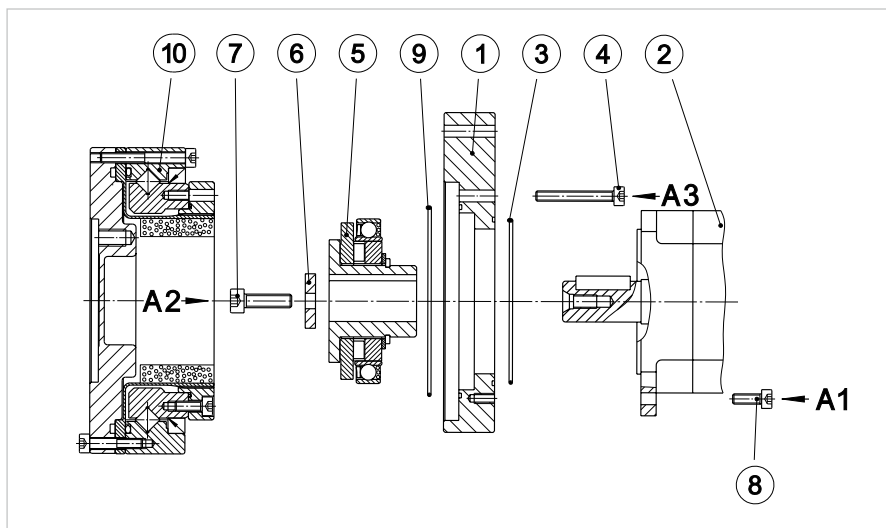
O-rings (3) and (9) or sealing agent should be used for sealing the adapter flange (1) towards the motor (2) and the unit (10). The sealing surfaces of the o-ring or the sealing agent must not be interrupted (e. g. by boreholes). When the unit is lubricated with 4B No.2 or mainly operated with Wave Generator below, a motor with shaft seal should be used in order to avoid the intrusion of the grease base oil into the motor.

5.7.2   Wave Generator Components SHG-2SO

Illustration 57.1 shows a standard Wave Generator with Oldham Coupling.

Illustration 57.1

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 recommended 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

Very rarely, an eccentric tooth mesh, called dedoidal, may occur, see illustration 57.1. 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 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 of 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 58.1

Right

Wrong
(dedoidal)
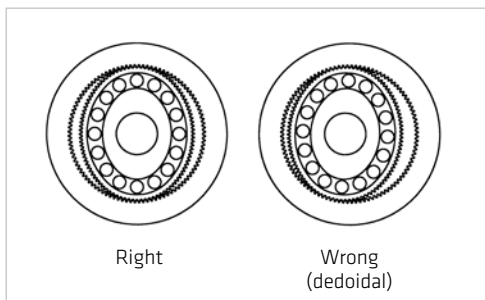
5.7.7 Assembly of the Output Flange

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 51.2 are the sum of bearing and flange tolerances, valid for standard Units. On request Units with optimized flange tolerances are available.

Table 59.1

	Unit	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-65
Number of Bolts						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	154	178	195
Tightening Torque	[Nm]	2.4	2.4	2.4	5.4	10.8	18.3	44	44	89	89
Torque transmitting capacity[1]	[Nm]	88	216	248	520	1080	1867	2914	4274	5927	8658

5.7.8 Assembly of the Housing Flange

Table 59.2

	Unit	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-65
Number of Bolts		8	12	12	12	12	12	18	12	16	16
Bolt Size		M3	M3	M3	M4	M5	M6	M6	M8	M8	M10
Bolt pitch diameter	[mm]	64	74	84	102	132	158	180	200	226	258
Tightening Torque	[Nm]	2.4	2.4	2.4	5.4	10.8	18.4	18.4	44	44	74
Torque transmitting capacity[1]	[Nm]	128	222	252	516	1069	1813	3098	4163	6272	9546

* Friction coefficient μ = 0.15; 12.9 quality screws

Housing and output flange is to be assembled as per tables 59.1 and 59.2

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

Table 59.3

	Unit	SHG-14	SHG-17	SHG-20	SHG-25	SHG-32	SHG-40	SHG-45	SHG-50	SHG-58	SHG-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. The applications average input speed must be lower than the permitted average input speed of the gear.

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

Maximum permissible average gear input speed for oil lubrication. The applications average input speed must be lower than the permitted average input speed of the gear.

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}]
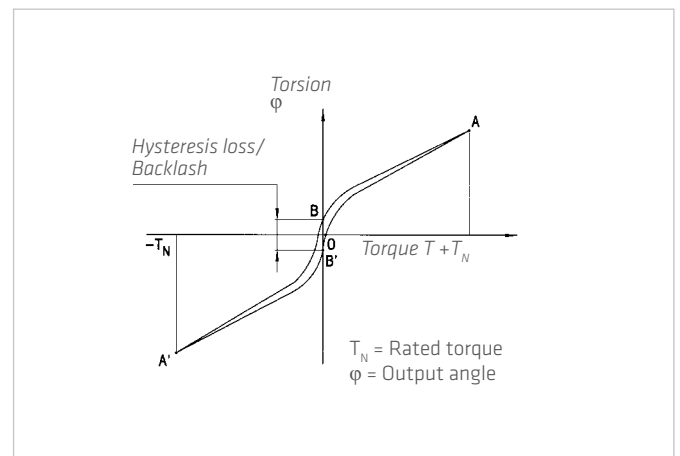
Current required to open the brake.

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. This value is not based on the equation for lifetime calculation of the output bearing but on the maximum allowable deflection of the Harmonic Drive® Component Set. This value must not be exceeded even if the lifetime calculation of the bearing permits higher values.

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 axial hollow shaft.

Hysteresis loss (Harmonic Drive® Gears)

When a torque is applied to the output of a Harmonic Drive® Gear with the input locked, the torque-torsion relationship measured at the output typically follows, starting from point 0, the successive points the hysteresis curve A-B-A'-B'-A (see figure). The value of the displacement B-B' is defined as the hysteresis loss.
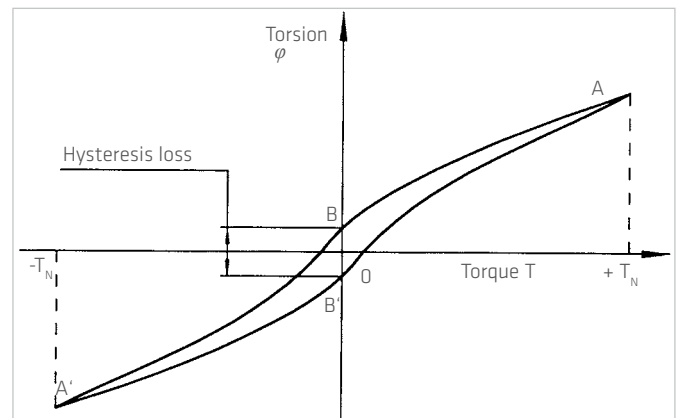
T_N = Rated output torque
φ = Output rotation angle

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® Gears) [arcmin]

Harmonic Drive® Gears exhibit 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.
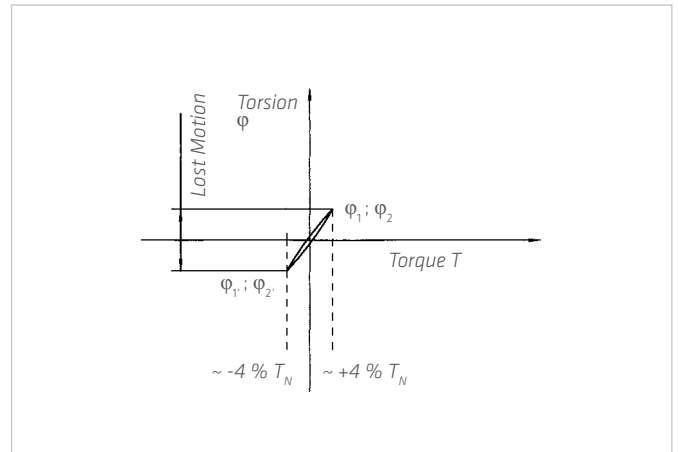
Maximum current I_{max} [A]

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 for short period. The maximum input speed can be applied as often as desired, as long as the application's average speed is lower than the permitted average input speed of the gear.

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

Maximum allowable input speed for gearing with oil lubrication for short period. The maximum input speed can be applied as often as desired, as long as the application's average speed is lower than the permitted average input speed of the gear.

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® Gear may be subjected to a brief momentary peak torque. The magnitude and frequency of this peak torque should be kept to a minimum and under no circumstances should the momentary peak torque occur during the normal operating cycle. The allowable number of momentary peak torque events can be calculated with the equations given in chapter "selection procedure".

Moment of inertia J [kgm²]
Mass moment of inertia at motor side.

Moment of inertia J_{in} [kgm²]
Mass moment of inertia of the gear with respect to the input.

Moment of inertia J_{out} [kgm²]
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.

Nominal Service Life L_n [h]
When loaded with rated torque and running at rated speed the Wave Generator Bearing will reach the nominal service life L_n with 50 % propability of failure. For different load conditions the service life of the Wave Generator Bearing can be calculated using the equations in chapter "selection procedure".

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

Offset R [m]
Distance between output 's center plane and contact point of the load.

Pitch circle diameter d_p [m] or [mm]
Pitch circle diameter of the output bearing rolling element raceway.

Protection class 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], Servo

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

Rated speed n_N [rpm], Mechanical

The rated speed is a reference speed for the calculation of the gear life. When loaded with rated torque and running at rated speed the Wave Generator Bearing will reach the nominal service life L_n with 50 % propability of failure. The rated speed n_N is not used for the dimensioning of the gear.

Product series	Unit	n_N
CobaltLine®, HFUC, HFUS, CSF, CSG, CSD, SHG, SHD	[rpm]	2000
PMG size 5	[rpm]	4500
PMG size 8 to 14	[rpm]	3500
HPG, HPGP, HPN	[rpm]	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 rated torque and running at rated speed the Wave Generator Bearing will reach the nominal service life L_n with 50 % propability of failure. 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.
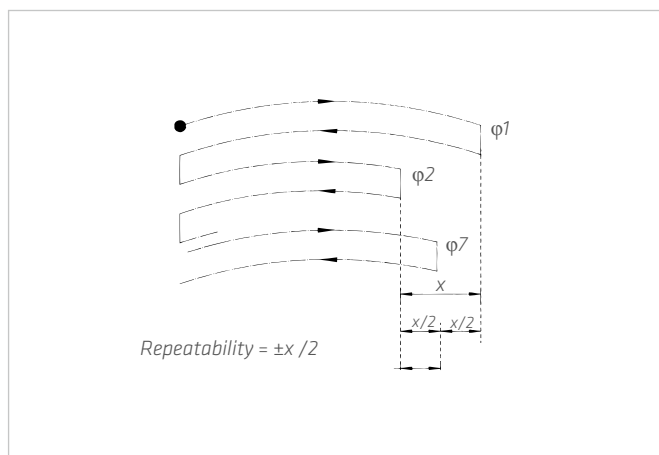
Ratio i [ ]

The ratio is the reduction of input speed to the output speed.
Note for Harmonic Drive® Gears: In the standard drive arrangement, the Wave Generator is the drive element while the Flexspline is the driven 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 must be considered.

Repeatability [arcmin]

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

Repeatability = ±x /2

Repeated peak torque T_R [Nm]

Specifies the maximum allowable acceleration and deceleration torque. During the normal operating cycle the repeated peak torque T_R must not be exceeded. The repeated peak torque can be applied as often as desired, as long as the application's average torque is lower than the permitted average torque of the gear.

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.

Synchronous inductance L_d [mH]

Sum of air gap inductance and leakage inductance in relation to the single-phase equivalent circuit diagram of the synchronous motor.

Tilting moment stiffness K_B [Nm/arcmin]

The ratio of the tilting angle of the output bearing and the applied moment load.

Torque constant (motor) k_{TM} [Nm/A$_{rms}$]

Quotient of stall torque and stall current.

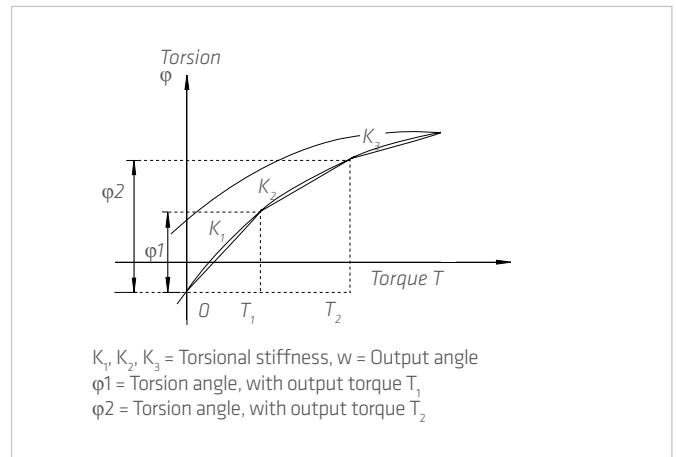## Torque constant (output) k_{Tout} [Nm/A$_{rms}$]

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

Torsional stiffness
(Harmonic Drive® Gears) K_1, K_2, K_3 [Nm/rad]

The amount of elastic rotation at the output for a given torque with the Wave Generator blocked. The torsional stiffness may be evaluated by dividing the torque-torsion curve into three regions. The torsional stiffness values K_1, K_2 and K_3 are determined by linearization of the curve.

K_1: low torque region $\qquad$ 0 ~ T_1
K_2: middle torque region $\quad$ T_1 ~ T_2
K_3: high torque region $\qquad$ > T_3

The values given for the torsional stiffness K_1, K_2 and K_3 are average values that have been determined during numerous tests. The limit torques T_1 and T_2 and an calculation example for the torsional angle can be found in chapter "torsional stiffness" and "calculation of the torsion angle" 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_3 [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
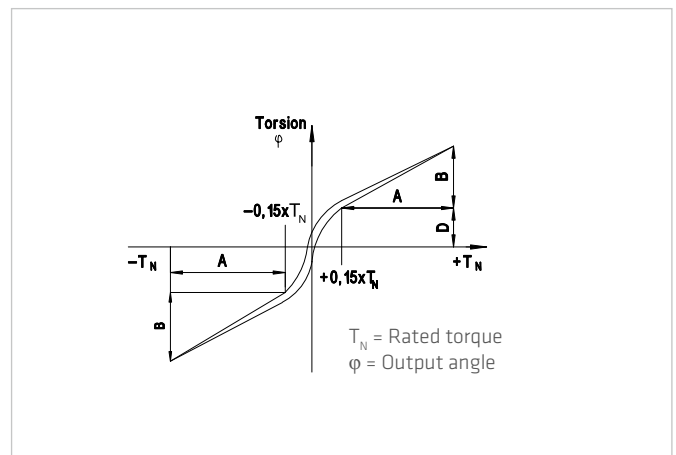
Transmission accuracy [arcmin]

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.
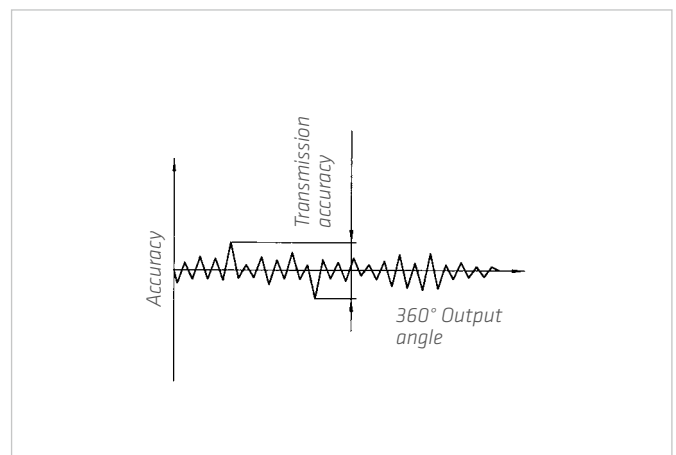
Weight m [kg]

The weight specified in the catalogue 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 the product meets the applicable requirements of the EU harmonization legislation.

REACH Regulation

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

RoHS EU Directive

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