Engineering Data
SHD-2SH Units

Harmonic Drive AG

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

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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65555 Limburg / Lahn
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E-Mail: info@harmonicdrive.de

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

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 predection, 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

Short overall length with largest hollow shaft

SHD Series Units are available in six sizes with gear ratios of 50, 80, 120 and 160:1 offering repeatabled peak torques from 12 to 453 Nm.

The output bearing with high tilting rigidity enables the direct introduction of high payloads without further support and thus permits simple and space saving design installations.

The SHD-2SH Simplicity Units are characterised by highly compact dimensions and low weight, consisting of the component set with shortened Flexspline and the high capacity output bearing. The absence of input and output flanges means maximum flexibility in design integration. The integrated hollow shaft can be used to feed through supply lines or services for further axes. The high capacity, integrated output bearing means that the Unit can quickly and easily withstand heavy payloads.

3.2 Ordering Code

Table 10.1

Series	Size	Ratio[1]					Version	Special design
SHD	14	50	80	100			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		
Ordering code								
SHD	**20**	**100**					**2SH**	**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 the chapter 4 “Ratio”.

Table 10.2

Version	
Ordering code	**Description**
2SH	Simplicity Unit with hollow shaft

Explanation 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]	SHD-14-2SH			SHD-17-2SH			
Ratio	i [ ]	50	80	100	50	80	100	120
Repeated peak torque	T_R [Nm]	12	16	19	23	29	37	37
Average torque	T_A [Nm]	4.8	7.7	7.7	18	19	27	27
Rated torque	T_N [Nm]	3.7	5.4	5.4	11	15	16	16
Momentary peak torque	T_M [Nm]	23	35	35	48	61	71	71
Maximum input speed (grease lubrication)	$n_{in\,(max)}$ [rpm]	8500			7300			
Average input speed (grease lubrication)	$n_{av\,(max)}$ [rpm]	3500			3500			
Moment of inertia	J_{in} [$\cdot 10^{-4}$ kgm²]	0.021			0.054			
Weight	m [kg]	0.33			0.42			

Table 11.2

	Symbol [Unit]	SHD-20-2SH					SHD-25-2SH				
Ratio	i [ ]	50	80	100	120	160	50	80	100	120	160
Repeated peak torque	T_R [Nm]	39	51	57	60	64	69	96	110	117	123
Average torque	T_A [Nm]	24	33	34	34	34	38	60	75	75	75
Rated torque	T_N [Nm]	17	24	28	28	28	27	44	47	47	47
Momentary peak torque	T_M [Nm]	69	89	95	95	95	127	179	184	204	204
Maximum input speed (grease lubrication)	$n_{in\,(max)}$ [rpm]	6500					5600				
Average input speed (grease lubrication)	$n_{av\,(max)}$ [rpm]	3500					3500				
Moment of inertia	J_{in} [$\cdot 10^{-4}$ kgm²]	0.090					0.282				
Weight	m [kg]	0.52					0.91				

3.3.2 Dimensions

Illustration 12.1 SHD-14-2SH [mm]

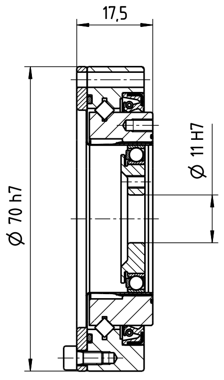


Illustration 12.2 SHD-17-2SH [mm]

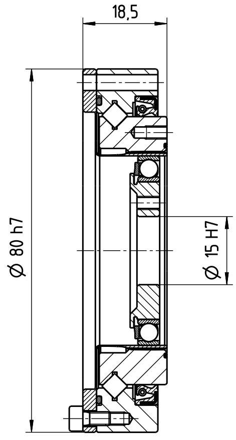


Illustration 12.3 SHD-20-2SH [mm]

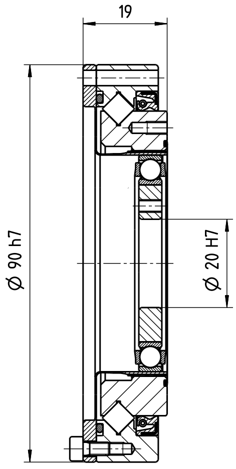


Illustration 12.4 SHD-25-2SH [mm]

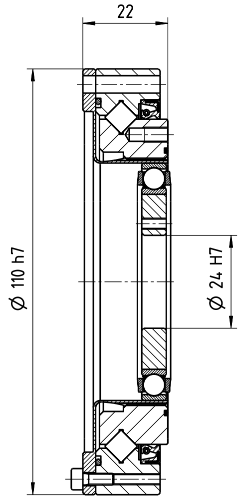


Table 13.1

	Symbol [Unit]	SHD-32-2SH					SHD-40-2SH				
Ratio	i [ ]	50	80	100	120	160	50	80	100	120	160
Repeated peak torque	T_R [Nm]	151	213	233	247	261	281	364	398	432	453
Average torque	T_A [Nm]	75	117	151	151	151	137	198	260	315	316
Rated torque	T_N [Nm]	53	83	96	96	96	96	144	185	205	206
Momentary peak torque	T_M [Nm]	268	398	420	445	445	480	686	700	765	765
Maximum input speed (grease lubrication)	$n_{in\,(max)}$ [rpm]	4800					4000				
Average input speed (grease lubrication)	$n_{av\,(max)}$ [rpm]	3500					3000				
Moment of inertia	J_{in} [$\cdot 10^{-4}$ kgm²]	1.09					2.85				
Weight	m [kg]	1.87					3.09				

Illustration 13.2

SHD-32-2SH [mm]

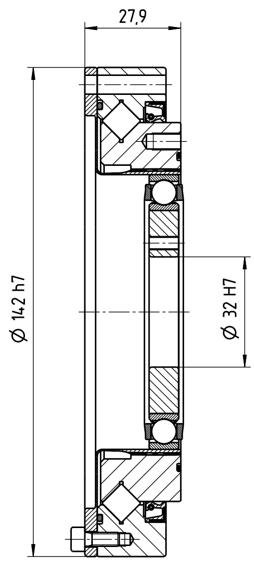
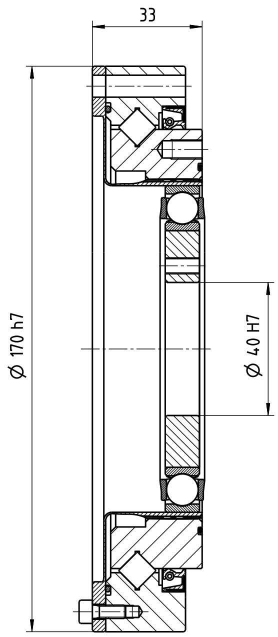


Illustration 13.3

SHD-40-2SH



3.3.3 Minimum Housing Clearance

Table 14.1

	Unit	SHD-14	SHD-17	SHD-20	SHD-25	SHD-32	SHD-40
Ø w	[mm]	31	38	45	56	73	90
x	[mm]	1.0	1.0	1.5	1.5	2.0	2.5
y	[mm]	1.4	1.8	1.7	1.8	1.8	1.8
Ø z	[mm]	38	45	53	66	86	106

Illustration 14.2

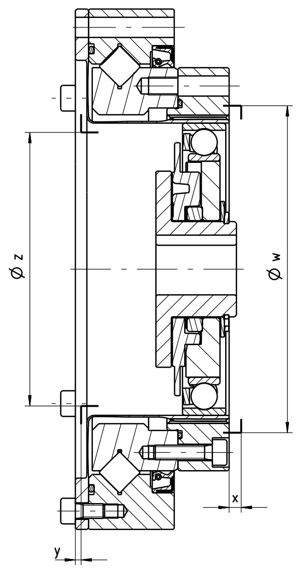


Illustration is representative only.Please see the confirmation drawing for details of the actual unit.

3.3.4 Accuracy

Table 14.3

	Symbol [Unit]	SHD-14		SHD-17		SHD-20		SHD-25		SHD-32		SHD-40	
Ratio	i [ ]	50	≥ 80	50	≥ 80	50	≥ 80	50	≥ 80	50	≥ 80	50	≥ 80
Transmission accuracy	[arcmin]	< 1.5		< 1.5		< 1.0		< 1.0		< 1.0		< 1.0	
Repeatability	[arcmin]	< ±0.1		< ±0.1		< ±0.1		< ±0.1		< ±0.1		< ±0.1	
Hysteresis Loss	[arcmin]	< 2.5	< 2	< 2	< 1	< 2	< 1	< 2	< 1	< 2	< 1	< 2	< 1
Lost Motion	[arcmin]	< 1		< 1		< 1		< 1		< 1		< 1	

3.3.5 Torsional Stiffness

Table 14.4

	Symbol [Unit]	SHD-14		SHD-17		SHD-20		SHD-25		SHD-32		SHD-40	
Limit torque	T_1 [Nm]	2		3.9		7		14		29		54	
	T_2 [Nm]	6.9		12		25		48		108		196	
Ratio	i [ ]	50	≥ 80	50	≥ 80	50	≥ 80	50	≥ 80	50	≥ 80	50	≥ 80
Torsional Stiffness	K_3 [$\cdot 10^3$ Nm/rad]	4.7	6.1	12	13	20	25	37	47	84	110	150	200
	K_2 [$\cdot 10^3$ Nm/rad]	3.7	4.4	8.8	9.4	13	17	27	37	61	78	110	140
	K_1 [$\cdot 10^3$ Nm/rad]	2.9	4	6.7	8.4	11	13	20	27	47	61	88	110

3.3.6 Bearings

Output Bearing

SHD 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 costs, 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 15.1 lists ratings and important dimensions for the output bearings.

Table 15.1

	Symbol [Unit]	**SHD-14**	**SHD-17**	**SHD-20**	**SHD-25**	**SHD-32**	**SHD-40**
Pitch circle	d_p [m]	0.0503	0.061	0.070	0.086	0.112	0.133
Offset	R [m]	0.0111	0.0115	0.0110	0.0121	0.0173	0.0195
Dynamic load rating	C [N]	2900	5200	7300	10900	19100	21600
Static load rating	C_0 [N]	4300	8100	11000	17900	32700	40800
Permissible dynamic tilting moment	M [Nm]	37	62	93	129	290	424
Tilting moment stiffness	K_B [Nm/arcmin]	21	37	61	90	239	422

- The basic dynamic rated load is a given static radial load, in which the basic dynamic service life of the bearing is one million revolutions.
- The basic static nominal load is a static load for a specific contact (4 kN/mm^2) applied in the center of the contact surface between the rolling elements (on which this maximum load is applied) and the raceway.
- The value of the tilting stiffness is the average value.

3.3.7 Materials used

Output bearing: bearing steel, corrosion protected
Flexspline: bright steel
Wave Generator: bright steel

4. Actuator Selection

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

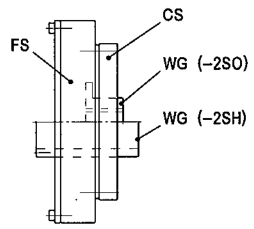
Equation 16.1

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

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 16.2.

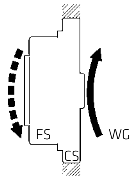
Illustration 16.2



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

Ratio

1)



Reduction gearing

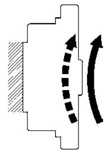
CS	Fixed
WG	Input
FS	Output

Equation 17.1

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

Input and output rotate in opposite directions.

2)



Reduction gearing

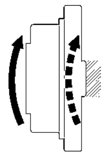
FS	Fixed
WG	Input
CS	Output

Equation 17.2

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

Input and output rotate in same direction.

3)



Reduction gearing

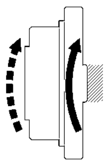
WG	Fixed
FS	Input
CS	Output

Equation 17.3

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

Input and output rotate in same direction.

4)



Speed increaser gearing

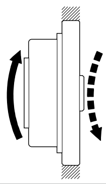
WG	Fixed
CS	Input
FS	Output

Equation 17.4

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

Input and output rotate in same direction.

5)



Speed increaser gearing

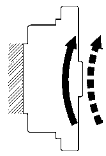
CS	Fixed
FS	Input
WG	Output

Equation 17.5

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

Input and output rotate in opposite directions.

6)



Speed increaser gearing

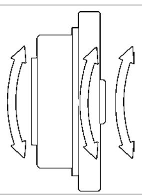
FS	Fixed
CS	Input
WG	Output

Equation 17.6

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

Input and output rotate in same direction.

7)



Differential gear

WG	Control input
CS	Main drive input
FS	Main drive output

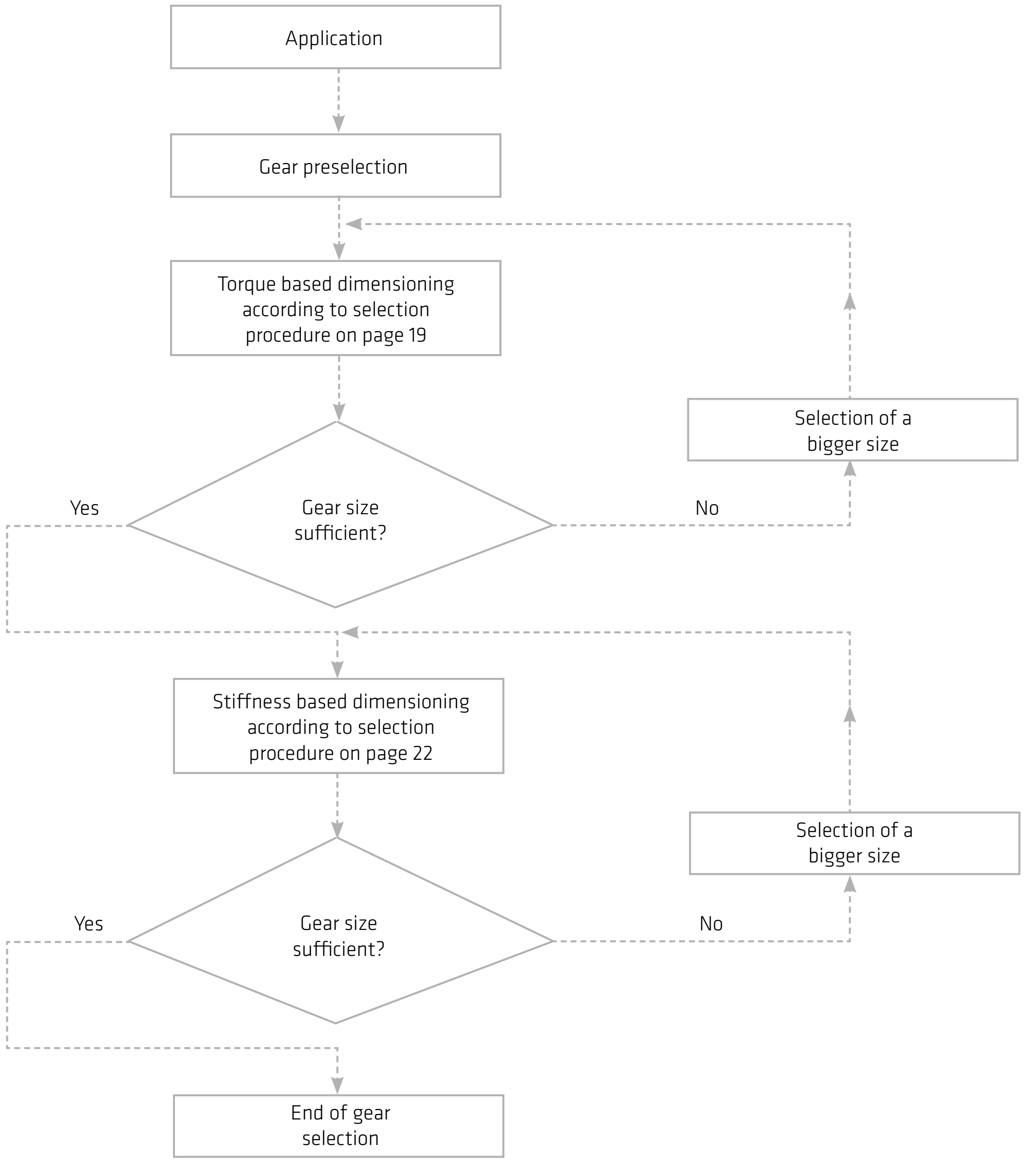
Numerous differential functions can be obtained by combinations of the speed and rotational direction of the three basic elements. Please refer to our broshure “Differential Applications” available to download from our website.

4.1 Selecting Harmonic Drive® Gears

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

ADVICE

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

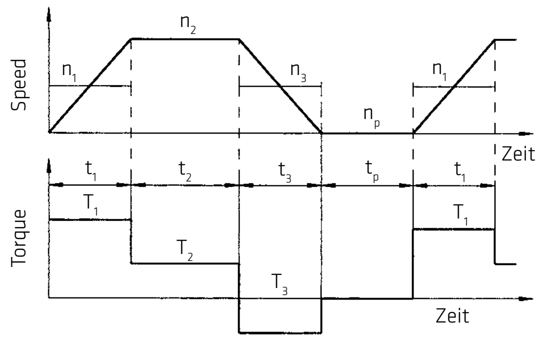


4.1.1 Torque Based Dimensioning

Output Data

Torques	$T_1 \dots T_n$	[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 19.1



Equation 19.2

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 19.3

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

No → Selection of a bigger size

Equation 19.4

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 19.5

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

Equation 19.6

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

Equation 19.7

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

Equation 19.8

Load limit 2, T_R

$T_{max} \leq T_R$

Equation 19.9

Load limit 3, T_M

$T_k \leq T_M$

Equation 19.10

Allowable number of momentary peak torques

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

Equation 19.11

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 20.1

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 Ln 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

Table 21.1 [h]

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

Equation 21.2

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

Equation 21.3

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

n_N = Rated input speed [2000 rpm]
$n_{in\ av}$ = Average input speed [rpm] (equation 19.5)
T_N = Rated output torque at rated speed [Nm]
T_{av} = Average output torque [Nm] (equation 19.2)
L_n = See table 21.1

4.1.3 Stiffness Based Dimensioning

In addition to the “Torque Based Dimensioning” stated on page 19, we recommend that you carry out a selection based on stiffness. For this, the values provided in table 22.1 for the individual resonance frequencies recommended for each application should be taken into account.

Table 22.1 [Hz]

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

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

Selection Example: Stiffness Based Dimensioning

Resonance Frequency (Gear Output)

The formula

Equation 23.1

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

fn = Resonance frequency [Hz]
K1 = Gear torsional stiffness K1 [Nm/rad]
J = Load moment of inertia [kgm^2]

allows the calculation of the resonance frequency at the gear output from the given torsional stiffness, K_1, of the Harmonic Drive® Gear and the load's moment of inertia. The calculated frequency should correspond with the value provided in table 21.1. The higher the load's moment of inertia, the more influence the application has on the gear selection. If the moment of inertia = 0, the selected application has no numerical influence on the selection result.

Resonance Speed (Gear Input)

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

Selection Example

HFUC-40-120-2A-GR preselected from "Selection Procedure" on page 20.

Intended application: milling head for woodworking
Moment of inertia at the gear output: 7 kgm^2. Recommended resonance frequency from table 22.1: ≥ 30 Hz.
Resonance frequency using the preselected gear
HFUC-40-120-2A-GR:

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

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

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

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

The resonance speed at the input (motor) amounts to:
$n_n = 30 \cdot 30 = 900$ [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 24.1

$$T \leq T_1$$

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

Equation 24.2

$$T_1 < T \leq T_2$$

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

Equation 24.3

$$T > T_2$$

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

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	K_1 = 6.7 · 10^4 Nm/rad
T_1 = 29 Nm	K_2 = 1.1 · 10^5 Nm/rad
T_2 = 108 Nm	K_3 = 1.2 · 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 24.4

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

4.3 Efficiency Calculation

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.

4.3.1 Efficiency Calculation Scheme

Table 25.1

Calculation Procedure	Example
	Efficiency of SHD-20-80-2SH with input speed n=1000 rpm ouput torque T= 19.6 Nm at 20° C ambient temperature. Lubrication: Grease
The efficiency may be determined using the efficiency graphs.	From matching chart $\eta_R = 72\,\%$
Calculate the torque factor V. $V = \frac{T_{av}}{T_N}$ [Equation 25.2] with: T_{av} = Average torque T_N = Rated torque at rated speed	$T_{av} = 19.6$ Nm $T_N = 24.0$ Nm $V = \frac{19.6\ \text{Nm}}{24.0\ \text{Nm}} = 0.82$
Determination of the correction factor K depending on the torque factor V, see illustration 26.2.	K = 0.96
Determination of correction value η_e, see illustration 26.3	$\eta_e = 2.1\,\%$
Calculation of the total efficiency η_L $\eta_L = K \cdot (\eta_R + \eta_e)$ [Equation 25.3]	$\eta_L = 0.96 \cdot (72\,\% + 2.1\,\%) = 71\,\%$

4.3.2 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 25.4. When the load torque is higher than the rated torque, the correction factor is K = 1.

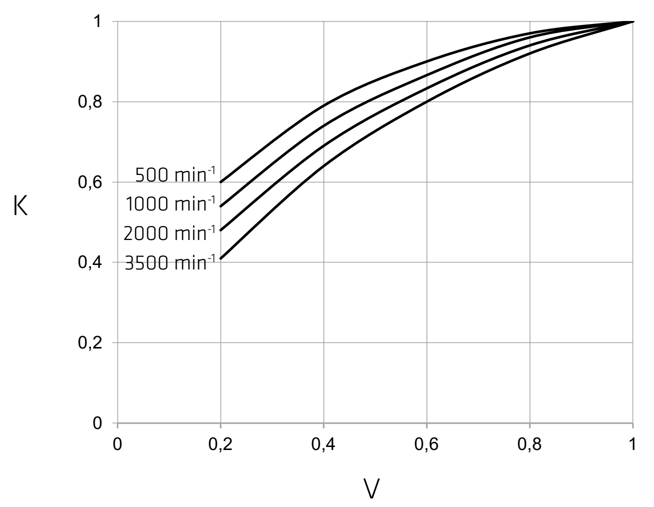
Calculation of torque factor V

Equation 26.1

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

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

Illustration 26.2



4.3.3 Efficiency Correction Value

The impact of the gear size and ratio on the efficiency is considered by the correction value ηe.

Table 26.3

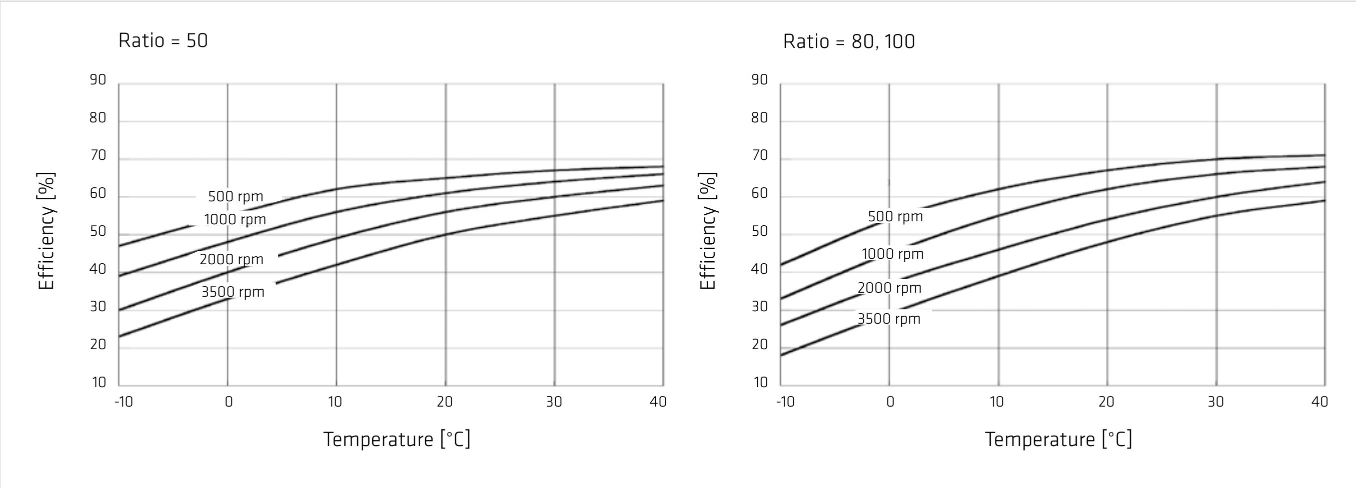
Ratio	Unit	SHD-14	SHD-17	SHD-20	SHD-25	SHD-32	SHD-40
50	%	0.0	2.4	2.1	-0.7	-1.9	-1.9
80	%	3.1	1.9	2.1	1.6	2.0	-1.2
100	%	0.0	0.0	1.6	-0.3	-1.1	-0.2
120	%	-	-2.6	-0.9	-2.9	-3.7	-1.1
160	%	-	-	1.3	-0.8	-1.6	0.9

4.3.4 Efficiency Tables

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

Size 14

Illustration 27.1



Size 17-40

Illustration 27.2

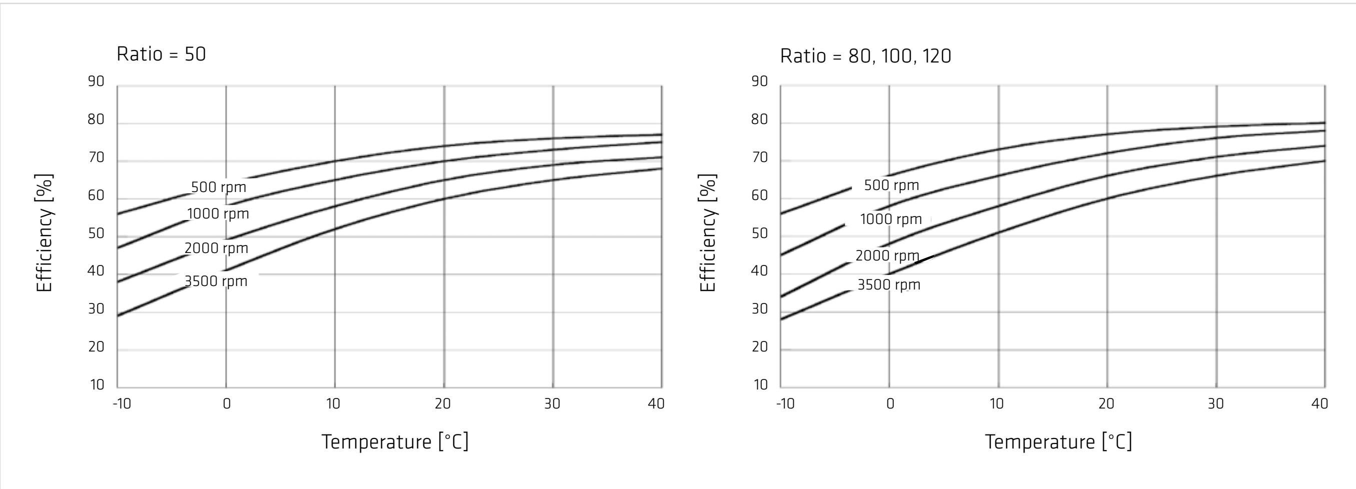
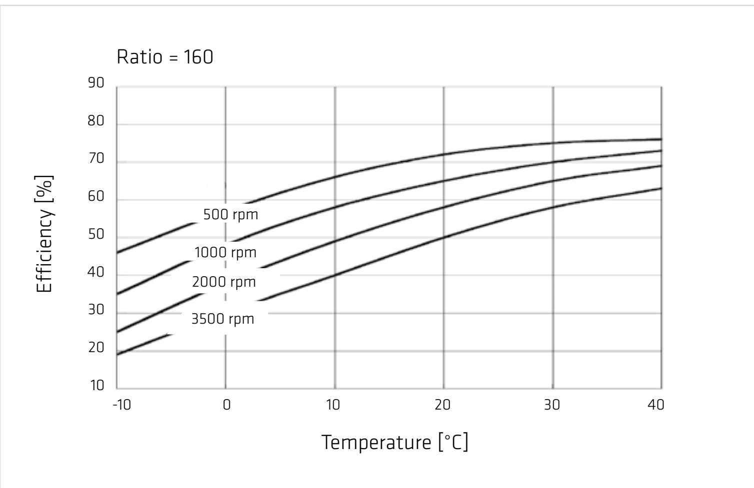


Illustration 27.3



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

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

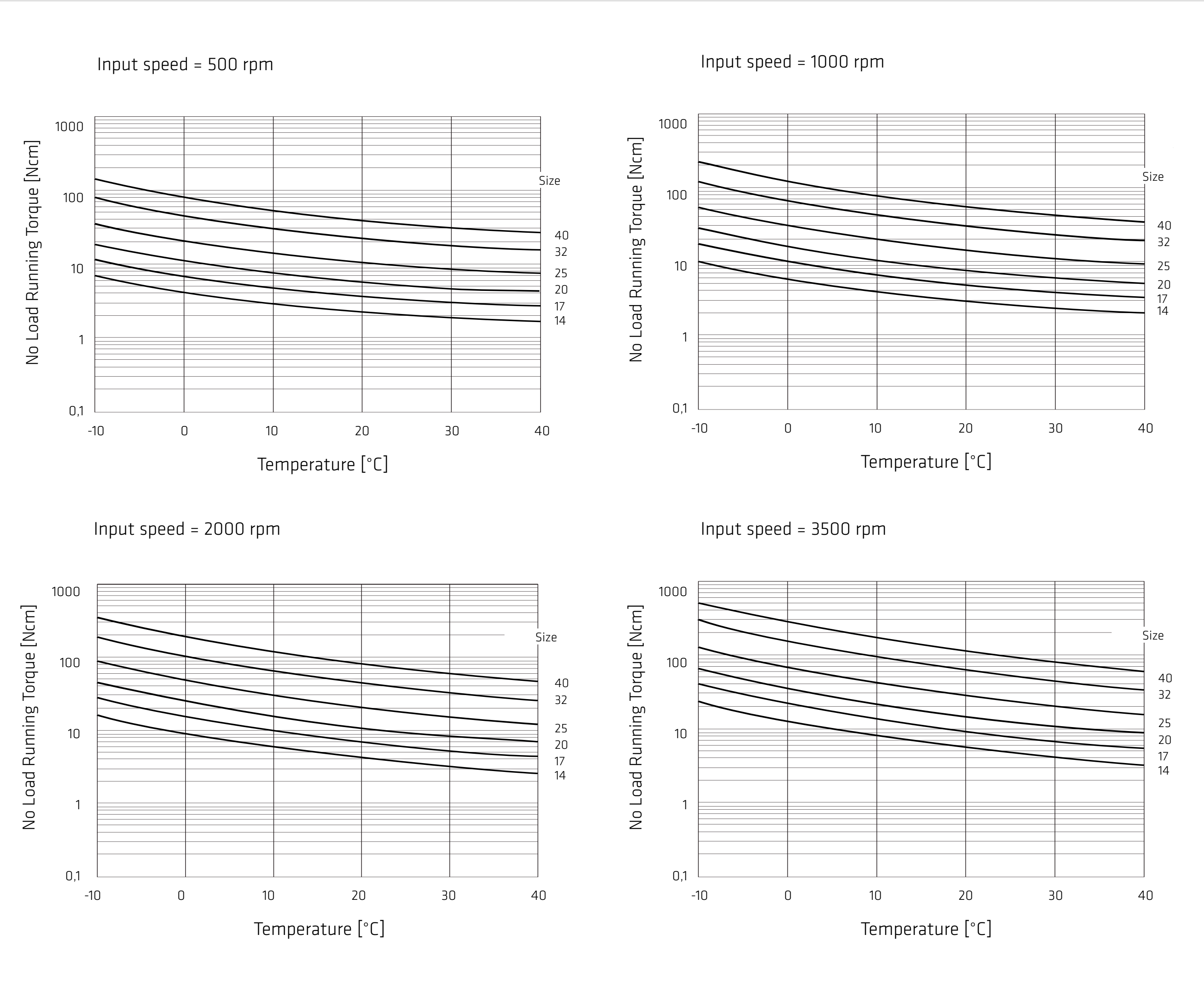
No Load Starting Torque
The no load starting torque is the quasistatic torque required to commence rotation of the input element (high speed side) with no load applied to the output element (low speed side).

No Load Back Driving Torque
The no load back driving torque is the torque required to commence rotation of the output element (low speed side) with no load applied to the input element (high speed side). The approximate range for no load back driving torque, based on tests of actual production gears, is shown in the matching table. In no case should the values given be regarded as a margin in a system that must hold an external load. Where back driving is not permissible a brake must be fitted.

The following curves are valid for: Harmonic Drive® Grease, standard lubricant quantity according to engineering data and ratio i = 100. For other ratios please apply the compensation values below. For oil lubrication please contact Harmonic Drive AG.

4.4.1 No Load Running Torque

Illustration 28.1



Compensation Values for No Load Running Torque

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 29.1

Ratio	Unit	SHD-14	SHD-17	SHD-20	SHD-25	SHD-32	SHD-40
50	Ncm	1.0	1.6	2.4	4.0	7.0	13
80	Ncm	0.2	0.3	0.5	0.8	1.4	2.4
120	Ncm	-	-0.2	-0.3	-0.5	-1.0	-1.7
160	Ncm	-	-	-0.7	-1.2	-2.4	-3.9

4.4.2 No Load Starting Torque

Table 29.2

Ratio	Unit	SHD-14	SHD-17	SHD-20	SHD-25	SHD-32	SHD-40
50	Ncm	6.2	19	25	39	60	95
80	Ncm	5.0	16	23	36	55	83
100	Ncm	4.8	17	22	34	50	78
120	Ncm	-	13	22	34	48	77
160	Ncm	-	-	22	33	47	74

4.4.3 No Load Black Driving Torque

Table 29.3

Ratio	Unit	SHD-14	SHD-17	SHD-20	SHD-25	SHD-32	SHD-40
50	Ncm	3.7	11	15	24	36	57
80	Ncm	4.3	15	21	32	46	72
100	Ncm	5.8	21	27	41	60	94
120	Ncm	-	28	33	51	68	113
160	Ncm	-	-	42	64	91	143

4.5 Output Bearing Operating Life

The operating life of the output bearing can be calculated using equation 30.1.

Equation 30.1

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

with:

L_{10} [h] = Operating life

n_{av} [rpm] = Average output speed (equation 30.2)

C [N] = Dynamic load rating see table 15.1

P_C [N] = Dynamic equivalent load (equation 31.1)

f_W = Operating factor (table 30.3)

B = Bearing type (table 30.4)

Average Output Speed

Equation 30.2

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

Table 30.3

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 30.4

Bearing type	**B**
Cross roller bearings	$\frac{10}{3}$

Dynamic Equivalent Load

Equation 31.1

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

with:

F_{rav} [N]	=	Radial force (equation 31.2)	x	=	Radial load factor (table 31.4)
F_{aav} [N]	=	Axial force (equation 31.3)	y	=	Axial load factor (table 31.4)
d_p [m]	=	Pitch circle (see table 14.1)	M	=	Tilting moment

Equation 31.2

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

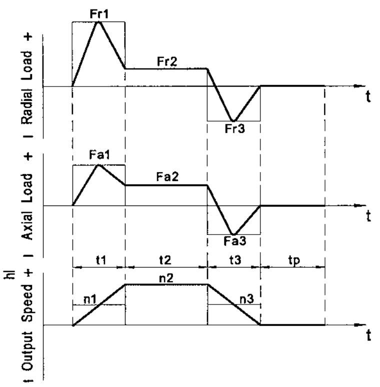
Equation 31.3

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

Table 31.4

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

Illustration 31.5



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

4.5.1 Output Bearing at Oscillating Motion

Life for Oscillating Motion

The operating life at oscillating motion can be calculated using equation 32.1

Equation 32.1

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

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 15.1)
P_C [N]	=	Dynamic equivalent load (equation 31.1)
φ [deg]	=	Oscillating angle
f_W	=	Operating factor (table 30.3)

* 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 32.2

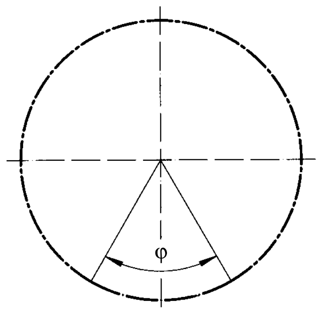


Table 32.4

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

4.6 Permissible Static Tilting Moment

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

Equation 33.1

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

and so

Equation 33.2

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

f_s = Static load safety factor
(f_s = 1.5 ... 3) (table 33.3)
C_0 = Static load rating
F_r = F_a = 0
x_0 = 1
y_0 = 0.44
P_0 = Static equivalent load (equation 33.1)
d_p = Pitch circle diameter of the output bearing (table 15.1)
M = Moment acting
M_0 = Allowable static overturning moment

Table 33.3

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

4.7 Angle of Inclination

The angle of inclination of the output flange, as a function of the tilting moment acting on the output bearing, can be calculated by means of equation 33.4:

Equation 33.4

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

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 15.1)

4.8 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.

4.8.1 Grease Lubrication

Application of Harmonic Drive® Grease
Depending on product, size and if necessary ratio, the matching Harmonic Drive® Grease should be selected. We recommend the application of the Harmonic Drive® Lubricating Greases according to the data in the tables 34.1 and 34.2.

Caution!
The Harmonic Drive® high performance 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 34.1

<table>
<tr><th rowspan="3">Grease</th><th colspan="15">Ratio ≥ 50</th></tr>
<tr><th colspan="15">Size</th></tr>
<tr><th>8</th><th>11</th><th>14</th><th>17</th><th>20</th><th>25</th><th>32</th><th>40</th><th>45</th><th>50</th><th>58</th><th>65</th><th>80</th><th>90</th><th>100</th></tr>
<tr><td>Flexolub®-A1</td><td colspan="2">–</td><td colspan="13">Standard for CPU and CobaltLine®</td></tr>
<tr><td>SK-1A</td><td colspan="4">–</td><td colspan="11">Standard</td></tr>
<tr><td>SK-2</td><td colspan="4">Standard</td><td colspan="11">–</td></tr>
<tr><td>4B No.2</td><td colspan="2">–</td><td colspan="13">For heavy duty operation*</td></tr>
</table>

Table 34.2

<table>
<tr><th rowspan="3">Grease</th><th colspan="7">Ratio = 30</th></tr>
<tr><th colspan="7">Size</th></tr>
<tr><th>8</th><th>11</th><th>14</th><th>17</th><th>20</th><th>25</th><th>32</th></tr>
<tr><td>Flexolub®-A1</td><td colspan="2">–</td><td colspan="5">Standard for CPU</td></tr>
<tr><td>SK-1A</td><td colspan="4">–</td><td colspan="3">Standard</td></tr>
<tr><td>SK-2</td><td colspan="4">Standard</td><td colspan="3">–</td></tr>
<tr><td>4B No.2</td><td colspan="4">–</td><td colspan="3">For heavy duty operation*</td></tr>
</table>

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

Table 35.1 gives some important information regarding Harmonic Drive® Lubricating Greases.

Table 35.1

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

2) Aging (running-in):
The aging process before the fully loading the gears softens the grease. More effective grease performance can be realised when the grease flows around the required contact areas of the Harmonic Drive® Gear.
Therefore the following aging method is recommended:
- Keep the internal operating temperature below 80 °C. Do not allow a steep increase in temperature during the aging process.
- Limit the input speed to between 1000 and 3000 rpm. Lower speeds are more effective. Select an input speed as close to 1000 rpm as possible.
- The time required for aging is 20 minutes or longer.
- Keep the output rotation angle as large as possible during the aging process.

Contact our offices if you have any questions about handling Harmonic Drive® Grease 4B No.2.

Special Operating Demands

Table 36.1 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 36.1

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, HFUS-XX, CPL-XX, CHA-XX with i = 100 at full usage of the catalogue performance data. Please consult Harmonic Drive AG for i>100 applications. For food / pharmaceutical compatibility, grease change is necessary for output- and support bearings, if used. 400 g bundles available at Harmonic Drive AG.
5) Recommended for applications requiring best possible efficiency at low temperatures. Not suitable for high output torque.

4.8.2 Oil Lubrication

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

Table 36.2

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

Please note the information in section 5.5.

4.9 Axial Forces at the Wave Generator

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

Illustration 37.1

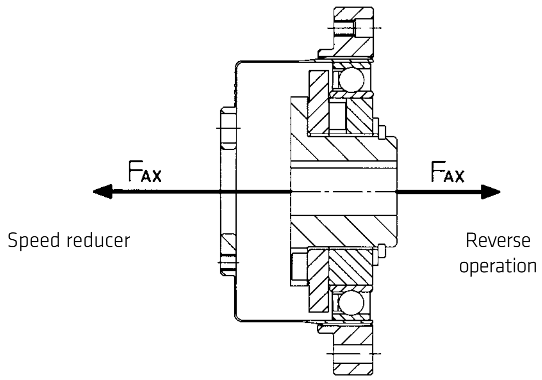


Table 37.2

Ratio		
30	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 32°$	[Equation 37.3]
50	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 30° + 2\mu PF$	[Equation 37.4]
80...160	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 20° + 2\mu PF$	[Equation 37.5]

with:

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

Example

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

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

F_{AX} = 215 N

Table 37.6

	Unit	SHD-14	SHD-17	SHD-20	SHD-25	SHD-32	SHD-40	SHD-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
The SHD-2UH 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 4.8.1 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

In order for the new features of Harmonic Drive® Units to be exploited fully, it is essential that the tolerances according to table 39.2 are observed for the input assembly.

Illustration 39.1

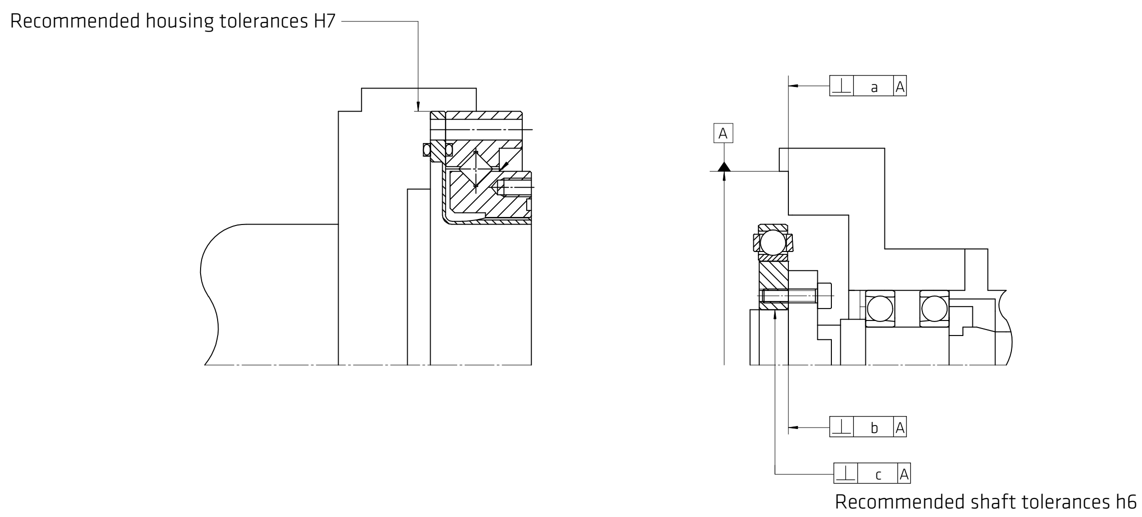


Table 39.2

	Unit	SHD-14	SHD-17	SHD-20	SHD-25	SHD-32	SHD-40
a	[mm]	0.011	0.012	0.013	0.014	0.016	0.016
b	[mm]	0.006	0.010	0.012	0.012	0.012	0.012
Ø c	[mm]	0.016	0.018	0.019	0.022	0.022	0.024

5.5 Lubrication

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

5.5.1 Grease Lubrication

These units are delivered without lifetime lubrication. Before commissioning of the unit an initial lubrication has to be applied by the customer. The recommended grease types are shown in chapter 4.10.1. If any other grease is used this will be indicated on the customer drawing.

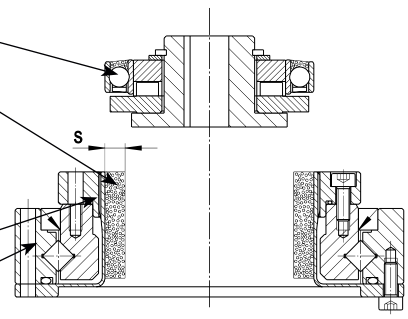
On delivery, Flexspline and Circular Spline teeth are lubricated ready for use. Before mounting, the Wave Generator bearing and the inner part of the Flexspline must be greased. It may be necessary to place an additional amount of grease on the front face of the Wave Generator (see chapter 5.5.3).

Illustration 40.1 shows the areas requiring grease.

Illustration 40.1

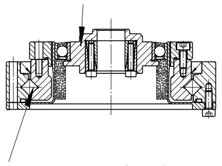
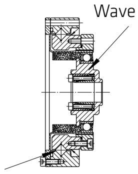
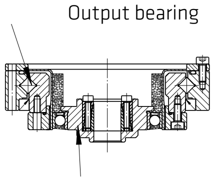
The areas
- Wave Generator bearing
- Inside of the Flexspline must be lubricated when the unit is mounted into the machine

On delivery, standard Units are greased ready for use in the areas
- Gear teeth
- Output bearing



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 40.2.

Illustration 40.2

Operating position		
Wave Generator above	Wave Generator vertical	Wave Generator below
Wave Generator  Output bearing	Wave Generator  Output bearing	Output bearing  Wave Generator

5.5.2 Amount of Grease

Table 41.1

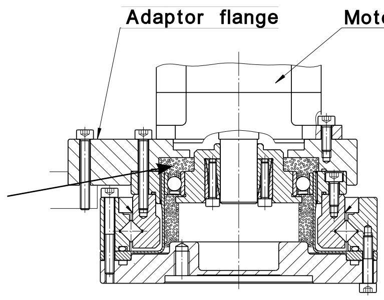
	Symbol [Unit]	SHD-14	SHD-17	SHD-20	SHD-25	SHD-32	SHD-40
Dimension s (illustration 40.1)	[mm]	3	4	5	6	8	10
Standard amount of grease	[g]	5	9	13	24	51	99
	[cm³]	5.5	10	14	26	56	109
Additionally required grease quantity for operation with Wave Generator above	[g]	1	1	2	4	7	13
	[cm³]	1,1	1	2	4	8	14

5.5.3 Additional Grease Package

The unit can be used in all operating positions. To achieve the maximum gear life, we recommend that an additional grease package is provided in a grease reservoir between Wave Generator and motor d-shield during assembly, see illustration 41.2 and table 41.1.

Illustration 41.2

For applications with the Wave Generator above is an additional grease package required.

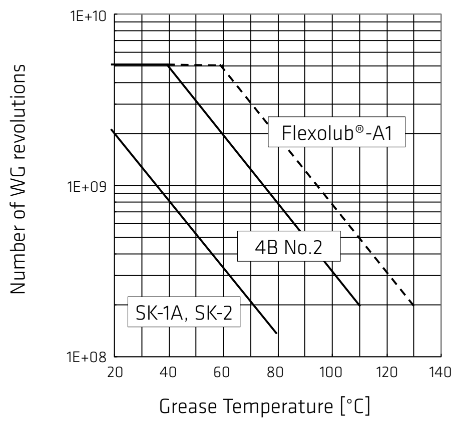


5.5.4 Grease Change

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

In illustration 41.3 the grease change interval depending on the grease temperature is given. The number of allowable revolutions of the input shaft which represents the grease change interval can be estimated as shown in the example. This means, that for a temperature of SK-1A or SK-2 grease of 40 °C a change should take place after approx. $8.5 \cdot 10^8$ revolutions of the input shaft. All grease change data refers to rated speed and rated torque.

Illustration 41.3



Equation 41.4

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

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

L_{GTn} = see diagram

T_N = Rated torque

T_{av} = Average torque of the application

5.6 Preparation for Assembly

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

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

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

Surface sealing

- Loctite 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. Loctite 243 is recommended for all screw connections.

Assembly paste

- Klüber Q NB 50

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

Adhesives

- Loctite 638

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

5.7 Assembly

The following explanations refer to SHD Series units, having a Wave Generator with Oldham Coupling or a Solid Wave Generator.

The assembly of the SHD 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 take place without the use of undue force. The assembly instructions of the machine manufacturer should be referred to. Unless otherwise noted, all screws must be tightened crosswise in 3 steps to the prescribed torque.
Screws that have been tightened on delivery must not be released.

On delivery, Flexspline and Circular Spline of SHD Units are pre-assembled only by a few screws. Therefore the full output bearing and torque load can only be applied after the unit has been attached completely to the machine frame and the load. Therefore we recommend the user to connect the unit to the machine housing and load (please take care of the dead weight) before initiating/applying any radial and / or axial forces.

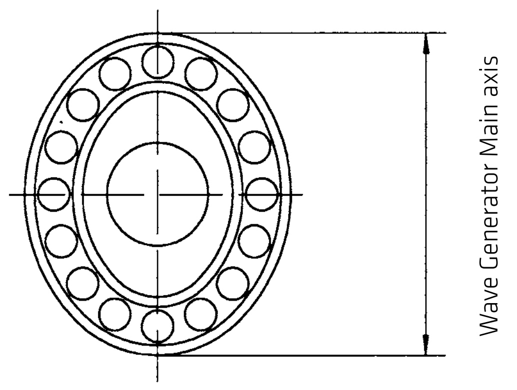
5.7.1 Motor Assembly

For the planning of the assembly sequence it may be helpful to know the max. diameter of the Wave Generator, see illustration 44.2. In table 44.1 the diameters of the Wave Generator main axes are indicated.

Table 44.1

	Unit	SHD-14	SHD-17	SHD-20	SHD-25	SHD-32	SHD-40
Ca. Ø Wave Generator - Main axis	[mm]	36	43	50	63	82	100

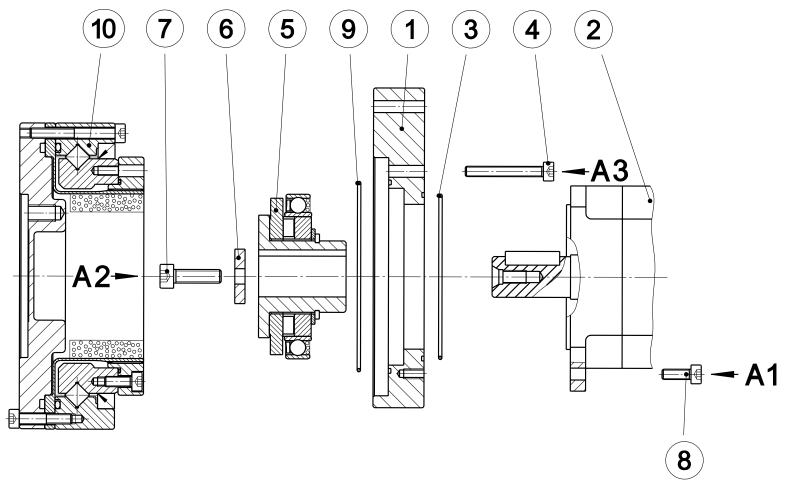
Illustration 44.2



Installation steps (see Illustration 43.3):

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 44.3



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 Mounting the Wave Generator (WG) to the Motor Shaft

Before or after the assembly to the input shaft the Wave Generator is to be lubricated according to section 5.5. During the assembly the axial mounting position indicated on the catalogue/confirmation drawing is to be considered.

When a clamping element is used please thighten the clamping element screws crosswise and in five steps up to the torque indicated on the drawing (alternatively: manufacturer information), see also illustration 38.2. When the Wave Generator hub is glued to the input shaft please consider section 5.6.

5.7.3 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 in accordance with illustration 38.1. When the gear is oil lubricated, fill in the prescribed oil quantity.

5.7.4 Assembly of the Wave Generator into the Flexspline

When the Wave Generator is assembled into the Flexspline please consider that the parts must not be tilted during assembly. By parallel assembly 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.

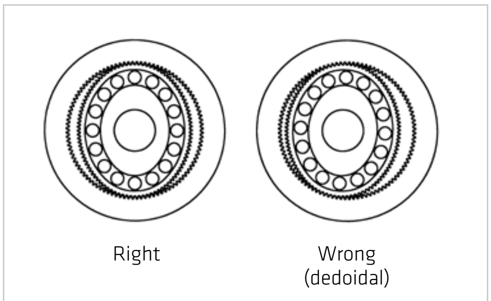
5.7.5 Assembly Control

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

- Check the running behaviour by rotating the input shaft (in case of types with input shaft).
  Alternatively you may rotate the output flange.
  If you notice torque variations these may be caused by eccentric tooth mesh.
- Check the running behaviour and the motor current while the motor is rotating.
  Strong fluctuations in the motor current and/or an excessive no-load current may be the result of an eccentric tooth mesh.

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

Illustration 45.1



5.7.6 Assembly of the Output Flange

In the case of the 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 inner raceway of the output bearing is used as the output flange for the standard configuration.

Table 46.1

	Unit	**SHD-14**	**SHD-17**	**SHD-20**	**SHD-25**	**SHD-32**	**SHD-40**
Number of Bolts	[mm]	8	12	12	12	12	12
Bolt Size	[mm]	M3	M3	M3	M4	M5	M6
Pitch circle diameter	[mm]	43	52	61	76	99	120
Screw tightening torque	[Nm]	2.0	2.0	2.0	4.5	9.0	15.3
Torque transmitting capacity*	[Nm]	72	130	154	321	668	1148

* Friction coefficient μ = 0.15; 12.9 quality screws

5.7.7 Assembly of the Housing

Table 46.2

	Unit	**SHD-14**	**SHD-17**	**SHD-20**	**SHD-25**	**SHD-32**	**SHD-40**
Number of Bolts	[mm]	8	12	12	12	12	12
Bolt Size	[mm]	M3	M3	M3	M4	M5	M6
Pitch circle diameter	[mm]	64	74	84	102	132	158
Screw tightening torque	[Nm]	2.0	2.0	2.0	4.5	9.0	15.3
Torque transmitting capacity*	[Nm]	108	186	210	431	892	1509

* Friction coefficient μ = 0.15; 12.9 quality screws

5.7.8 Assembly of the Wave Generator to the motor shaft

Table 46.3

	Unit	**SHD-14**	**SHD-17**	**SHD-20**	**SHD-25**	**SHD-32**	**SHD-40**
Number of Bolts		4	4	4	4	4	4
Bolt Size		M3	M3	M3	M3	M4	M5
Pitch circle diameter [mm]	[mm]	17	21	26	30	40	50
Screw tightening torque [Nm]	[Nm]	2.0	2.0	2.0	2.0	4.5	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]

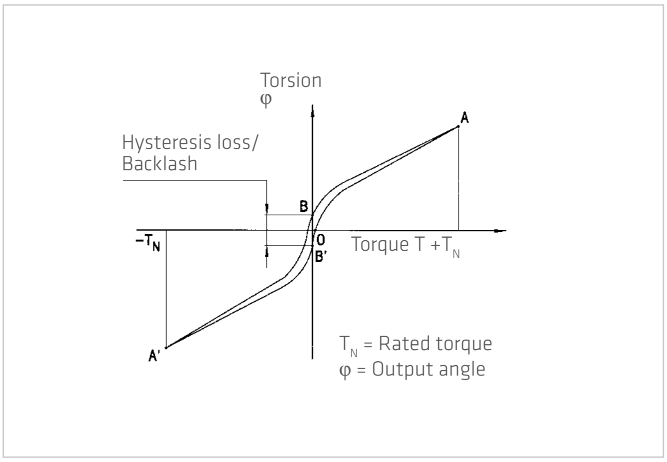
Maximum permissible average gear input speed for oil lubrication. The applications average input speed must be lower than the permitted average input speed of the gear.

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]

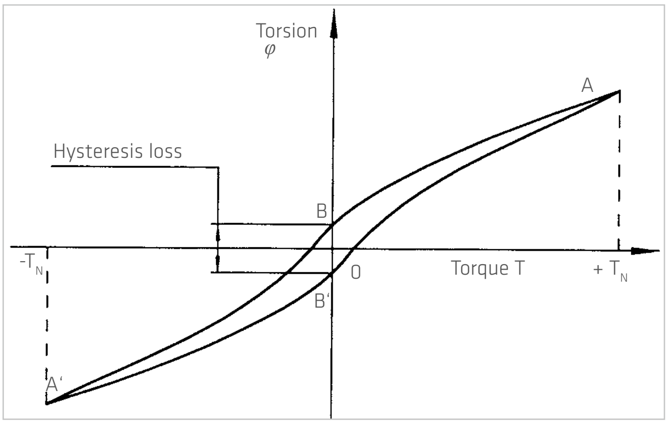
The electrical time constant is the time required for the current to reach 63 % of its final value.

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

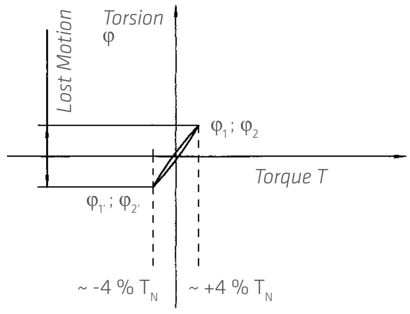
Inductance (L-L) L_{L-L} [mH]

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 [kgm^2]

Mass moment of inertia at motor side.

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

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

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

Mass moment of inertia with respect to the output.

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

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

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}]

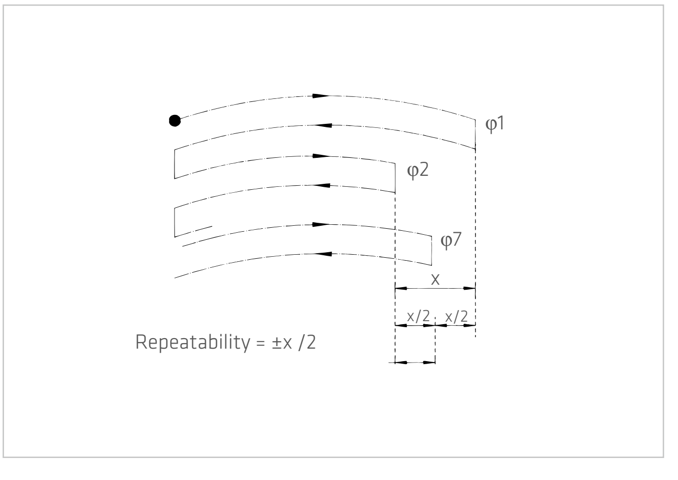
Supply voltage for operation with rated torque and rated speed.

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.



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}]

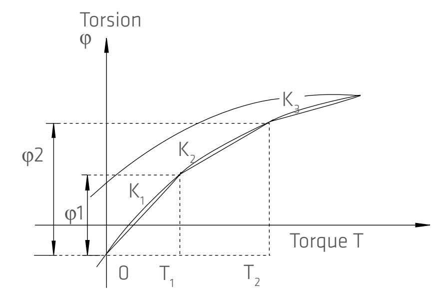
Quotient of stall torque and stall current, taking into account the transmission losses.

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	$0 \sim T_1$
K_2:	middle torque region	$T_1 \sim T_2$
K_3:	high torque region	$> T_3$

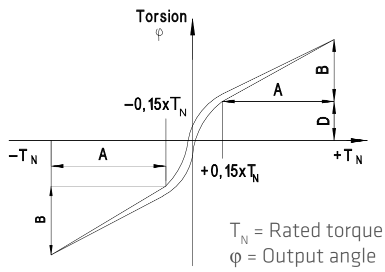
The values given for the torsional stiffness K_1, K_2 and K_3 are average values that have been determined during numerous tests. The limit torques T_1 and T_2 and an calculation example for the torsional angle can be found in chapter "torsional stiffness" and "calculation of the torsion angle" of this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

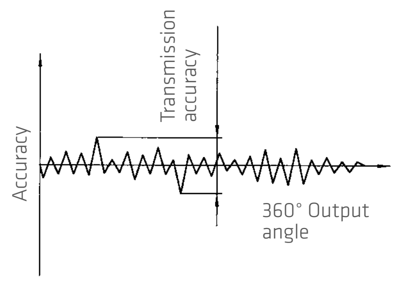
The amount of elastic rotation at the output for a given torque and blocked input shaft. The torsional rigidity of the Harmonic Planetary Gear describes the rotation of the gear above a reference torque of 15 % of the rated torque. In this area the torsional stiffness is almost linear.



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.

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