

Engineering Data  
SHD-2SH Units



Harmonic  
Drive AG



QUICKLINK  
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*...just move it!*

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## 1. General

### **About this documentation**

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

### **Rules for storage**

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

### **Additional documentation**

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

[www.harmonicdrive.de](http://www.harmonicdrive.de)

### **Third-party systems**

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



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

### **Your feedback**

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

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Marketing and Communications  
Hoenbergstraße 14  
65555 Limburg / Lahn  
Germany  
E-Mail: [info@harmonicdrive.de](mailto:info@harmonicdrive.de)

## 1.1 Description of Safety Alert Symbols

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

## 1.2 Disclaimer and Copyright

The contents, images and graphics contained in this document are protected by copyright. In addition to the copyright, logos, fonts, company and product names can also be protected by brand law or trademark law. The use of text, extracts or graphics requires the permission of the publisher or rights holder.

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

### 2.1 Hazards



**DANGER**

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

#### Observing the five safety rules:

- Disconnect mains
- Prevent reconnection
- Test for absence of harmful voltages
- Ground and short circuit
- Cover or close off nearby live parts

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



**DANGER**

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



**DANGER**

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



**WARNING**

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



**ATTENTION**

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



## ADVICE

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

## ADVICE

Cables must not come into direct contact with hot surfaces.

## INFORMATION

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

## 2.2 Intended Purpose

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

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

The products may only be operated within the operating ranges and environmental conditions shown in the documentation (altitude, degree of protection, temperature range etc).

Before plant and machinery which have Harmonic Drive® products built into them are commissioned, the compliance must be established with the Machinery Directive, Low Voltage Directive and EMC guidelines.

Plant and machinery with inverter driven motors must satisfy the protection requirements in the EMC guidelines. It is the responsibility of the installer to ensure that installation is undertaken correctly.

Signal and power lines must be shielded. The EMC instructions from the inverter manufacturer must be observed in order that installation meets the EMC regulations.

## 2.3 Non Intended Purpose

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

## ADVICE

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

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

## 2.4 Declaration of Conformity

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

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

## 3. Technical Description

### 3.1 Product Description

# Short overall length with largest hollow shaft

SHD Series Units are available in six sizes with gear ratios of 50, 100 and 160:1 offering repeatable 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 9.1

Series	Size	Ratio <sup>1)</sup>			Version	Special design
SHD	14	50	100		2SH	According to customer requirements
	17	50	100			
	20	50	100	160		
	25	50	100	160		
	32	50	100	160		
	40	50	100	160		
Ordering code						
<b>SHD</b>	<b>20</b>	<b>100</b>		<b>2SH</b>	<b>SP</b>	

<sup>1)</sup> 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 9.2

Ordering code	Version
	Description
2SH	Units 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 10.1

	Unit	SHD-14-2SH		SHD-17-2SH	
Ratio	$i$ [ ]	50	100	50	100
Repeated peak torque	$T_R$ [Nm]	12	19	23	37
Average torque	$T_A$ [Nm]	4.8	7.7	18	27
Rated torque	$T_N$ [Nm]	3.7	5.4	11	16
Momentary peak torque	$T_M$ [Nm]	23	35	48	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	$J_{in}$ [ $\times 10^{-4}$ kgm <sup>2</sup> ]	0.021		0.054	
Weight	$m$ [kg]	0.33		0.42	

Table 10.2

	Unit	SHD-20-2SH			SHD-25-2SH		
Ratio	$i$ [ ]	50	100	160	50	100	160
Repeated peak torque	$T_R$ [Nm]	39	57	64	69	110	123
Average torque	$T_A$ [Nm]	24	34	34	38	75	75
Rated torque	$T_N$ [Nm]	17	28	28	27	47	47
Momentary peak torque	$T_M$ [Nm]	69	95	95	127	184	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	$J_{in}$ [ $\times 10^{-4}$ kgm <sup>2</sup> ]	0.090			0.282		
Weight	$m$ [kg]	0.52			0.91		

### 3.3.2 Dimensions

Illustration 11.1

SHD-14-2SH [mm]

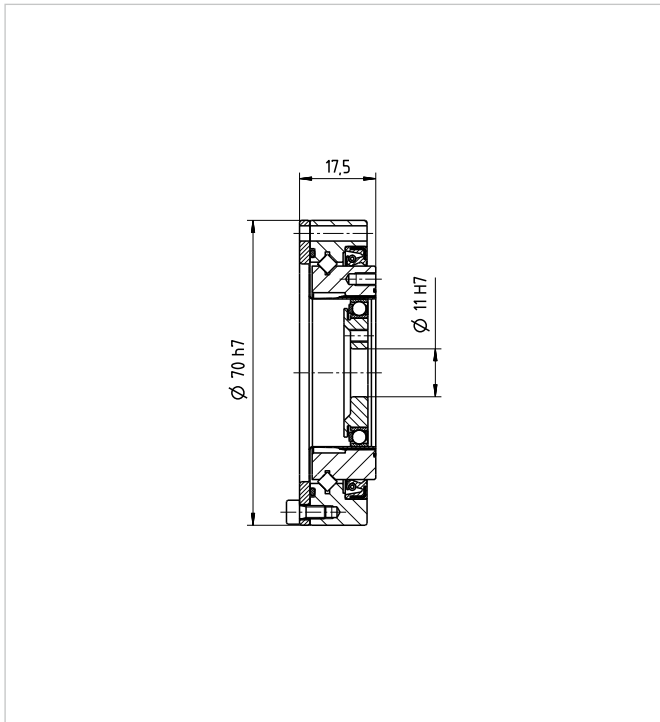


Illustration 11.2

SHD-17-2SH [mm]

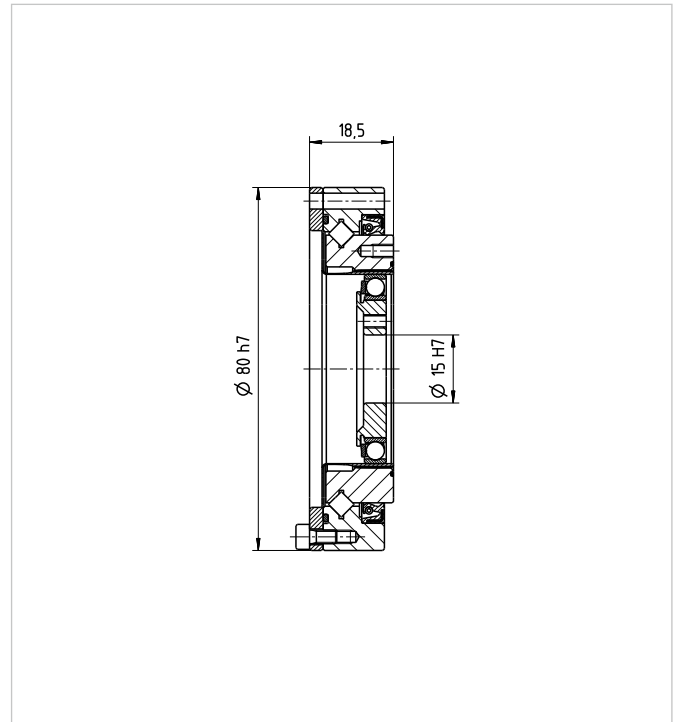


Illustration 11.3

SHD-20-2SH [mm]

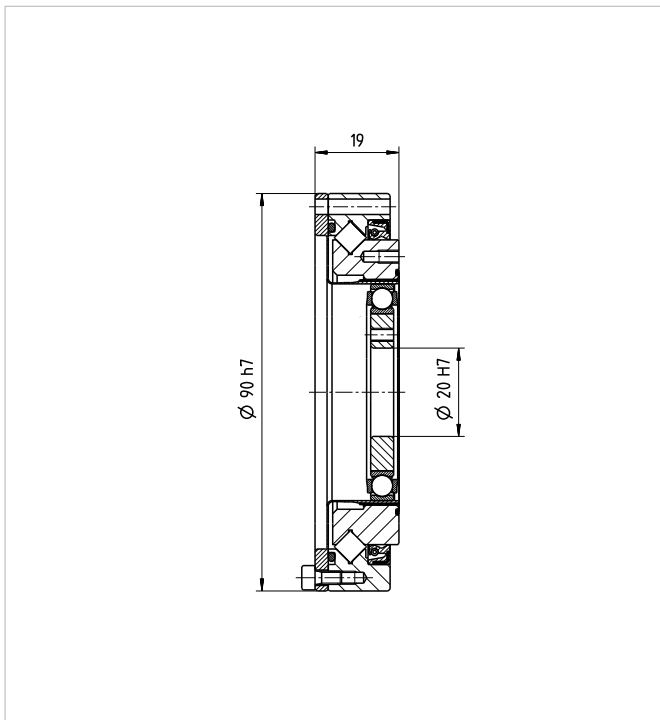


Illustration 11.4

SHD-25-2SH [mm]

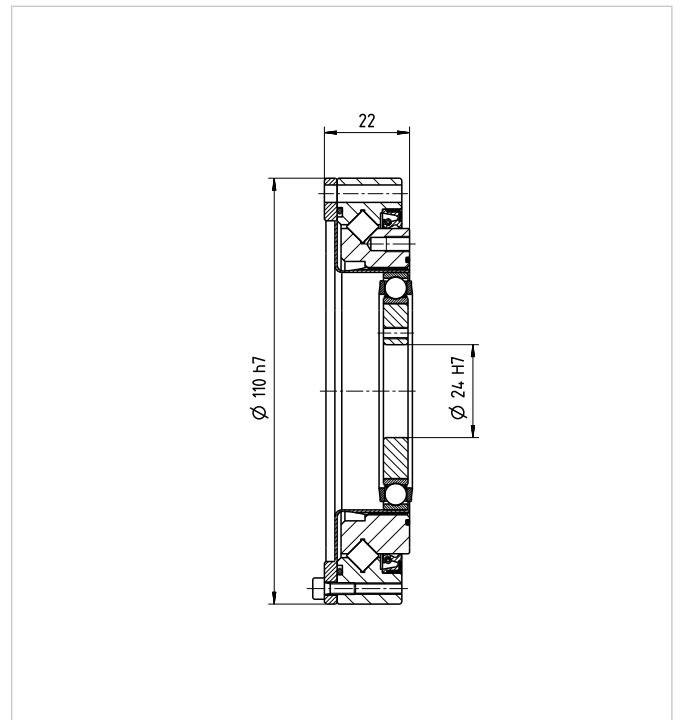


Table 12.1

	Unit	SHD-32-2SH			SHD-40-2SH		
Ratio	$i$ [ ]	50	100	160	50	100	160
Repeated peak torque	$T_R$ [Nm]	151	233	261	281	398	453
Average torque	$T_A$ [Nm]	75	151	151	137	260	316
Rated torque	$T_N$ [Nm]	53	96	96	96	185	206
Momentary peak torque	$T_M$ [Nm]	268	420	445	480	700	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	$J_{in}$ [ $\times 10^{-4}$ kgm <sup>2</sup> ]	1.09			2.85		
Weight	$m$ [kg]	1.87			3.09		

Illustration 12.2

SHD-32-2SH [mm]

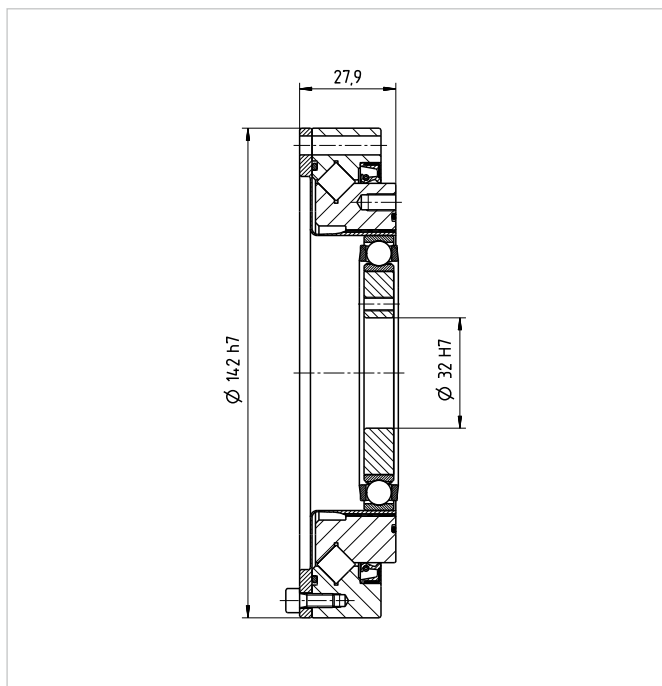
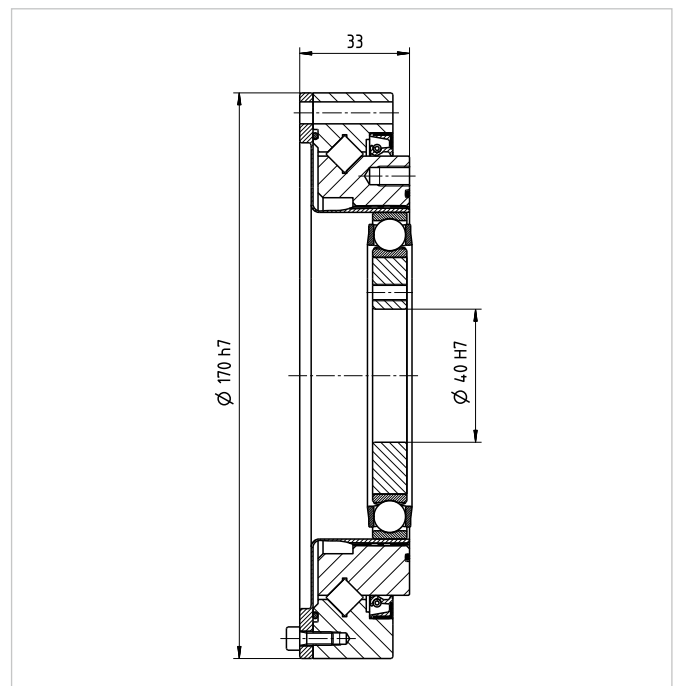


Illustration 12.3

SHD-40-2SH



### 3.3.3 Minimum Housing Clearance

Table 13.1

[mm]

Size	14	17	20	25	32	40
$\varnothing w$	31	38	45	56	73	90
x	1.0	1.0	1.5	1.5	2.0	2.5
y	1.4	1.8	1.7	1.8	1.8	1.8
$\varnothing z$	38	45	53	66	86	106

Illustration 13.2

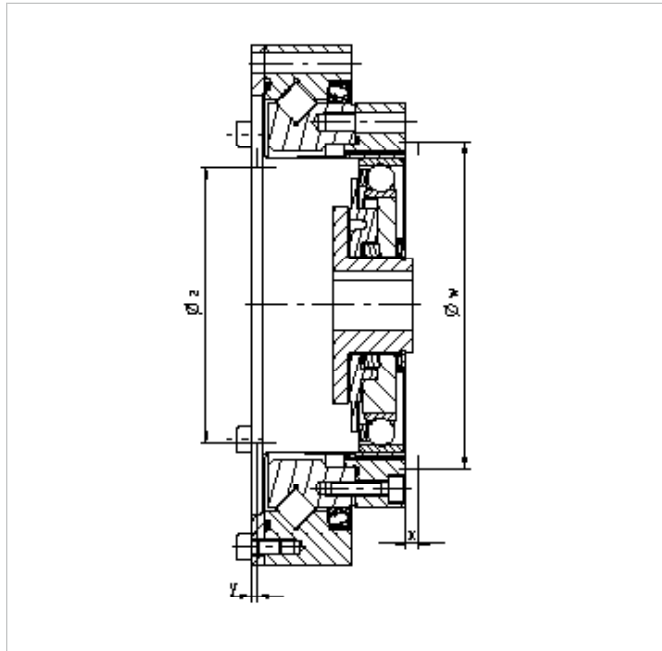


Illustration is representative only. Please see the confirmation drawing for details of the actual unit.

### 3.3.4 Accuracy

Table 13.3

[arcmin]

Size		14	17	20	25	32	40
Transmission accuracy		< 1.5	< 1.5	< 1	< 1	< 1	< 1
Hysteresis loss	i=50	2.5	2.0	2.0	2.0	2.0	2.0
	i=100 or more	2.0	1.0	1.0	1.0	1.0	1.0

### 3.3.5 Torsional Stiffness

Table 13.4

Size		14	17	20	25	32	40
$T_1$ [Nm]		2.0	3.9	7	14	29	54
$T_2$ [Nm]		6.9	12	25	48	108	196
i = 50	$K_3$ [ $\times 10^3$ Nm/rad]	4.7	12	20	37	84	150
	$K_2$ [ $\times 10^3$ Nm/rad]	3.7	8.8	13	27	61	110
	$K_1$ [ $\times 10^3$ Nm/rad]	2.9	6.7	11	20	47	88
i > 50	$K_3$ [ $\times 10^3$ Nm/rad]	6.1	13	25	47	110	200
	$K_2$ [ $\times 10^3$ Nm/rad]	4.4	9.4	17	37	78	140
	$K_1$ [ $\times 10^3$ Nm/rad]	4.0	8.4	13	27	61	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 14.1 lists ratings and important dimensions for the output bearings.

Table 14.1

Size		14	17	20	25	32	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<sup>2</sup>) 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.

## 4. Driving Arrangements

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

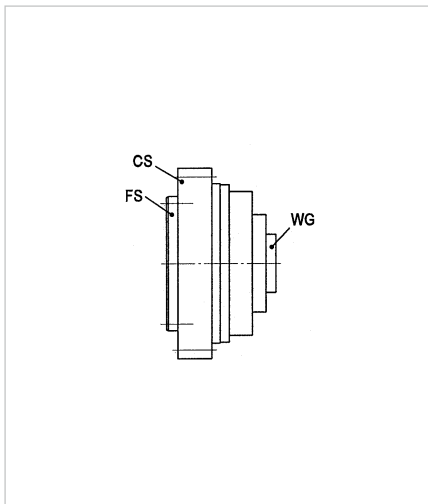
Equation 15.1

Ratio $i$ =	$\frac{\text{Input speed}}{\text{Output speed}}$
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### Overview Harmonic Drive® Products

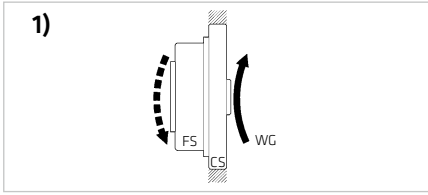
The three main components of the Harmonic Drive® units, Circular Spline (CS), Flexspline (FS) and Wave Generator (WG) can be seen in the illustration 15.2.

Illustration 15.2



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



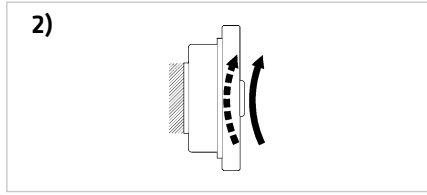
**Reduction gearing**

CS Fixed  
WG Input  
FS Output

Equation 16.1

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

Input and output rotate in opposite directions.



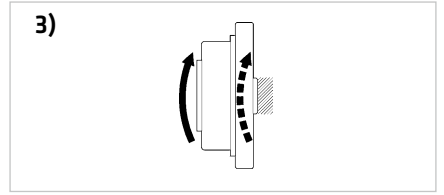
**Reduction gearing**

FS Fixed  
WG Input  
CS Output

Equation 16.2

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

Input and output rotate in same direction.



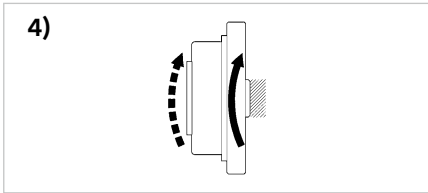
**Reduction gearing**

WG Fixed  
FS Input  
CS Output

Equation 16.3

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

Input and output rotate in same direction.



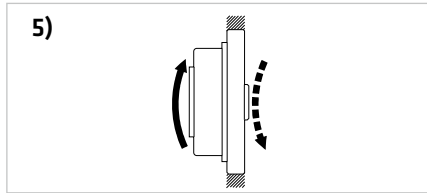
**Speed increaser gearing**

WG Fixed  
CS Input  
FS Output

Equation 16.4

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

Input and output rotate in same direction.



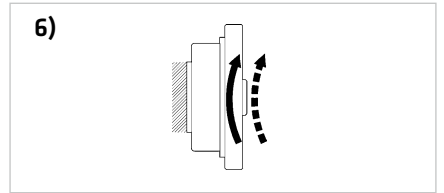
**Speed increaser gearing**

CS Fixed  
FS Input  
WG Output

Equation 16.5

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

Input and output rotate in opposite directions.



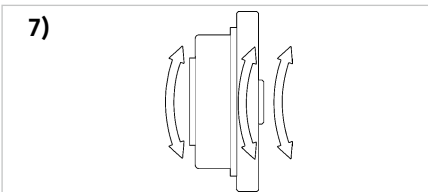
**Speed increaser gearing**

FS Fixed  
CS Input  
WG Output

Equation 16.6

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

Input and output rotate in same direction.



**Differential gear**

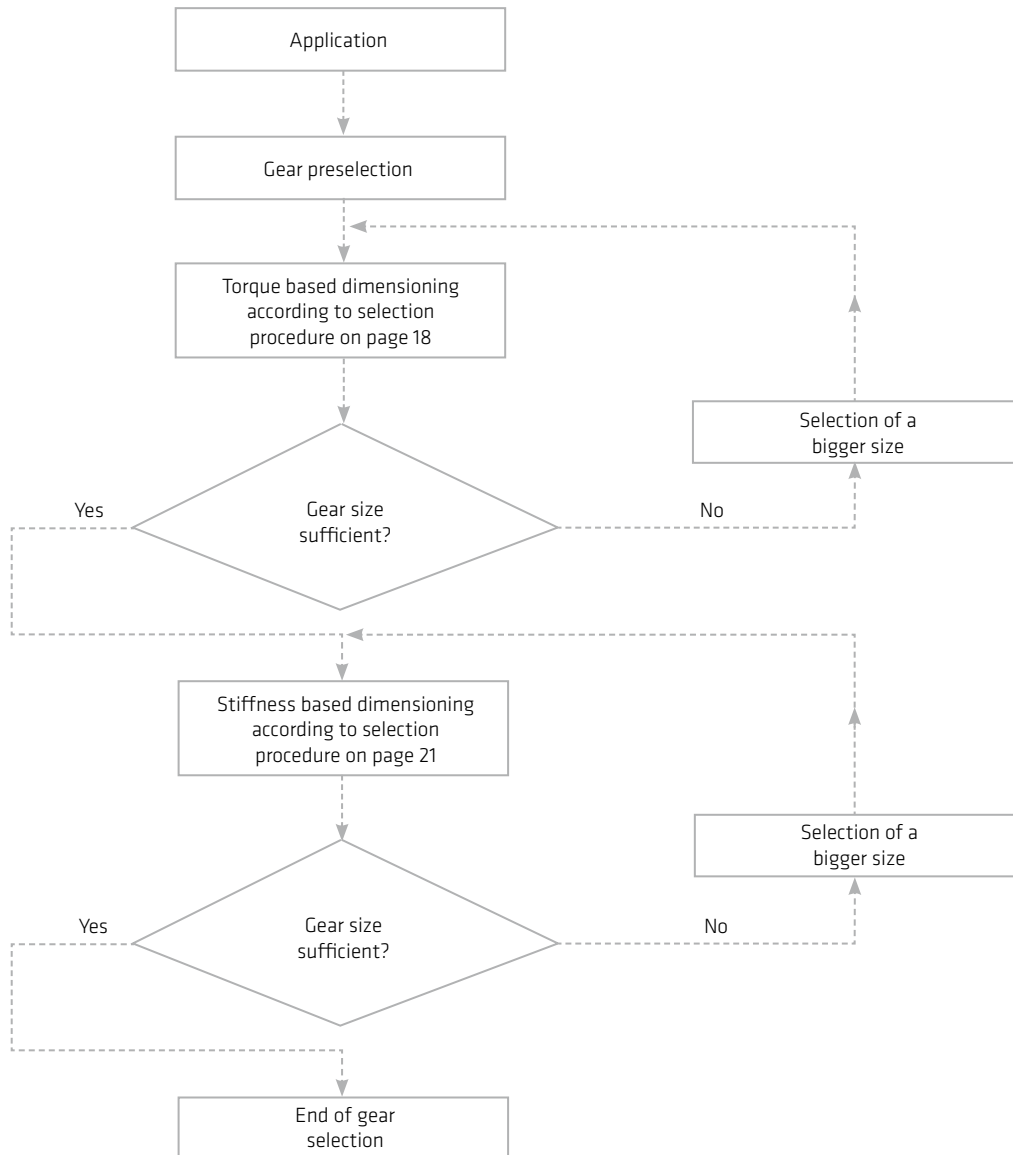
WG Control input  
CS Main drive input  
FS Main drive output

Numerous differential functions can be obtained by combinations of the speed and rotational direction of the three basic elements. Please refer to our brochure "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.

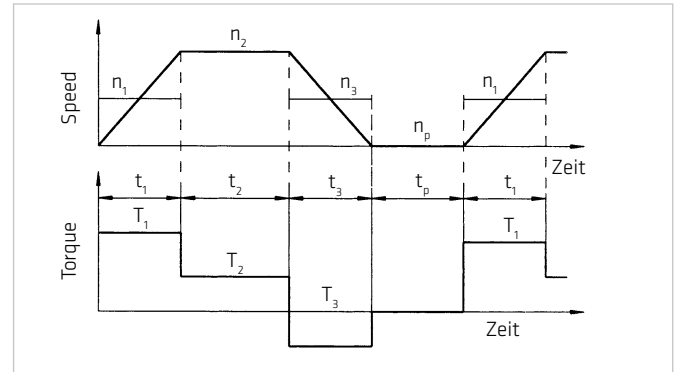


# 4.1.1 Torque Based Dimensioning

## Output Data

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

Illustration 18.1



Equation 18.2

**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 18.3

Values for $T_A$ see rating tables $T_{av} \leq T_A$	No	Selection of a bigger size
---	----	----------------------------

Equation 18.4

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 18.5

Average input speed

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

Equation 18.6

Permissible maximum input speed

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

Equation 18.7

Permissible average input speed

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

Equation 18.8

**Load limit 2,  $T_R$**

$$T_{max} \leq T_R$$

Equation 18.9

**Load limit 3,  $T_M$**

$$T_k \leq T_M$$

Equation 18.10

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 18.11

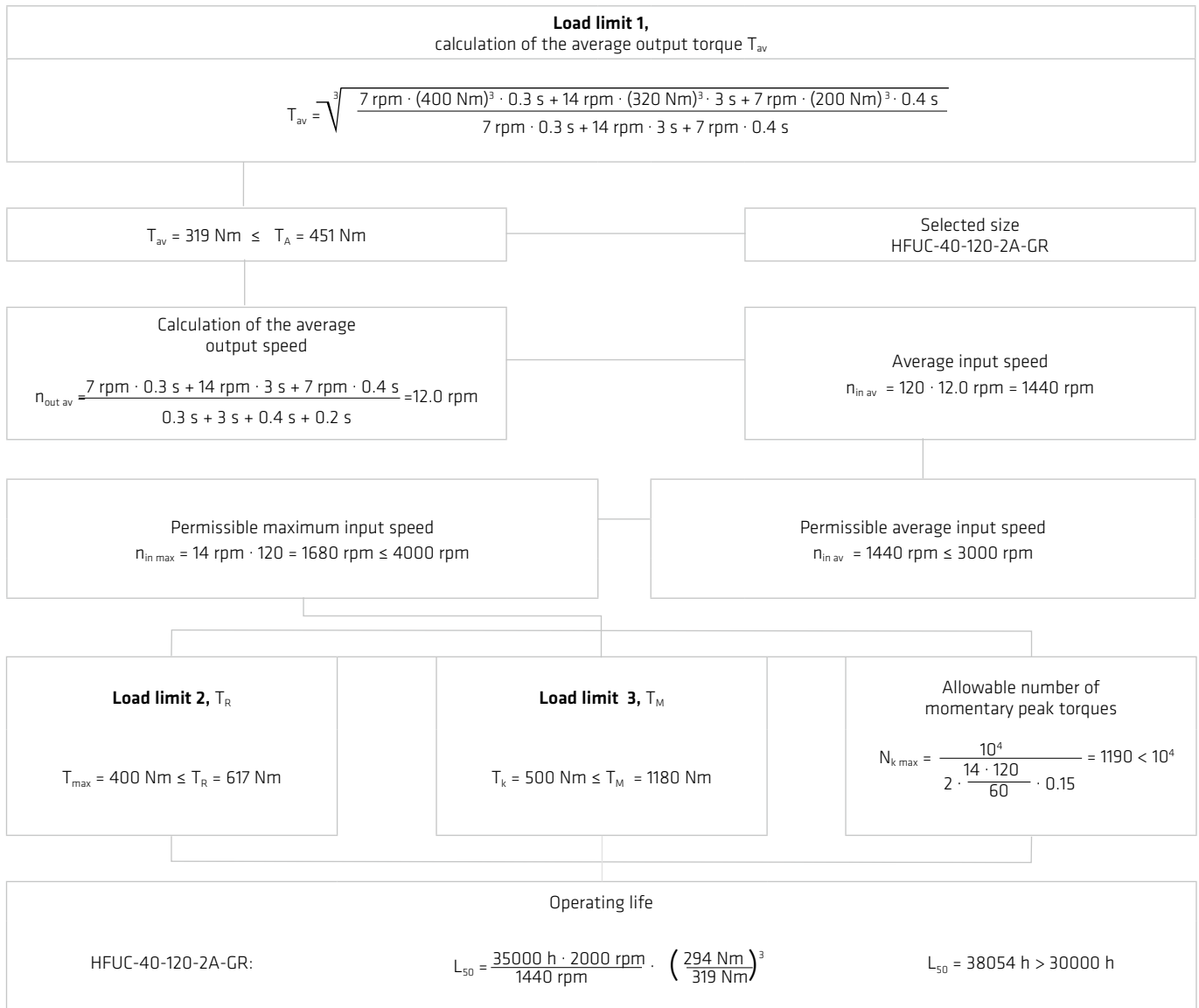
Operating life

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

Values for  $L_n$  see table 20.1

## Output Data

$T_1 = 400 \text{ Nm}$	$t_1 = 0.3 \text{ s}$	$n_1 = 7 \text{ rpm}$
$T_2 = 320 \text{ Nm}$	$t_2 = 3.0 \text{ s}$	$n_2 = 14 \text{ rpm}$
$T_3 = 200 \text{ Nm}$	$t_3 = 0.4 \text{ s}$	$n_3 = 7 \text{ rpm}$
$T_k = 500 \text{ Nm}$	$t_k = 0.15 \text{ s}$	$n_k = 14 \text{ rpm}$
	$t_p = 0.2 \text{ s}$	$n_p = 0 \text{ rpm}$
Ratio $i = 120$		
Life $L_{50} = 30000 \text{ h}$ (required)		



## 4.1.2 Life of the Wave Generator Bearing

Given that the Harmonic Drive® Gear is rated to provide infinite fatigue life for the Flexspline, the life expectancy is based on the average life of the Wave Generator bearing. The rated torque at the rated speed given in the rating table is based on the mean  $L_{50}$  bearing life. The life expectancy of a component set or an unit operating at an input speed  $n$  (rpm) and output torque  $T$  (Nm) may be estimated from equation 20.2.

Table 20.1

[h]

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

Equation 20.2

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

Equation 20.3

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

$n_N$  = Rated input speed [rpm]

$n_{in\ av}$  = Average input speed [rpm] (equation 18.5)

$T_N$  = Rated output torque at rated speed [Nm]

$T_{av}$  = Average output torque [Nm] (equation 18.2)

$L_n$  = See table 20.1

### 4.1.3 Stiffness Based Dimensioning

In addition to the “Torque Based Dimensioning” stated on page 18, we recommend that you carry out a selection based on stiffness. For this, the values provided in table 21.1 for the individual resonance frequencies recommended for each application should be taken into account.

Table 21.1

[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	$\geq 4$
Base axes of revolute robots, hand axes of revolute robots with low requirements regarding dynamic performance, tool revolvers, tool magazines, swivelling and positioning axes in medical and measuring devices	$\geq 8$
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 manipulators, base axes of welding robots (laser welding), swivelling and positioning axes of medical equipment	$\geq 15$
B/C axes in 5 axis grinding machines, hand axes of welding robots (laser welding), milling heads for plastics machining	$\geq 20$
C axes in turning machines, milling heads for light metal machining, milling heads for woodworking (chipboards etc.)	$\geq 25$
Milling heads for woodworking (hardwood etc.)	$\geq 30$
C axes in turning machines*	$\geq 35$
Milling heads for metal machining*, B axes in turning milling centers for metal machining	$\geq 40$
Milling heads for metal machining*, B axes in turning milling centers for metal machining with high requirements regarding surface quality*	$\geq 50$
Milling heads for metal machining with very high requirements regarding surface quality*	$\geq 60$

\* 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 22.1

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

$f_n$  = Resonance frequency [Hz]

$K_1$  = Gear torsional stiffness  $K_1$  [Nm/rad]

$J$  = Load moment of inertia [kgm<sup>2</sup>]

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

$$n_n = f_n \cdot 30 \text{ [rpm]}$$

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 19.

Intended application: milling head for woodworking

Moment of inertia at the gear output: 7 kgm<sup>2</sup>. Recommended resonance frequency from table 21.1:  $\geq 30$  Hz.

Resonance frequency using the preselected gear

HFUC-40-120-2A-GR:

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

According to stiffness based dimensioning, this gear size is too small for the application.

The larger gear HFUC-50-120-2A-GR results in a resonance frequency of:

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

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

The resonance speed at the input (motor) amounts to:

$$n_n = 30 \cdot 30 = 900 \text{ [rpm]}$$

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

## 4.2 Calculation of the Torsion Angle

Calculation of the Torsion Angle  $\varphi$  at Torque T:

Equation 23.1

$$T \leq T_1$$

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

Equation 23.2

$$T_1 < T \leq T_2$$

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

Equation 23.3

$$T > T_2$$

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

$\varphi$  = Angle [rad]  
 T = Torque [Nm]  
 K = Stiffness [Nm/rad]

Example: HFUC-32-100-2UH

$$T = 60 \text{ Nm} \quad K_1 = 6.7 \cdot 10^4 \text{ Nm/rad}$$

$$T_1 = 29 \text{ Nm} \quad K_2 = 1.1 \cdot 10^5 \text{ Nm/rad}$$

$$T_2 = 108 \text{ Nm} \quad K_3 = 1.2 \cdot 10^5 \text{ Nm/rad}$$

$$\varphi = \frac{29 \text{ Nm}}{6.7 \cdot 10^4 \text{ Nm/rad}} + \frac{60 \text{ Nm} - 29 \text{ Nm}}{1.1 \cdot 10^4 \text{ Nm/rad}}$$

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

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

Equation 23.4

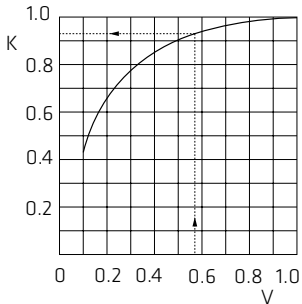
$$\varphi \text{ [arc min]} = \varphi \text{ [rad]} \cdot \frac{180 \cdot 60}{\pi}$$

### 4.3 Efficiency Versus Load

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

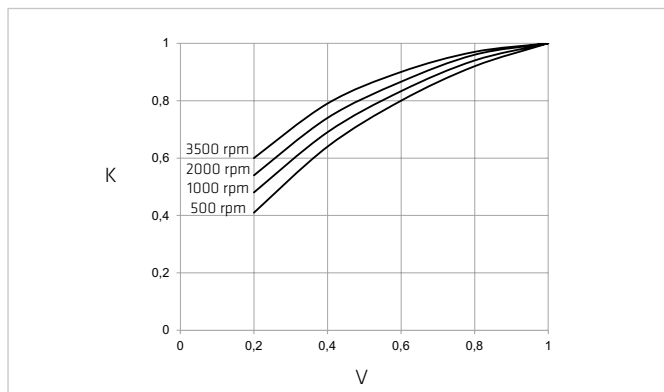
#### 4.3.1 Efficiency Calculations

Table 24.1

Calculation Procedure	Example
	Efficiency of HFUC-20-80-2A-GR with input speed n=1000 rpm output torque T= 19.6 Nm at 20° C ambient temperature. Lubrication: Grease
The efficiency may be determined using the efficiency graphs.	From matching chart $\eta = 78\%$
Calculate the torque factor V.  $V = \frac{T_{av}}{T_N} \quad \text{[Equation 24.2]}$ with: $T_{av}$ = Average torque $T_N$ = Rated torque at rated speed	$T_{av} = 19.6 \text{ Nm}$ $T_N = 34.0 \text{ Nm}$  $V = \frac{19.6 \text{ Nm}}{34.0 \text{ Nm}} = 0.57$
K depending on gear type and V, see illustration 24.4	
Efficiency $\eta_L = \eta \cdot K$ [Equation 24.3]	$\eta_L = 78 \cdot 0.93 = 73\%$

### Calculating Factor K

Illustration 24.4



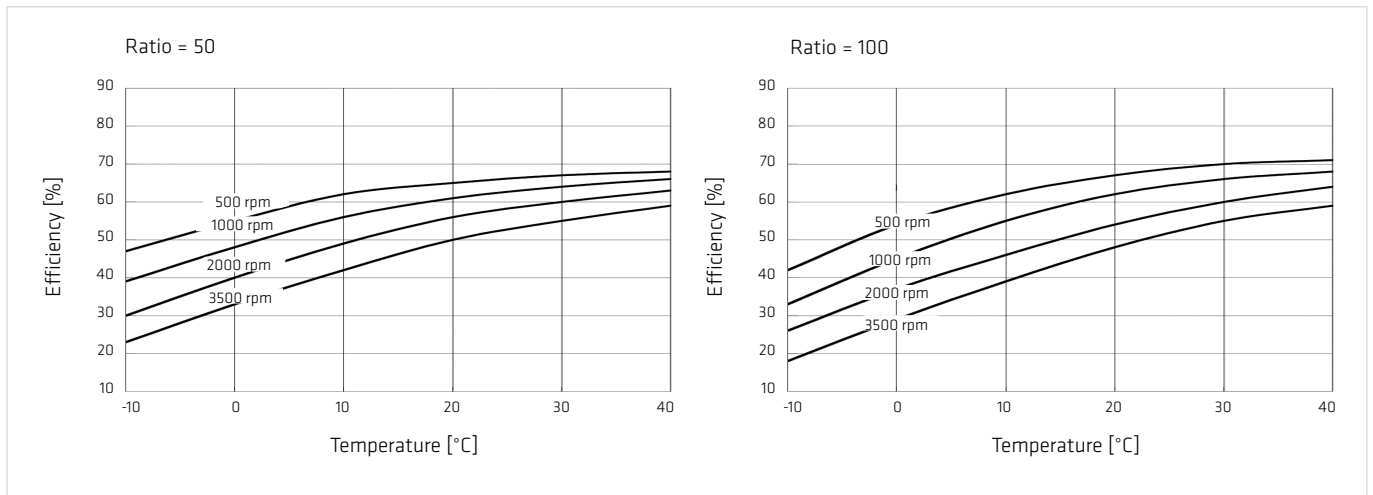


### 4.3.2 Efficiency Tables

Efficiency for grease lubrication at rated torque and Harmonic Drive® grease lubrication.

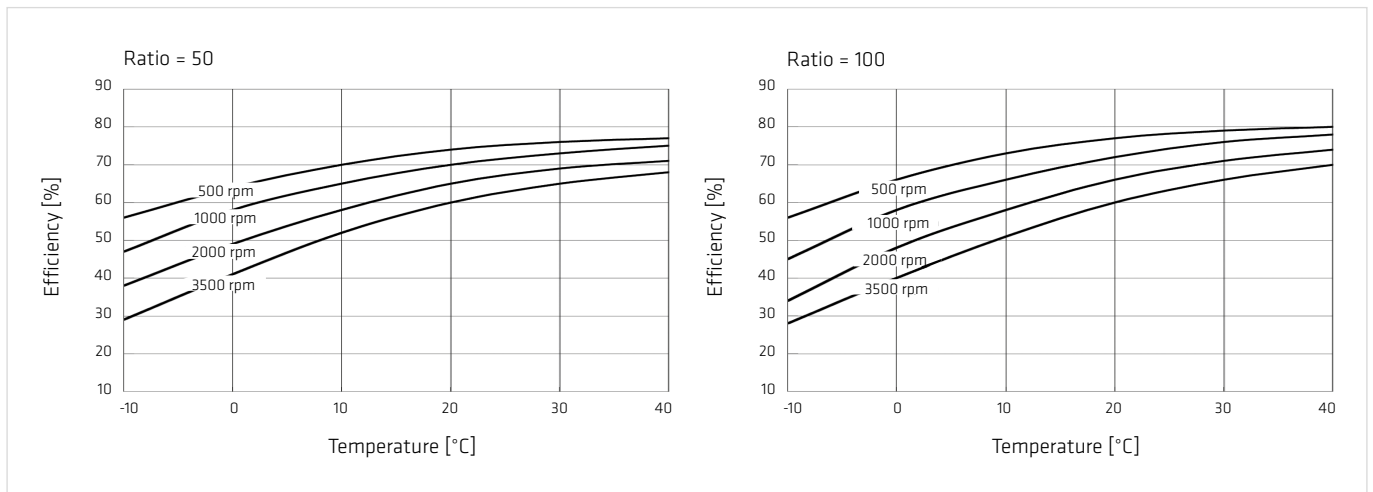
#### Size 14

Illustration 25.1



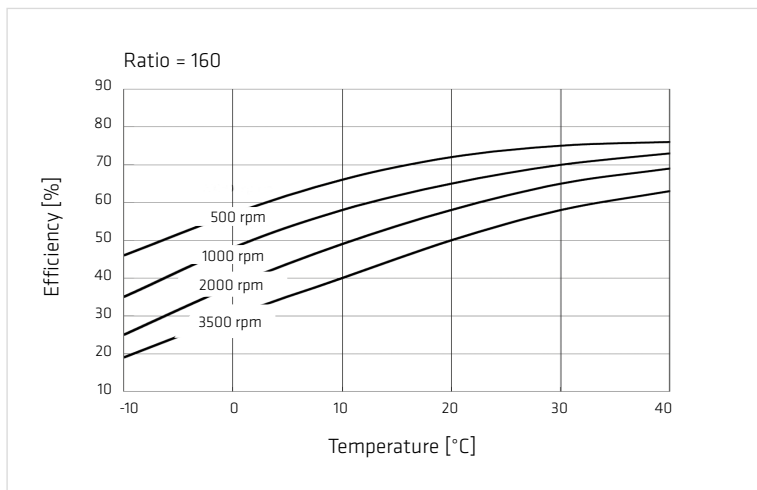
#### Size 17-20

Illustration 25.2



#### Size 20-40

Illustration 25.3



## 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

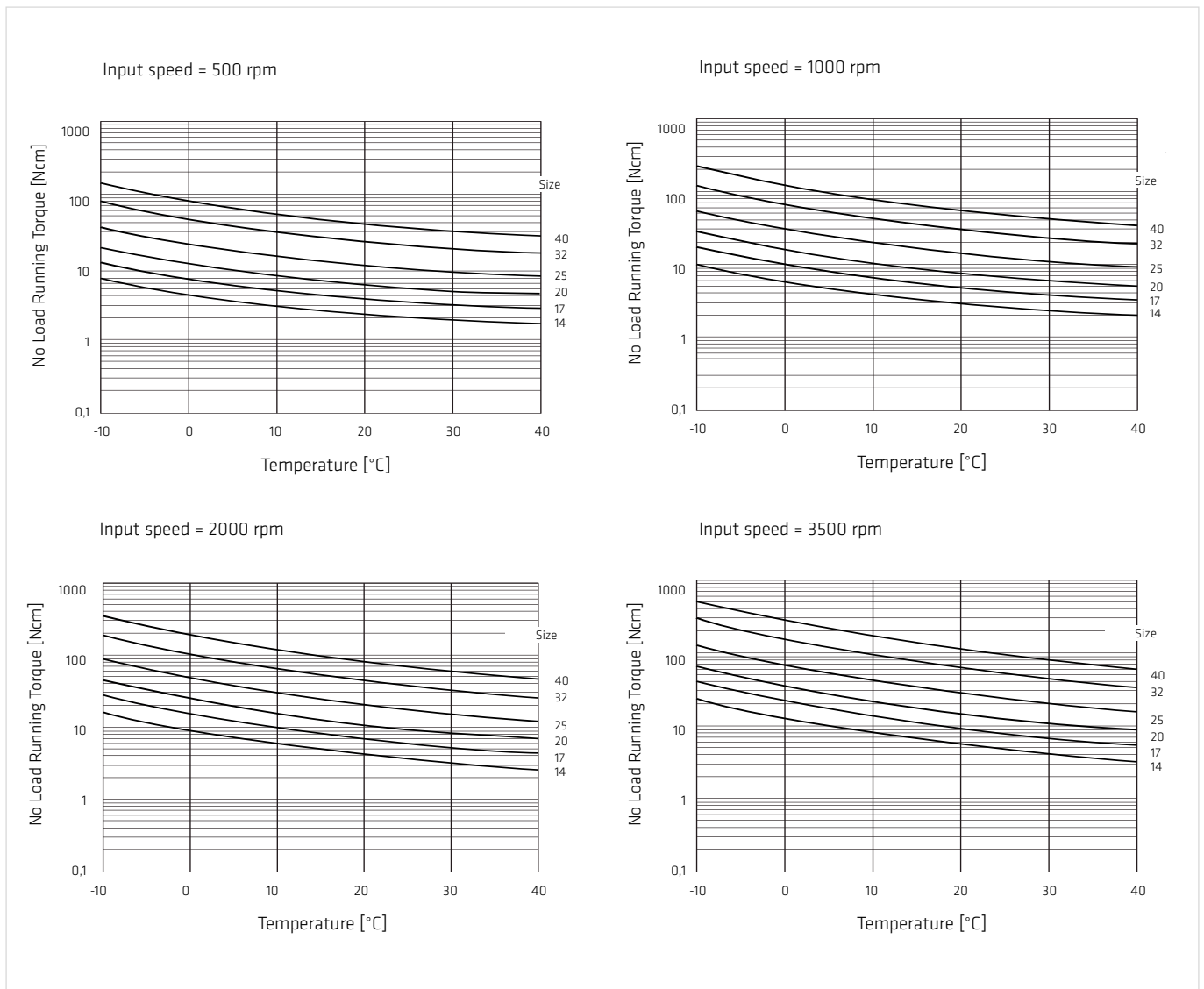
Gear ratio  $i = 100$

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 26.1



## Compensation Values for No Load Running Torque

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

Table 27.1

[Ncm]

Ratio	Size					
	14	17	20	25	32	40
50	+1.0	+1.6	+2.4	+4.0	+7.0	+13
160	-	-	-0.7	-1.2	-2.4	-3.9

## 4.4.2 No Load Starting Torque

Table 27.2

[Ncm]

Ratio	Size					
	14	17	20	25	32	40
50	6.2	19	25	39	60	95
100	4.8	17	22	34	50	78
160	-	-	22	33	47	74

## 4.4.3 No Load Back Driving Torque

Table 27.3

[Nm]

Ratio	Size					
	14	17	20	25	32	40
50	3.7	11	15	24	36	57
100	5.8	21	27	41	60	94
160	-	-	42	64	91	143

## 4.5 Life for Continuous Operation

The operating life of the output bearing can be calculated using equation 28.1.

Equation 28.1

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

with:

- $L_{10}$  [h] = Operating life
- $n_{av}$  [rpm] = Average output speed (equation 28.2)
- $C$  [N] = Dynamic load rating see table 14.1
- $P_c$  [N] = Dynamic equivalent load (equation 29.1)
- $f_w$  = Operating factor (table 28.3)
- $B$  = Bearing type (table 28.4)

## Average Output Speed

Equation 28.2

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

Table 28.3

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 28.4

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

## Dynamic Equivalent Load

Equation 29.1

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

with:

$F_{rav}$  [N] = Radial force (equation 29.2)

$x$  = Radial load factor (table 29.4)

$F_{aav}$  [N] = Axial force (equation 29.3)

$y$  = Axial load factor (table 29.4)

$d_p$  [m] = Pitch circle (see table 14.1)

$M$  = Tilting moment

Equation 29.2

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

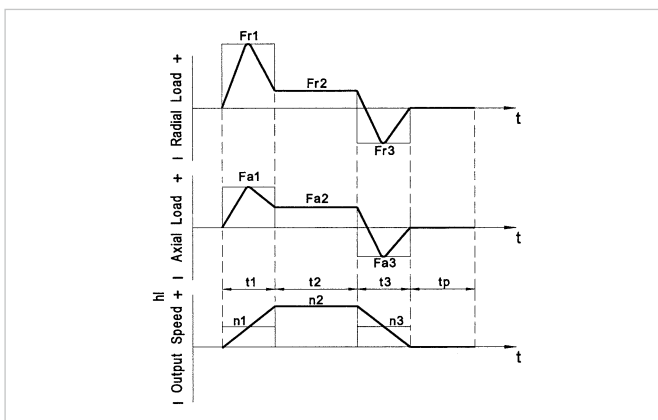
Equation 29.3

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

Table 29.4

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 29.5



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 30.1

Equation 30.1

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

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 14.1)

$P_c$  [N] = Dynamic equivalent load (equation 29.1)

$\varphi$  [deg] = Oscillating angle

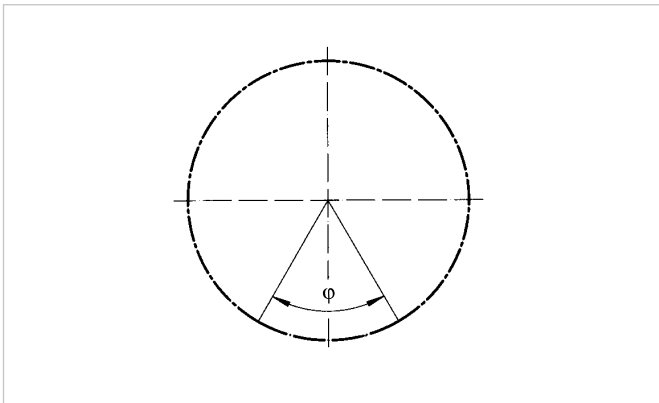
$f_w$  = Operating factor (table 28.3)

\* one oscillation means  $2\varphi$

### Oscillating angle

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

Illustration 30.2



## 4.6 Permissible Static Tilting Moment

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

Equation 31.1

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

and so

Equation 31.2

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

$f_s$  = Static load safety factor

( $f_s = 1.5 \dots 3$ ) (table 31.3)

$C_0$  = Static load rating

$F_r = F_a = 0$

$x_0 = 1$

$y_0 = 0.44$

$P_0$  = Static equivalent load (equation 30.1)

$d_p$  = Pitch circle diameter of the output bearing (table 14.1)

$M$  = Moment acting

$M_0$  = Allowable static overturning moment

Table 31.3

Rotation conditions of bearing	Lower limit value for $f_s$
Normal	$\geq 1.5$
Vibrations / Impacts	$\geq 2$
High transmission accuracy	$\geq 3$

## 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 31.4:

Equation 31.4

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

with:

$\gamma$  [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 14.1)

## 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® Lubricating 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 32.1 and 32.2.

#### Caution!

The Harmonic Drive® high performance 4BNo.2 grease becomes relatively thin 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 32.1

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				-										
4BNo.2	-	For heavy duty operation*													

Table 32.2

Grease	Ratio = 30						
	Size						
	8	11	14	17	20	25	32
Flexolub A1	-		Standard for CPU				
SK-1A	-				Standard		
SK-2	Standard				-		
4BNo.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 33.1 gives some important information regarding Harmonic Drive® lubricating greases.

Table 33.1

Type	Harmonic Drive® lubricating greases			
	Standard		Special	
	SK-1A	SK-2	Flexolub A1	4BNo.2
Operating temperature range	0° C ... +80° C	0° C ... +80° C	-40° C ... +120° C	-10° C ... +110° C
Base oil	Mineral oil	Mineral oil	PAO / Ester oil	Synthetic oil
Thickener	Lithium soap	Lithium soap	Lithium soap	Urea
Consistency class (NLGI)	2	2	1	1-2
Base oil viscosity (40° C; 100° C)	37; 5.9 mm <sup>2</sup> /St	37; 5.9 mm <sup>2</sup> /St	25; 5.2 mm <sup>2</sup> /St	50; 12 mm <sup>2</sup> /St
Drop point	197° C	198° C	180° C	247° C
Colour	yellow	green	magenta	pale yellow
Max. storage time in hermetically sealed container	5 years			
Ease of sealing (safety against grease- or base oil leakage at the oil seals)	+	+	+	+/-

**Notes:**

+ = Good

+/- = May be critical depending on design / mounting position / application, please contact Harmonic Drive AG

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

## Special Operating Demands

Table 34.1 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 34.1

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

### Notes:

- <sup>1)</sup> Operating temperature = Lubricant temperature
- <sup>2)</sup> User specific prototype tests recommended
- <sup>3)</sup> Applicability confirmed for all Harmonic Drive® catalogue products with cup type Flexspline for size 14 and up. 1 kg bundles available at HDAG
- <sup>4)</sup> 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.
- <sup>5)</sup> 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 34.2

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 35.1

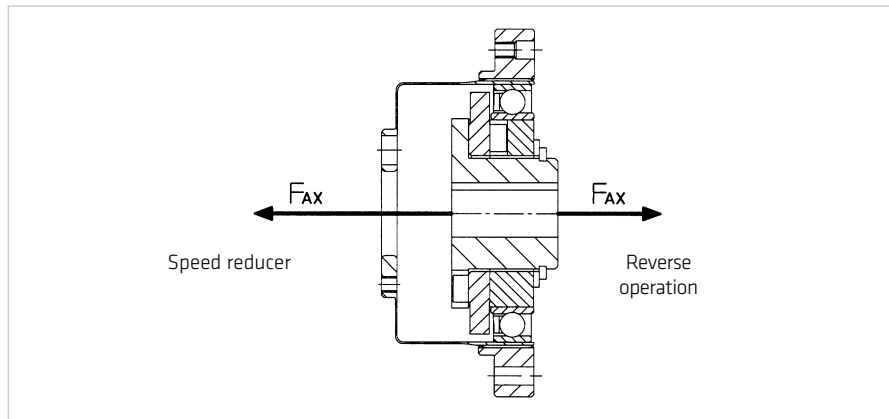


Table 35.2

Ratio		
30	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 32^\circ$	[Equation 35.3]
50	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 30^\circ + 2\mu PF$	[Equation 35.4]
80...160	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 20^\circ + 2\mu PF$	[Equation 35.5]

with:

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

Example

Size 32 (CSD-32-50)  
 Output torque = 300 Nm  
 Coefficient of friction  $\mu = 0.07$

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

$$F_{AX} = 215 \text{ N}$$

Table 35.6

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

## 5. Installation and Operation

### 5.1 Transport and Storage

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

### 5.2 Gear Condition at Delivery

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

#### **Gears with Grease Lubrication**

Units are supplied with grease lubricant as standard.

#### **Gears with Oil Lubrication**

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

#### **Oil Quantity**

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

### 5.3 Assembly Information

#### ADVICE

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

## 5.4 Recommended Tolerances for Assembly

In order for the new features of Harmonic Drive® Units to be exploited fully, it is essential that the tolerances according to table 37.2 are observed for the input assembly.

Illustration 37.1

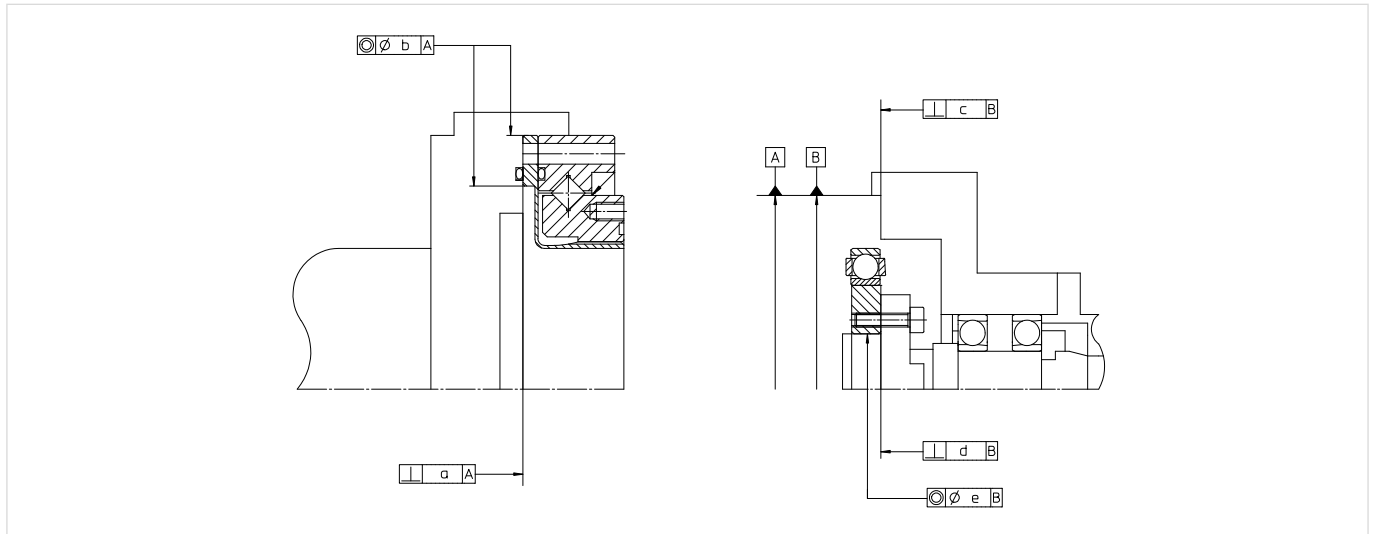


Table 37.2

Size	14	17	20	25	32	40
a	0.016	0.021	0.027	0.035	0.042	0.048
$\varnothing b$	0.015	0.018	0.019	0.022	0.022	0.024
c	0.011	0.012	0.013	0.014	0.016	0.016
d	0.006	0.010	0.012	0.012	0.012	0.012
$\varnothing e$	0.016	0.018	0.019	0.022	0.022	0.024

## 5.5 Lubrication

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

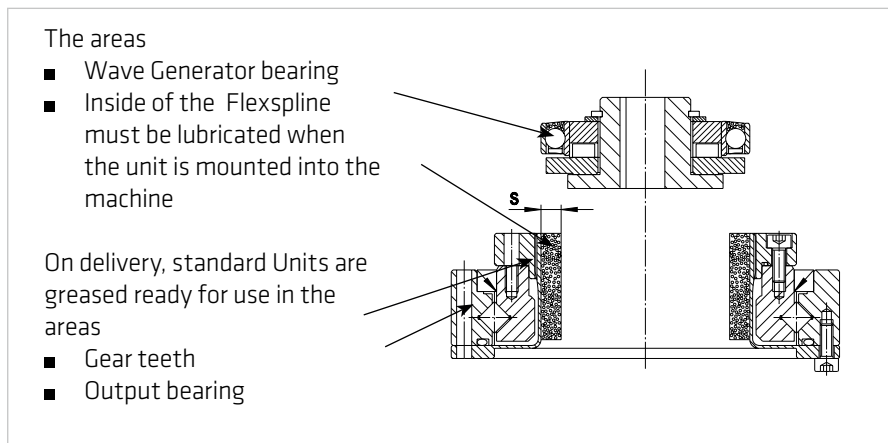
### 5.5.1 Grease Lubrication

Units are supplied with standard grease lubricant. If no special arrangements are made the specially developed high performance grease SK-1A (for sizes 20 to 65) and SK-2 (for size 14 and 17) are used. If any other grease is used this will be indicated on the customer drawing. High performance 4BNo. 2 grease with improved characteristics is also available for these products.

On delivery, Flexspline and Circular Spline teeth are lubricated ready for use. Before mounting, the Wave Generator bearing and the inner part of the Flexspline must be greased. It may be necessary to place an additional amount of grease on the front face of the Wave Generator (see illustration 39.2).

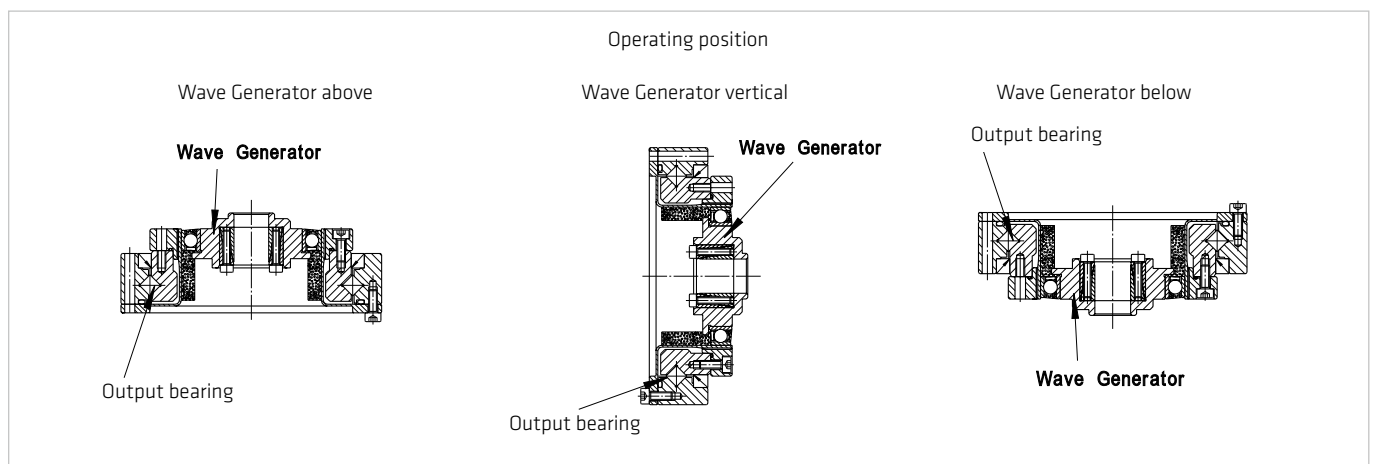
Illustration 38.1 shows the areas requiring grease.

Illustration 38.1



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 38.2.

Illustration 38.2



## 5.5.2 Amount of Grease

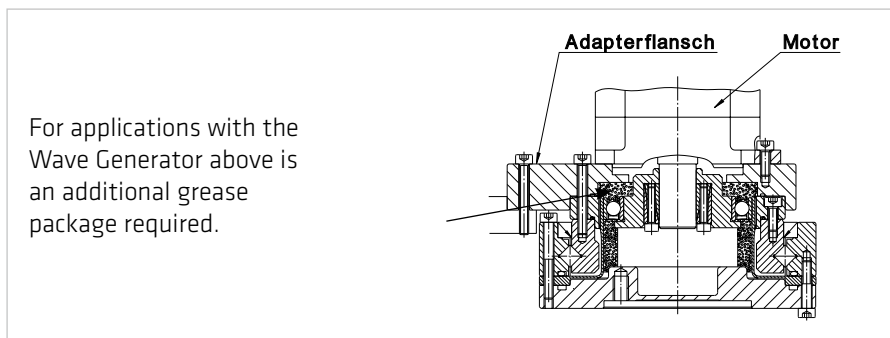
Table 39.1

Size		14	17	20	25	32	40
Total weight ca. [g]	Wave Generator mainly vertical or below	5	9	13	24	51	99
	Wave Generator mainly above	6	10	15	28	58	112
Standard Harmonic Drive® grease		SK-2		SK-1A			

## 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 39.2 and table 39.1.

Illustration 39.2

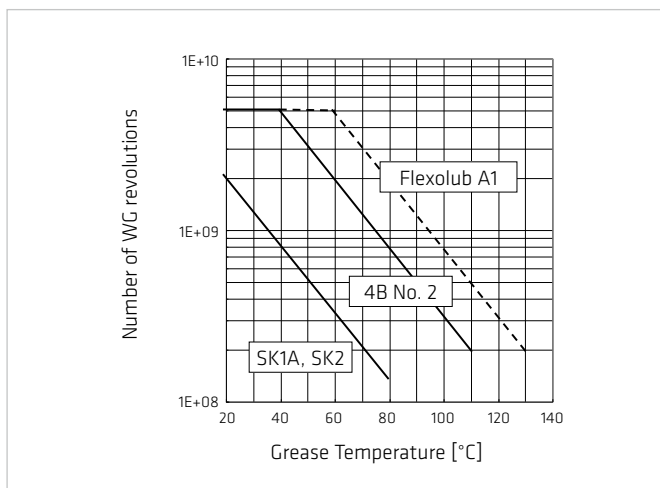


## 5.5.4 Grease Change

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 39.3 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.  $8.5 \times 10^8$  revolutions of the input shaft. All grease change data refers to rated speed and rated torque.

Illustration 39.3



Equation 39.4

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

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

$L_{GTn}$  = see diagram

$T_r$  = Rated torque

$T_{av}$  = Average torque

## 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 5203
- Loxeal 28-10

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

### **Screw fixing**

- Loctite 243

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

### **Assembly paste**

- Klüber Q NB 50

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

### **Adhesives**

- Loctite 638

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



## 5.7 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® 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.

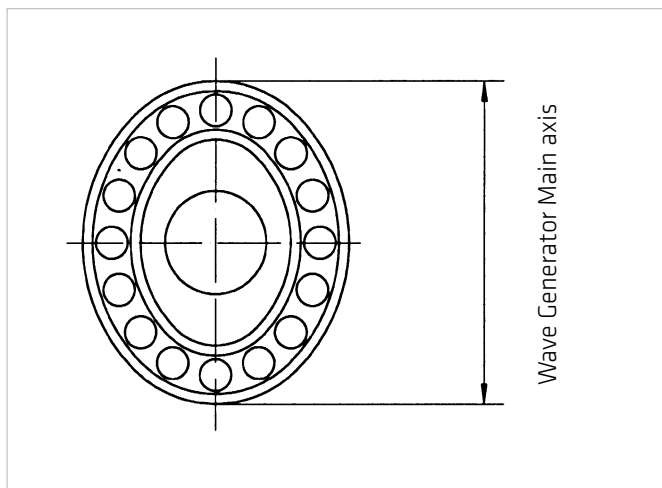
### 5.7.1 Motor Assembly

For the planning of the assembly sequence it may be helpful to know the max. diameter of the Wave Generator, see illustration 41.2. In table 41.1 the diameters of the Wave Generator main axes are indicated.

Table 41.1

Ca. Ø Wave Generator main axis										
Size	14	17	20	25	32	40	45	50	58	65
Ca. Ø	36	43	50	63	82	100	114	125	146	164

Illustration 41.2



## 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 tighten 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.

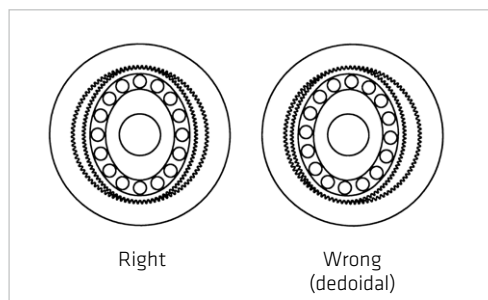
## 5.7.5 Assembly Control

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 42.1



## 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 43.1

Size	14	17	20	25	32	40
Number of Bolts	8	12	12	12	12	12
Bolt Size	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

## 5.7.7 Assembly of the Housing

Table 43.2

Size	14	17	20	25	32	40
Number of Bolts	8	12	12	12	12	12
Bolt Size	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  $\mu = 0.15$ ; 12.9 quality screws

## 6. Glossary

### 6.1 Technical Data

#### AC Voltage constant $k_{EM}$ [ $V_{rms} / 1000 \text{ rpm}$ ]

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 [ $^{\circ} \text{C}$ ]

The intended operating temperature for the operation of the drive.

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

Maximum permissible average gear input speed for grease lubrication.

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

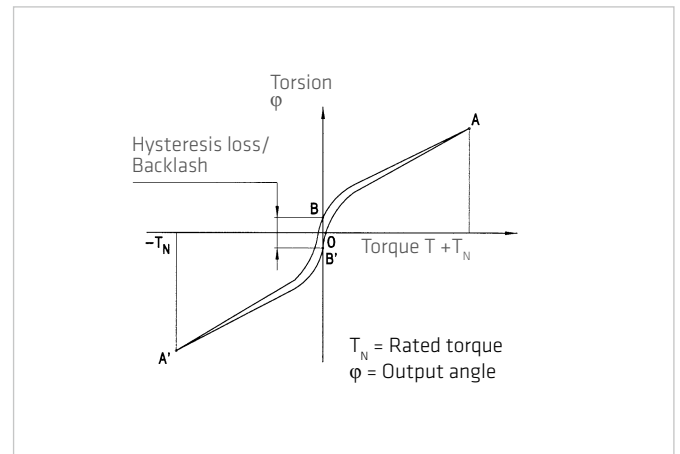
Maximum permissible average gear input speed for oil lubrication.

#### Average torque $T_A$ [Nm]

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

#### Backlash (Harmonic Planetary gears) [arcmin]

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



#### Brake closing time $t_c$ [ms]

Delay time to close the brake.

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

Current for applying the brake.

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

Current required to open the brake.

#### Brake holding torque $T_H$ [Nm]

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

#### Brake opening time $t_o$ [ms]

Delay time for opening the brake.

#### Brake voltage $U_{Br}$ [VDC]

Terminal voltage of the holding brake.

### Collision torque $T_M$ [Nm]

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

### Continuous stall current $I_0$ [ $A_{rms}$ ]

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

### Continuous stall torque $T_0$ [Nm]

Allowable actuator stall torque.

### Demagnetisation current $I_E$ [ $A_{rms}$ ]

Current at which rotor magnets start to demagnetise.

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

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

### Dynamic load rating $C$ [N]

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

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

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

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

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

### Electrical time constant $\tau_e$ [s]

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

### Hollow shaft diameter $d_H$ [mm]

Free inner diameter of the continuous axial hollow shaft.

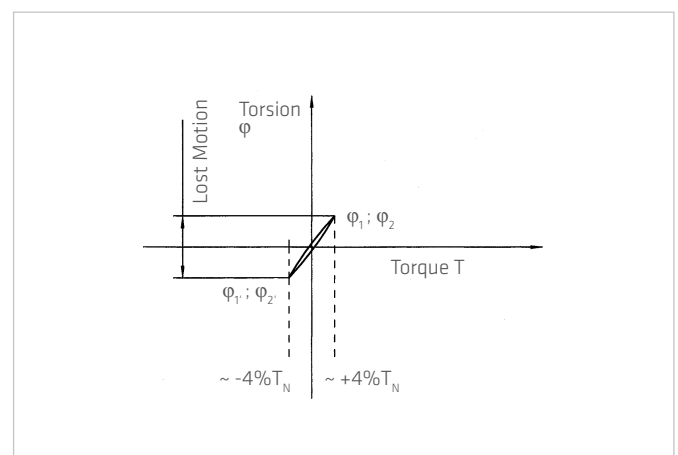
### Inductance (L-L) $L_{L-L}$ [mH]

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

### Lost Motion (Harmonic Drive® Gearing) [arcmin]

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

The illustration shows the angle of rotation  $\phi$  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  $\pm 4\%$  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 $U_{\text{DC}(\max)}$ [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 $d_{\text{H}(\max)}$ [mm]

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

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

Maximum allowed input speed for gearing with grease lubrication.

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

Maximum allowed input speed for gearing with oil lubrication.

### Maximum motor speed $n_{\max}$ [rpm]

The maximum allowable motor speed.

### Maximum output speed $n_{\max}$ [rpm]

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

### Maximum output torque $T_{\max}$ [Nm]

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

### Maximum power $P_{\max}$ [W]

Maximum power output.

### Mechanical time constant $\tau_m$ [s]

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

### Moment of inertia $J$ [kgm<sup>2</sup>]

Mass moment of inertia at motor side.

### Moment of inertia $J_{\text{in}}$ [kgm<sup>2</sup>]

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

### Moment of inertia $J_{\text{out}}$ [kgm<sup>2</sup>]

Mass moment of inertia with respect to the output.

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

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

### Number of pole pairs $p$

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

### Offset $R [mm]$

Distance between output bearing and contact point of load.

### Pitch circle diameter $d_p [mm]$

Pitch circle diameter of the output bearing.

### Protection IP

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

### Rated current $I_N [A]$

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

### Rated motor speed $n_N [rpm]$

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

### Rated power $P_N [W]$

Output power at rated speed and rated torque.

### Rated speed $n_N [rpm]$

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

### Rated torque $T_N [Nm]$ , Servo

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

### Rated torque $T_N [Nm]$ , Mechanic

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

### Rated voltage $U_N [V_{rms}]$

Supply voltage for operation with rated torque and rated speed.

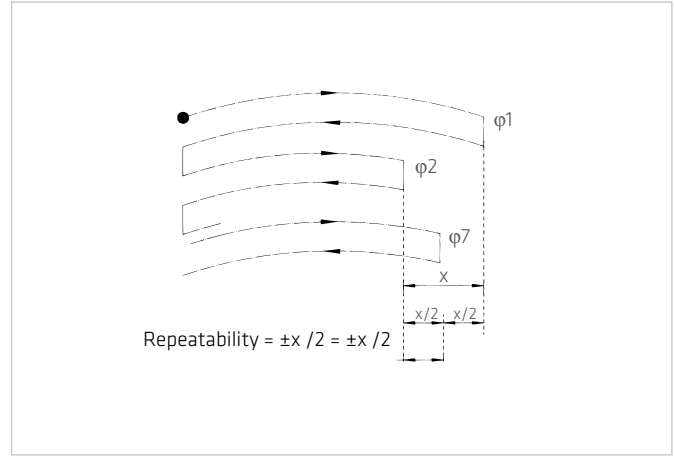
### Ratio $i [ ]$

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

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

### Repeatability [arcmin]

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



### Repeated peak torque $T_R$ [Nm]

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

### Resistance (L-L, 20° C) $R_{L-L}$ [ $\Omega$ ]

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

### Size

#### 1) Actuators / Gears with Harmonic Drive® gears or Harmonic Planetary gears

The frame size is derived from the pitch circle diameter of the gear teeth in inches multiplied by 10.

#### 2) CHM Servo motor series

The size of the CHM servo motors is derived from the stall torque in Ncm.

#### 3) Direct drives from the TorkDrive® series

The size of the TorkDrive® series is the outer diameter of theiron core of the stator.

### Static load rating $C_o$ [N]

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

### Static tilting moment $M_o$ [Nm]

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

### Tilting moment stiffness $K_b$ [Nm/arcmin]

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

### Torque constant (motor) $k_{TM}$ [Nm/A<sub>rms</sub>]

Quotient of stall torque and stall current.

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

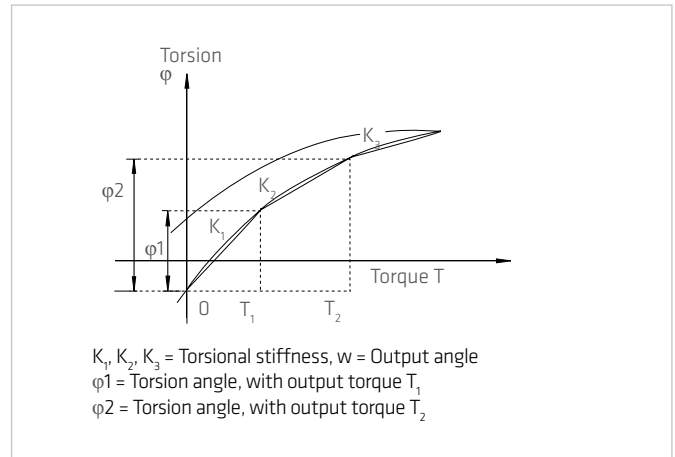
Quotient of stall torque and stall current, taking into account the transmission losses.



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

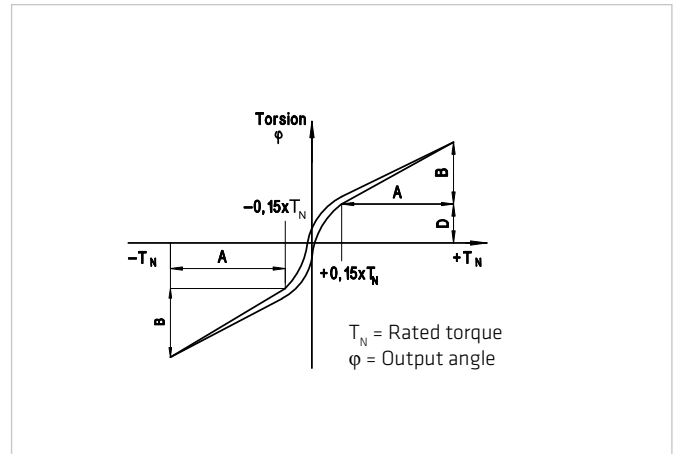
The amount of elastic rotation at the output for a given torque and the Wave Generator blocked. The torsional stiffness  $K_3$  describes the stiffness above a defined reference torque where the stiffness is almost linear. Values below this torque can be requested or found on our web site.

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



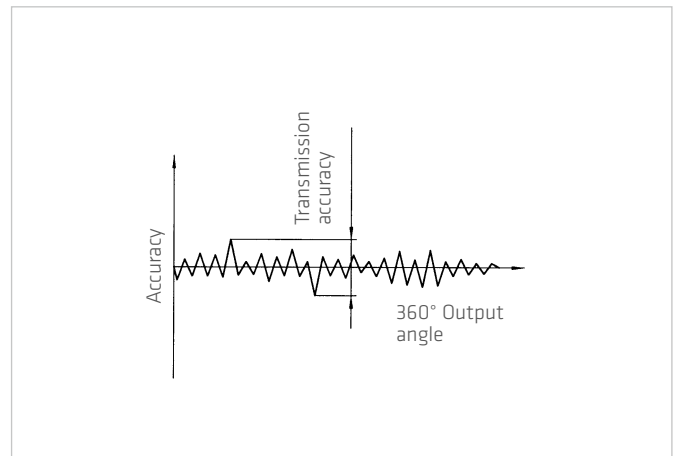
### Torsional stiffness (Harmonic Planetary gears) $K$ [Nm/rad]

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



### Transmission accuracy [arcmin]

The transmission accuracy of the gear represents a linearity error between input and output angle. The transmission accuracy is measured for one complete output revolution using a high resolution measurement system. The measurements are carried out without direction reversal. The transmission accuracy is defined as the sum of the maximum positive and negative differences between theoretical and actual output rotation angle.



### Weight $m$ [kg]

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

## 6.2 Labelling, Guidelines and Regulations

### CE-Marking

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



### REACH Regulation

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



### RoHS EU Directive

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



*...just move it!*



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Subject to technical changes.