

Engineering Data
CSD-2UF/2UH Units



Harmonic
Drive AG



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1. General

About this documentation

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

Rules for storage

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

Additional documentation

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

www.harmonicdrive.de

Third-party systems

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






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

Your feedback

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

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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 89/392/EWG. Commissioning is prohibited until such time as the end product has been proved to conform to the provisions of this directive.

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

3. Technical Descriptions

3.1 Product Description

The compact series

CSD Series Units are available in seven sizes with gear ratios of 50, 100 and 160:1 offering repeatable peak torques from 12 to 823 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 CSD Series is characterised by its' very short overall length and low weight. The CSD-2UF Unit is available with hollow shaft to feed through supply lines or services for further axes and with a high capacity output bearing that can withstand heavy payloads. The CSD-2UH Unit easily enables compact motor attachment for any standard servo motors.

Unit and motor form a compact, lightweight assembly, which can quickly withstand heavy loads. Due to the Units positioning accuracy, stable machine properties with short cycle times are guaranteed.

3.2 Ordering Code

Table 9.1

Series	Size	Ratio ¹⁾			Version	Special design		
CSD	14	50	100		2UH	According to customer requirements		
	17	50	100					
	20	50	100	160	2UF			
	25	50	100	160				
	32	50	100	160				
	40	50	100	160				
	50	50	100	160				
Ordering code								
CSD	-	20	-	100	-	2UH	-	SP

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

Table 9.2

Version	
Ordering code	Description
2UH	Units (Size 14-50)
2UF	Units with hollow shaft and increased capacity output bearing (Size 14-40)

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	CSD-14-2UH		CSD-17-2UH	
Ratio	i []	50	100	50	100
Repeatable 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]	24	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 ²]	0.021		0.054	
Weight	m [kg]	0.35		0.46	

Table 10.2

	Unit	CSD-20-2UH			CSD-25-2UH		
Ratio	i []	50	100	160	50	100	160
Repeatable 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 ²]	0.090			0.282		
Weight	m [kg]	0.65			1.2		

3.3.2 Dimensions

Illustration 11.1

CSD-14-2UH [mm]

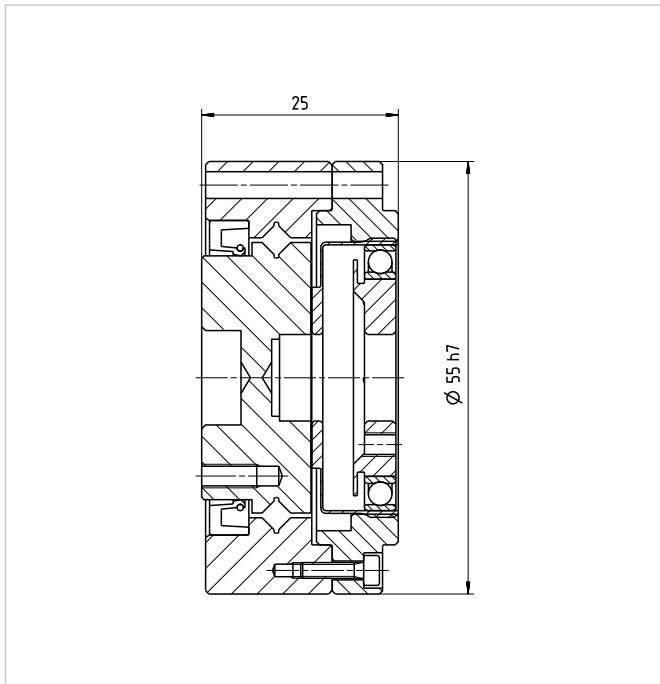


Illustration 11.2

CSD-17-2UH [mm]

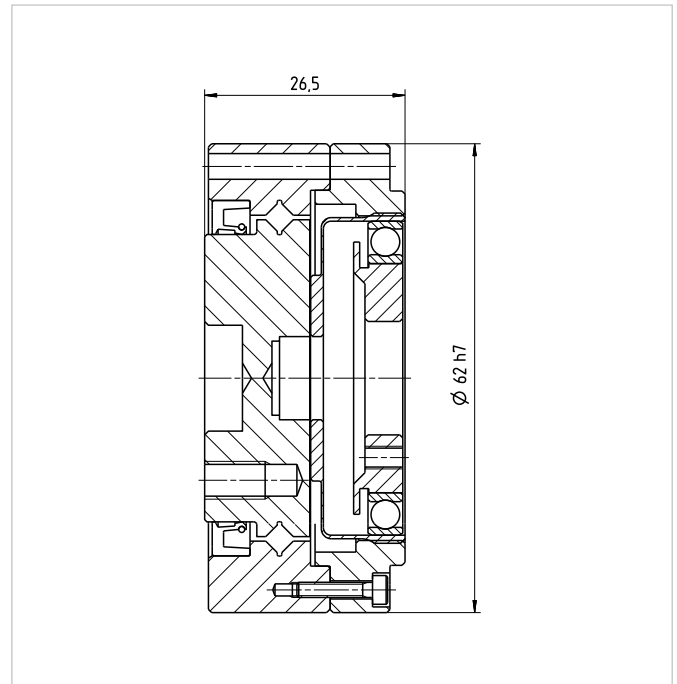


Illustration 11.3

CSD-20-2UH [mm]

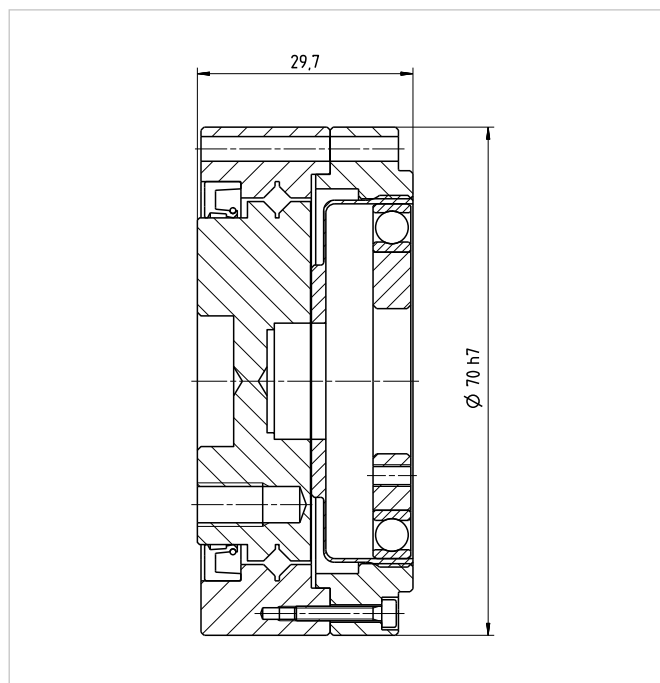


Illustration 11.4

CSD-25-2UH [mm]

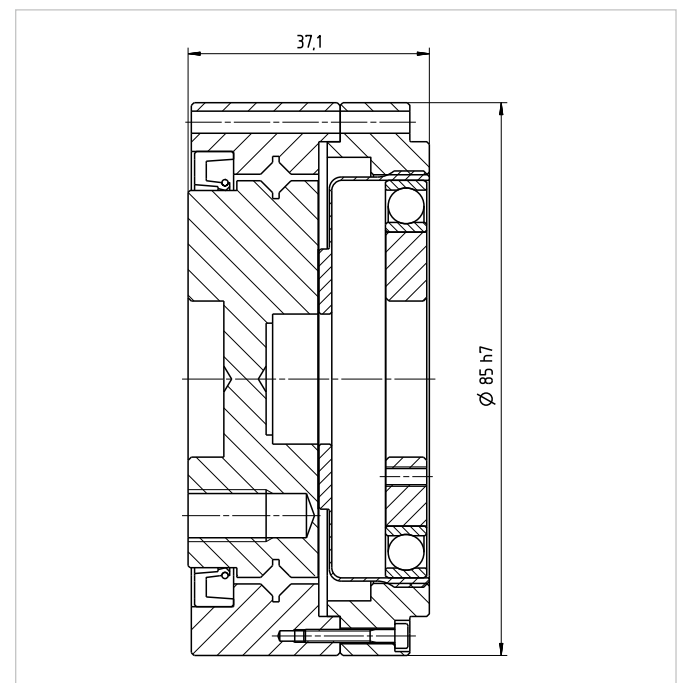


Table 12.1

	Unit	CSD-32-2UH			CSD-40-2UH		
Ratio	i []	50	100	160	50	100	160
Repeatable 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 ²]	1.09			2.85		
Weight	m [kg]	2.4			3.6		

Table 12.2

	Unit	CSD-50-2UH		
Ratio	i []	50	100	160
Repeatable peak torque	T_R [Nm]	500	686	823
Average torque	T_A [Nm]	247	466	590
Rated torque	T_N [Nm]	172	329	370
Momentary peak torque	T_M [Nm]	1000	1440	1715
Maximum input speed (grease lubrication)	$n_{in(max)}$ [rpm]	3500		
Average input speed (grease lubrication)	$n_{av(max)}$ [rpm]	2500		
Moment of inertia	J_{in} [$\times 10^{-4}$ kgm ²]	8.61		
Weight	m [kg]	6.9		

Illustration 13.1

CSD-32-2UH [mm]

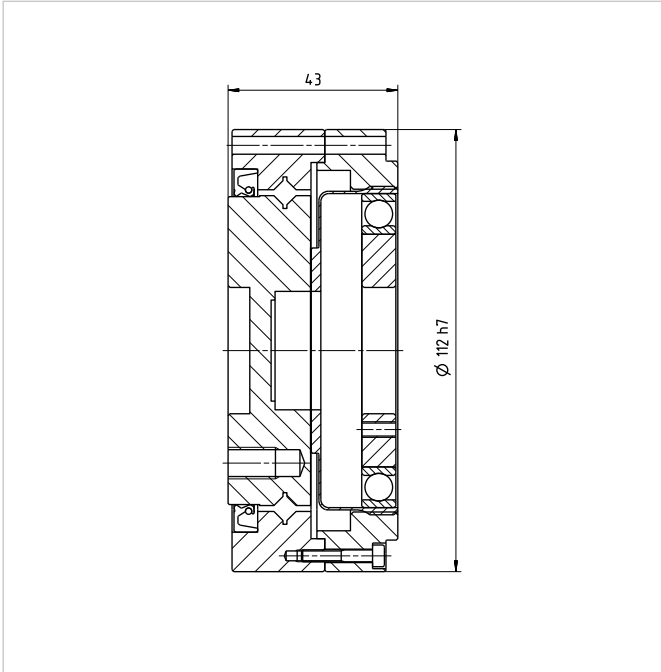


Illustration 13.2

CSD-40-2UH [mm]

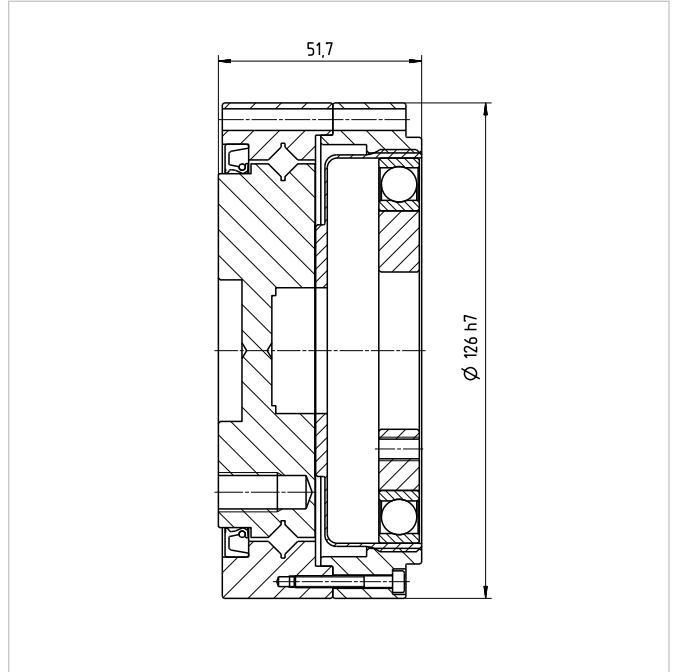


Illustration 13.3

CSD-50-2UH [mm]

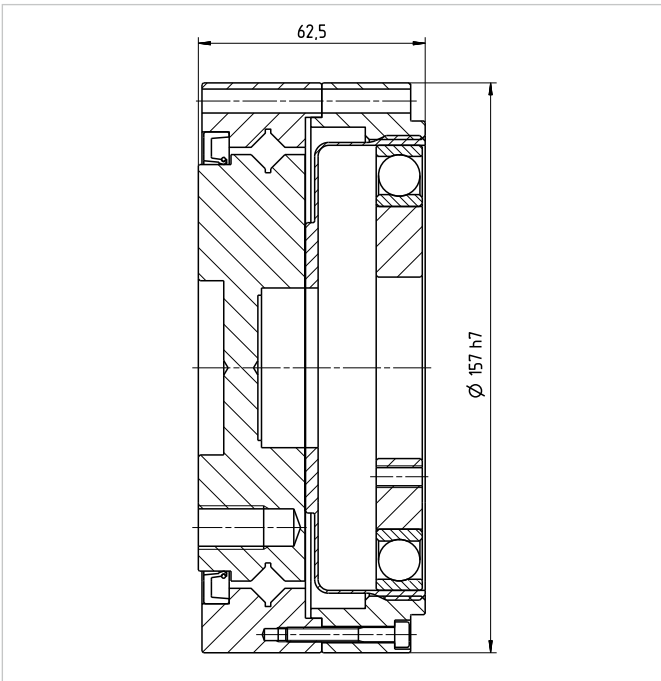


Table 14.1

	Unit	CSD-14-2UF		CSD-17-2UF	
Ratio	i []	50	100	50	100
Repeatable 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]	24	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 ²]	0.021		0.054	
Weight	m [kg]	0.5		0.66	

Table 14.2

	Unit	CSD-20-2UF			CSD-25-2UF		
Ratio	i []	50	100	160	50	100	160
Repeatable 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 ²]	0.090			0.282		
Weight	m [kg]	0.94			1.7		

Illustration 15.1

CSD-14-2UF [mm]

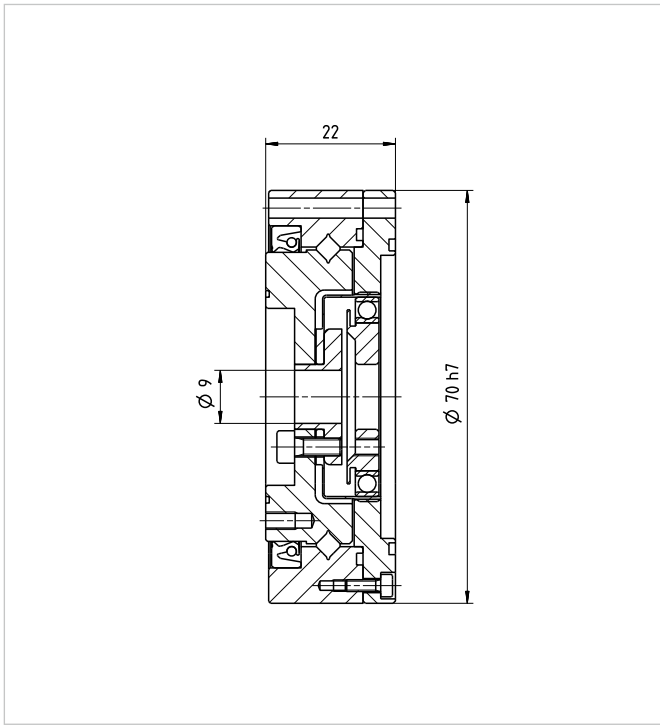


Illustration 15.2

CSD-17-2UF [mm]

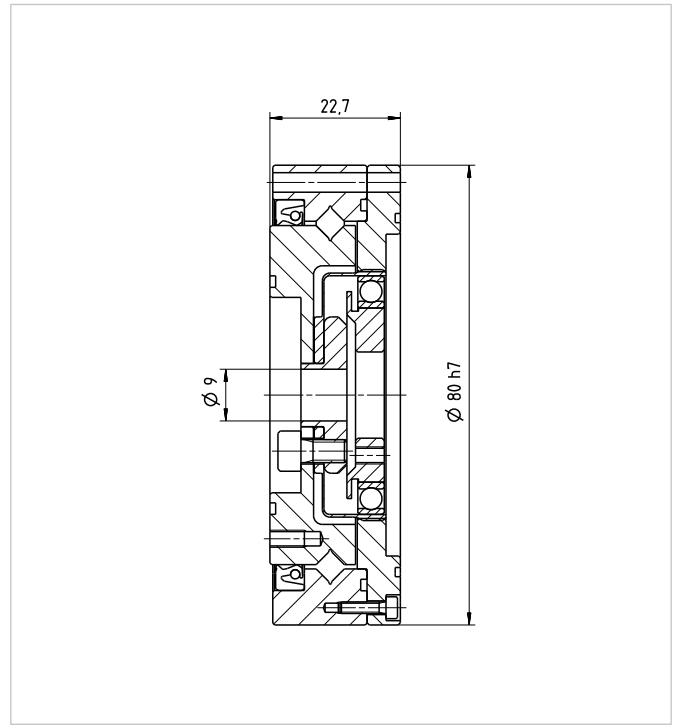


Illustration 15.3

CSD-20-2UF [mm]

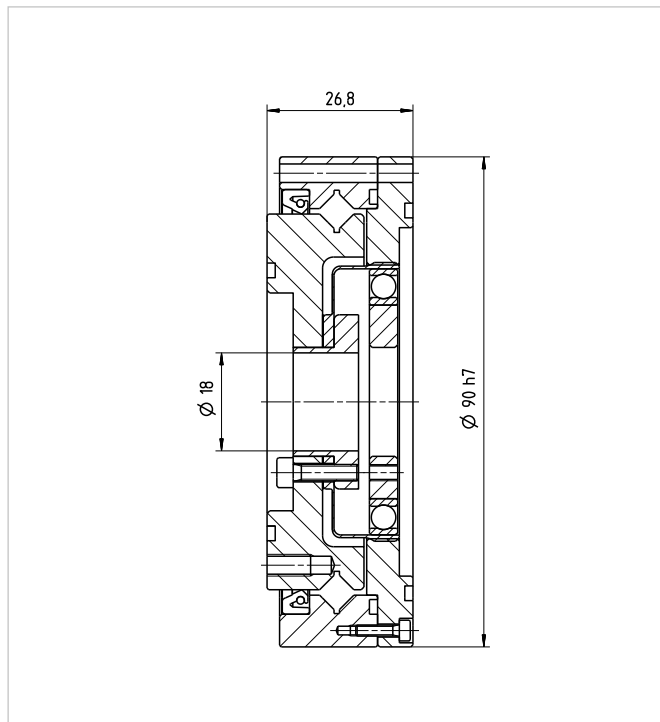


Illustration 15.4

CSD-25-2UF [mm]

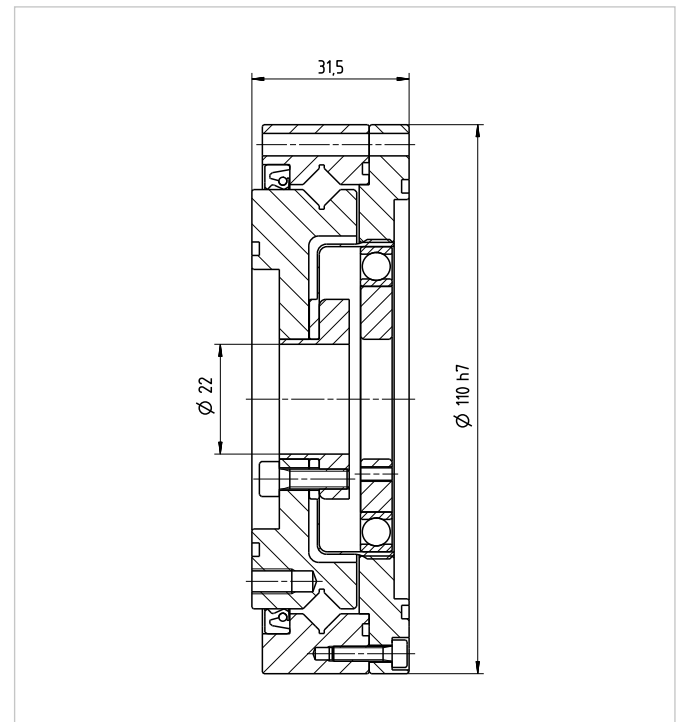


Table 16.1

	Unit	CSD-32-2UF			CSD-40-2UF		
Ratio	i []	50	100	160	50	100	160
Repeatable 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	480	185	206
Momentary peak torque	T_M [Nm]	268	420	445	281	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 ²]	1.09			2.85		
Weight	m [kg]	3.3			5.7		

Illustration 16.1

CSD-32-2UF [mm]

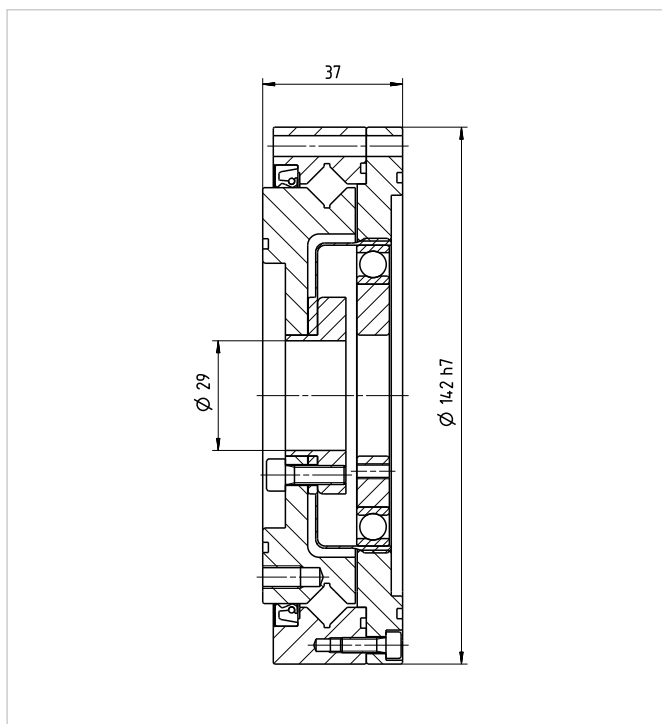
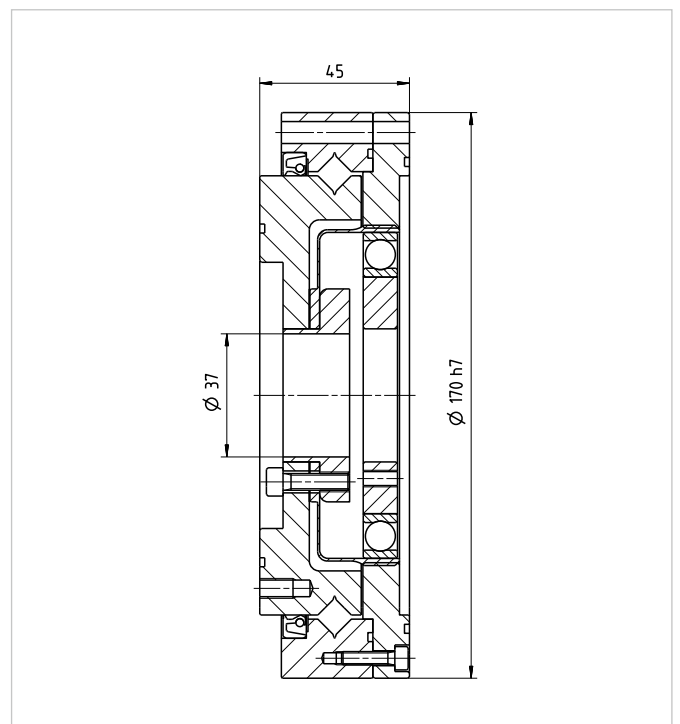


Illustration 16.2

CSD-40-2UF [mm]



3.3.3 Minimum Housing Clearance

The correct function of these units is guaranteed when the minimum clearance between the unit and the flange is achieved. Please consult the confirmation drawing.

3.3.4 Accuracy

Table 17.1

[arcmin]

Size	14	17	20	25	32	40	50
CSD-2UH/-2UF	1.5	1.5	1.0	1.0	1.0	1.0	1.0

3.3.5 Torsional Stiffness

Table 17.2

Size	14	17	20	25	32	40	50	
T_1 [Nm]	2.0	3.9	7.0	14	29	54	108	
T_2 [Nm]	6.9	12	25	48	108	196	382	
i = 50	K_1 [x10 ⁴ Nm/rad]	0.29	0.67	1.1	2.0	4.7	8.8	17
	K_2 [x10 ⁴ Nm/rad]	0.37	0.88	1.3	2.7	6.1	11	21
	K_3 [x10 ⁴ Nm/rad]	0.47	1.2	2.0	3.7	8.4	15	30
i > 50	K_1 [x10 ⁴ Nm/rad]	0.4	0.84	1.3	2.7	6.1	11	21
	K_2 [x10 ⁴ Nm/rad]	0.44	0.94	1.7	3.7	7.8	14	29
	K_3 [x10 ⁴ Nm/rad]	0.61	1.3	2.5	4.7	11	20	37

3.3.6 Bearing

Output Bearing

CSD 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, production and assembly cost, by removing the need for additional output bearings in many applications.

However, in some applications the machine element to be driven requires additional bearing support. In this case, please take care to avoid overdetermination of the bearing arrangement. The cross roller bearing of the unit should be used as the fixed bearing, whilst the additional support bearing should be floating, if possible. Table xxx lists ratings and important dimensions for the output bearings.

Table 18.1

	Series		Size						
			14	17	20	25	32	40	50
Pitch circle \varnothing^3	CSD-2UH	d_p [mm]	35	43	50	62	80	96	119
	CSD-2UF		50	60	70	85	111	133	-
Offset ⁴⁾	CSD-2UH	R [mm]	9.5	9.9	10.2	13.0	14.4	15.1	19.2
	CSD-2UF		11.8	12.3	12.8	13.4	16.8	21.5	-
Dynamic load rating	CSD-2UH	C [N]	4700	5290	5780	9600	15000	21300	34800
	CSD-2UF		5780	10400	14600	21800	38200	43300	-
Stating load rating	CSD-2UH	C_0 [N]	6070	7550	9000	15100	25000	36500	60200
	CSD-2UF		9000	16300	22000	35800	65400	81600	-
Permissible dynamic tilting moment ¹⁾	CSD-2UH	M [Nm]	41	64	91	156	313	450	759
	CSD-2UF		91	124	187	258	580	849	-
Tilting moment stiffness ⁵⁾	CSD-2UH	K_B [Nm/arcmin]	13	23	38	72	160	270	510
	CSD-2UF		38	46	75	116	296	532	-
Permissible axial load ³⁾	CSD-2UH	F_a [N]	1010	1130	1240	2050	3210	4560	7440
	CSD-2UF		1240	2220	3120	4660	8170	9260	-
Permissible radial load ²⁾	CSD-2UH	F_r [N]	6740	7580	8280	1380	2150	3050	14155
	CSD-2UF		8280	1490	2090	3120	5470	6200	-

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

¹⁾ These values are valid for moving gears. They are not based on the equation for lifetime calculation of the output bearing but on the maximum allowable deflection of the Harmonic Drive® component set. The values indicated in the table must not be exceeded even if the lifetime equation of the bearing permits higher values.

²⁾ These data are valid for $f_w = 1,3$; $n = 15$ rpm and $L_{10} = 15000$ h.

³⁾ The pitch circle diameter can vary slightly depending on the bearing supplier.

⁴⁾ Average value

¹⁰²⁾ These data are only valid if the following conditions are fulfilled:

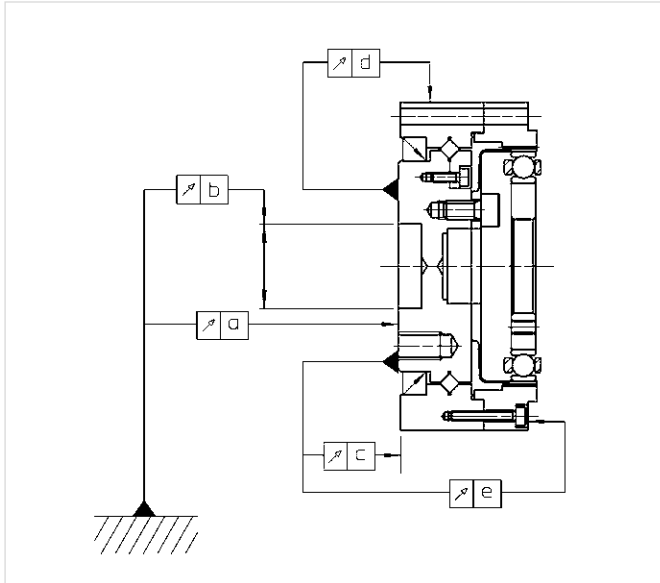
For: M : $F_a = 0$, $F_r = 0$ | F_a : M = 0, $F_r = 0$ | Fr : M = 0, $F_a = 0$

Output Bearing and Housing Tolerances

The following data are valid for a rotating output flange.

CSD-2UH

Illustration 19.1



CSD-2UF

Illustration 19.2

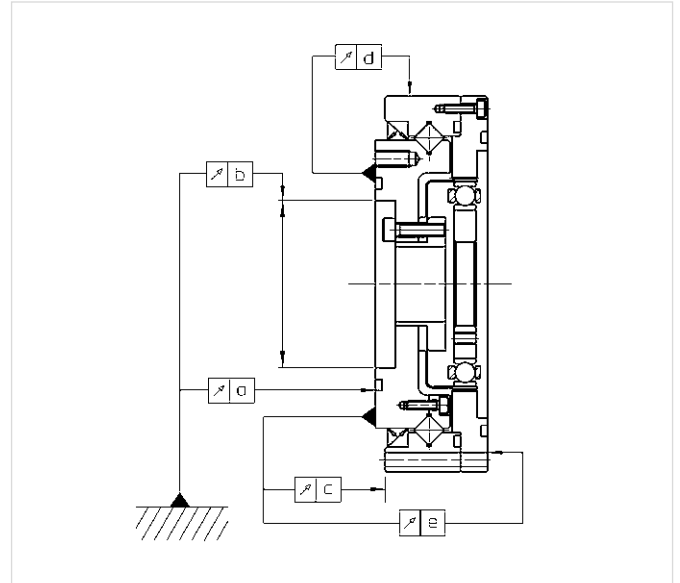


Table 19.3

[mm]

CSD-2UH Size	14	17	20	25	32	40	50
a	0.010	0.010	0.010	0.015	0.015	0.015	0.018
b	0.010	0.012	0.012	0.013	0.013	0.015	0.015
c	0.007	0.007	0.007	0.007	0.007	0.007	0.007
d	0.010	0.010	0.010	0.010	0.010	0.015	0.015
e	0.025	0.025	0.025	0.035	0.037	0.037	0.040

Table 19.4

[mm]

CSD-2UF Size	14	17	20	25	32	40
a	0.010	0.010	0.010	0.015	0.015	0.015
b	0.010	0.010	0.010	0.010	0.013	0.013
c	0.010	0.010	0.010	0.010	0.013	0.013
d	0.010	0.010	0.010	0.010	0.013	0.013
e	0.031	0.031	0.031	0.041	0.047	0.047

4. Actuator Selection Procedure

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

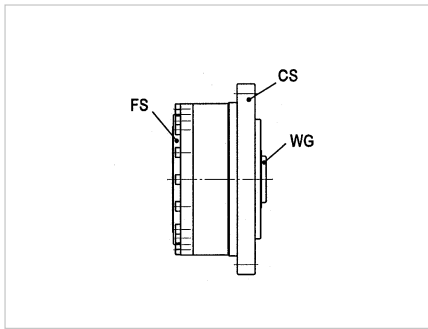
Equation 20.1

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

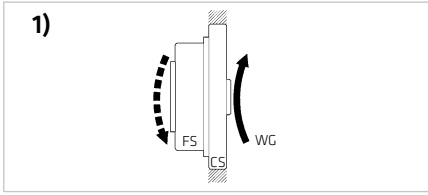
The three main components of the Harmonic Drive® units, Circular Spline (CS), Flexspline (FS) and Wave Generator (WG) can be seen in the illustration 20.2.

Illustration 20.2



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



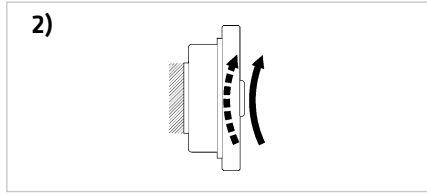
Reduction gearing

CS Fixed
WG Input
FS Output

Equation 21.1

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

Input and output rotate in opposite directions.



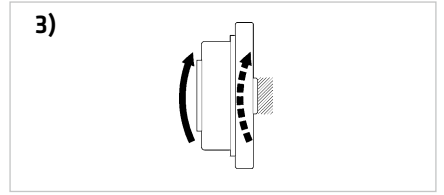
Reduction gearing

FS Fixed
WG Input
CS Output

Equation 21.2

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

Input and output rotate in same direction.



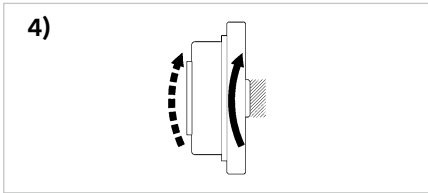
Reduction gearing

WG Fixed
FS Input
CS Output

Equation 21.3

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

Input and output rotate in same direction.



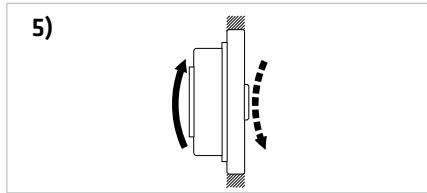
Speed increaser gearing

WG Fixed
CS Input
FS Output

Equation 21.4

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

Input and output rotate in same direction.



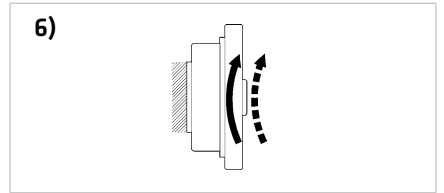
Speed increaser gearing

CS Fixed
FS Input
WG Output

Equation 21.5

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

Input and output rotate in opposite directions.



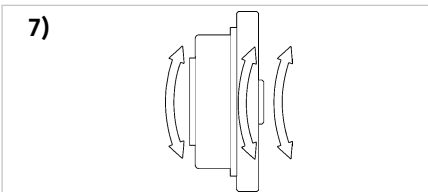
Speed increaser gearing

FS Fixed
CS Input
WG Output

Equation 21.6

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

Input and output rotate in same direction.



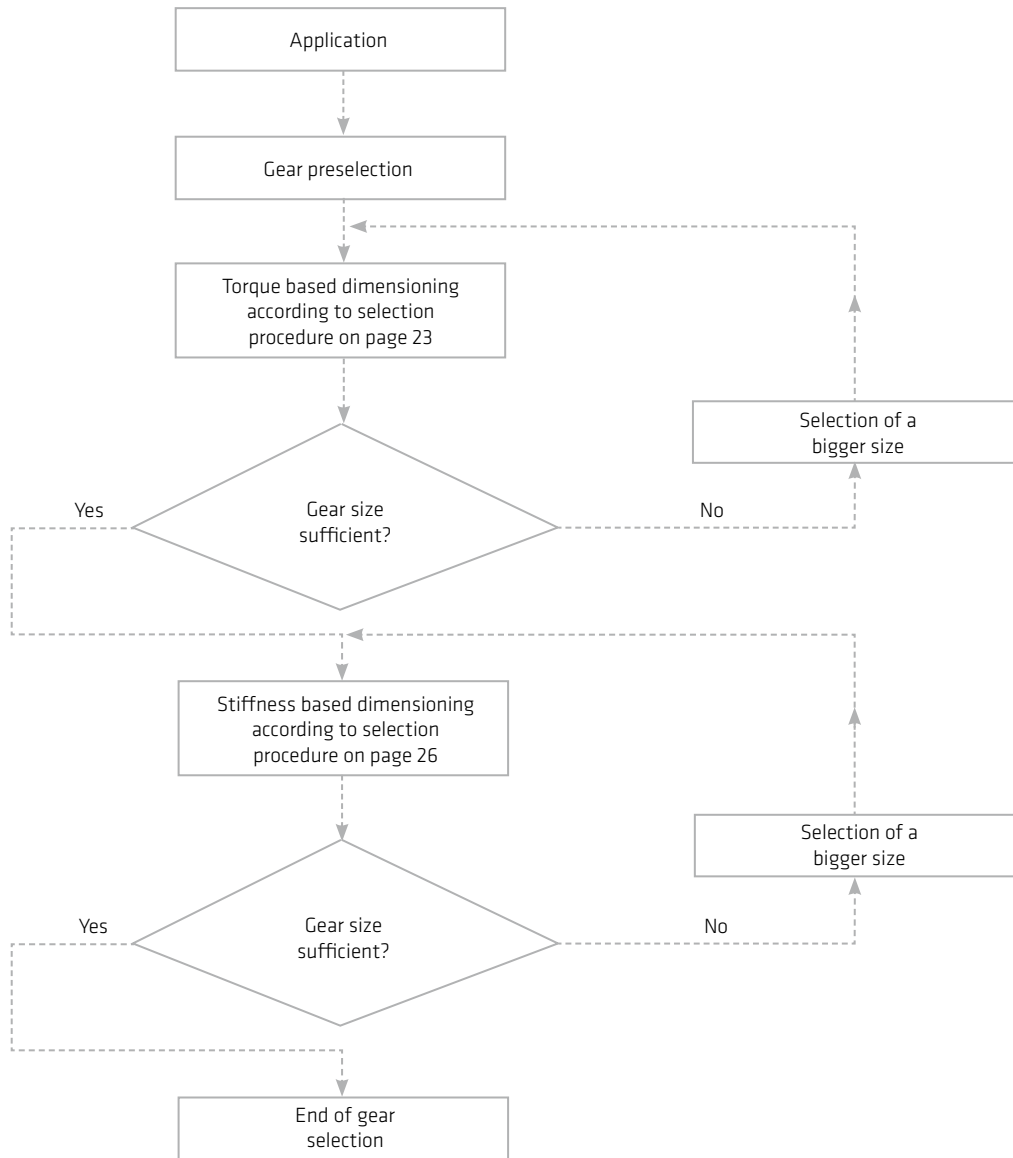
Differential gear

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.

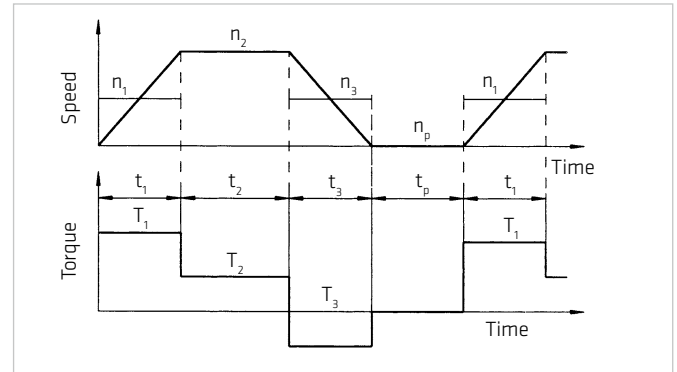


4.1.1 Torque Based Dimensioning

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 23.1



Equation 23.2

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 23.3

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

No

Selection of a bigger size

Equation 23.4

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 23.5

Average input speed

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

Equation 23.6

Permissible maximum input speed

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

Equation 23.7

Permissible average input speed

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

Equation 23.8

Load limit 2, T_R

$$T_{max} \leq T_R$$

Equation 23.9

Load limit 3, T_M

$$T_k \leq T_M$$

Equation 23.10

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 23.11

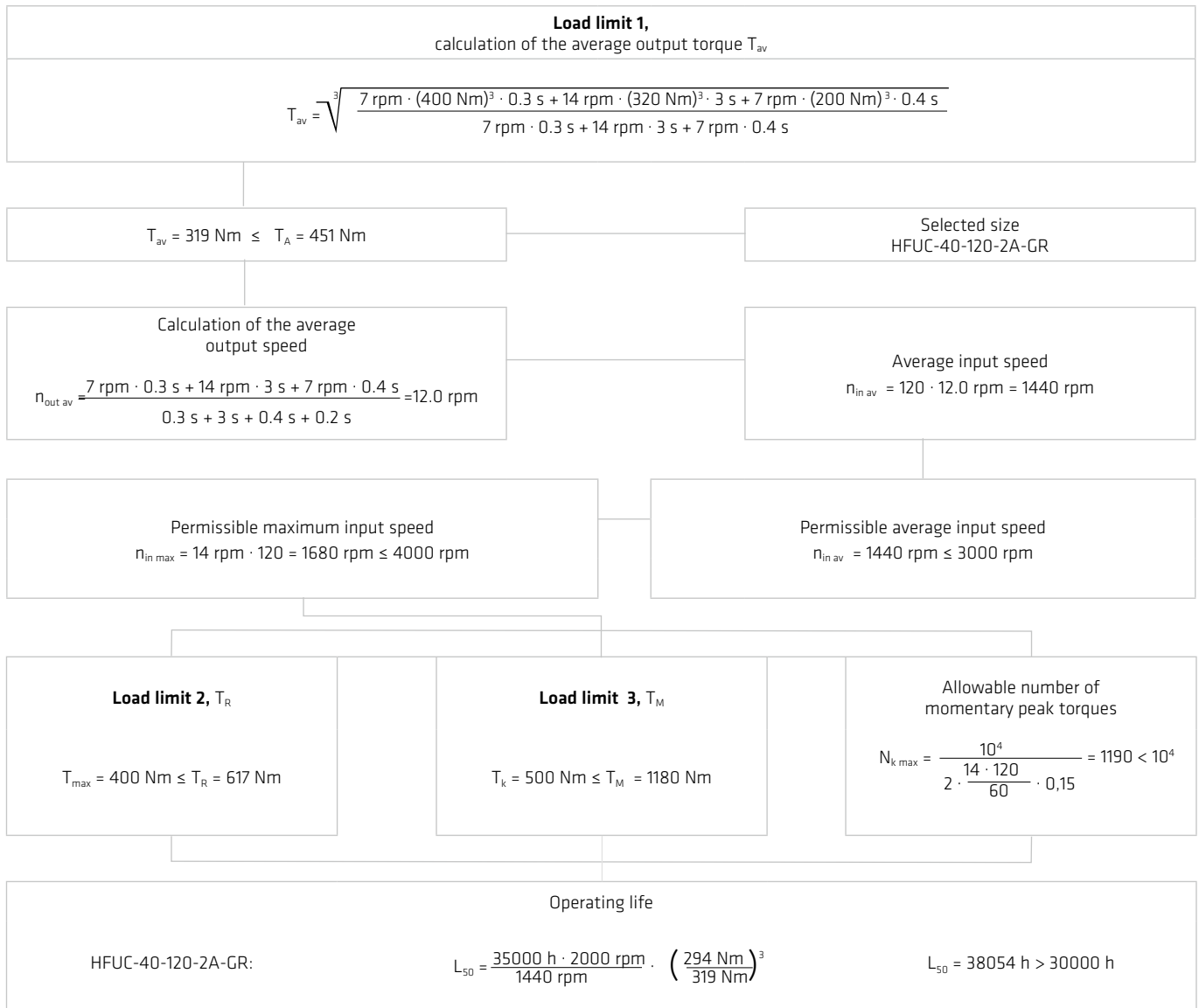
Operating life

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

Values for L_n see table 25.1

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 25.2.

Table 25.1

[h]

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

Equation 25.2

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

Equation 25.3

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

n_N = Rated input speed [rpm]

$n_{in\ av}$ = Average input speed [rpm] (equation 23.5)

T_N = Rated output torque at rated speed [Nm]

T_{av} = Average output torque [Nm] (equation 23.2)

L_n = See table 25.1

4.1.3 Stiffness Based Dimensioning

In addition to the “Torque Based Dimensioning” stated on page 23, we recommend that you carry out a selection based on stiffness. For this, the values provided in table 26.1 for the individual resonance frequencies recommended for each application should be taken into account.

Table 26.1

[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 performance, 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 manipulators, 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 27.1

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

f_n = Resonance frequency [Hz]

K_1 = Gear torsional stiffness K_1 [Nm/rad]

J = Load moment of inertia [kgm²]

allows the calculation of the resonance frequency at the gear output from the given torsional stiffness, K_1 , of the Harmonic Drive[®] gear and the load's moment of inertia. The calculated frequency should correspond with the value provided in table 26.1. 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 24.

Intended application: milling head for woodworking

Moment of inertia at the gear output: 7 kgm². Recommended resonance frequency from table 26.1: ≥ 30 Hz.

Resonance frequency using the preselected gear

HFUC-40-120-2A-GR:

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

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:

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

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 φ at Torque T:

Equation 28.1

$$T \leq T_1$$
$$\varphi = \frac{T}{K_1}$$

Equation 28.2

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

Equation 28.3

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

φ = Angle [rad]
T = 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 28.4

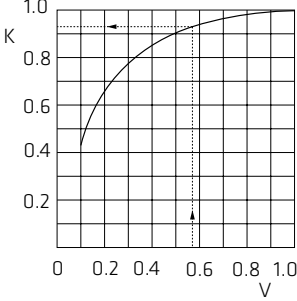
$$\varphi \text{ [arc min]} = \varphi \text{ [rad]} \cdot \frac{180 \cdot 60}{\pi}$$

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.

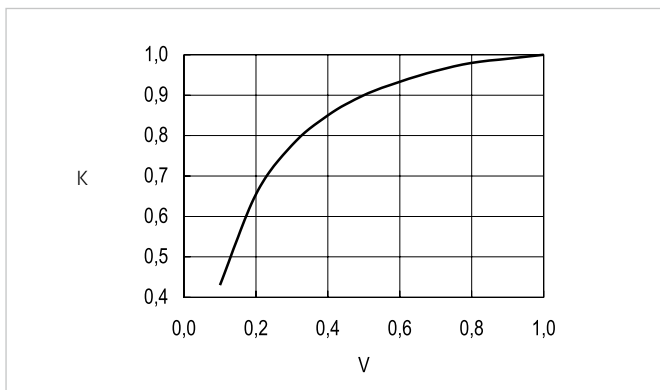
4.3.1 Efficiency Calculations

Table 29.1

Calculation Procedure	Example
	Efficiency of HFUC-20-80-2A-GR with input speed n=1000 rpm output torque T = 19.6 Nm at 20° C ambient temperature. Lubrication: Oil
The efficiency may be determined using the efficiency graphs.	From matching chart $\eta = 78\%$
Calculate the torque factor V. $V = \frac{T_{av}}{T_N} \quad \text{[Equation 29.2]}$ with: T _{av} = Average torque T _N = Rated torque at rated speed	T _{av} = 19.6 Nm T _N = 34.0 Nm $V = \frac{19.6 \text{ Nm}}{34.0 \text{ Nm}} = 0.57$
K depending on gear type and V, see illustration 29.4	
Efficiency $\eta_L = \eta \cdot K$ [Equation 29.3]	$\eta_L = 78 \cdot 0.93 = 73\%$

Calculating Factor K

Illustration 29.4

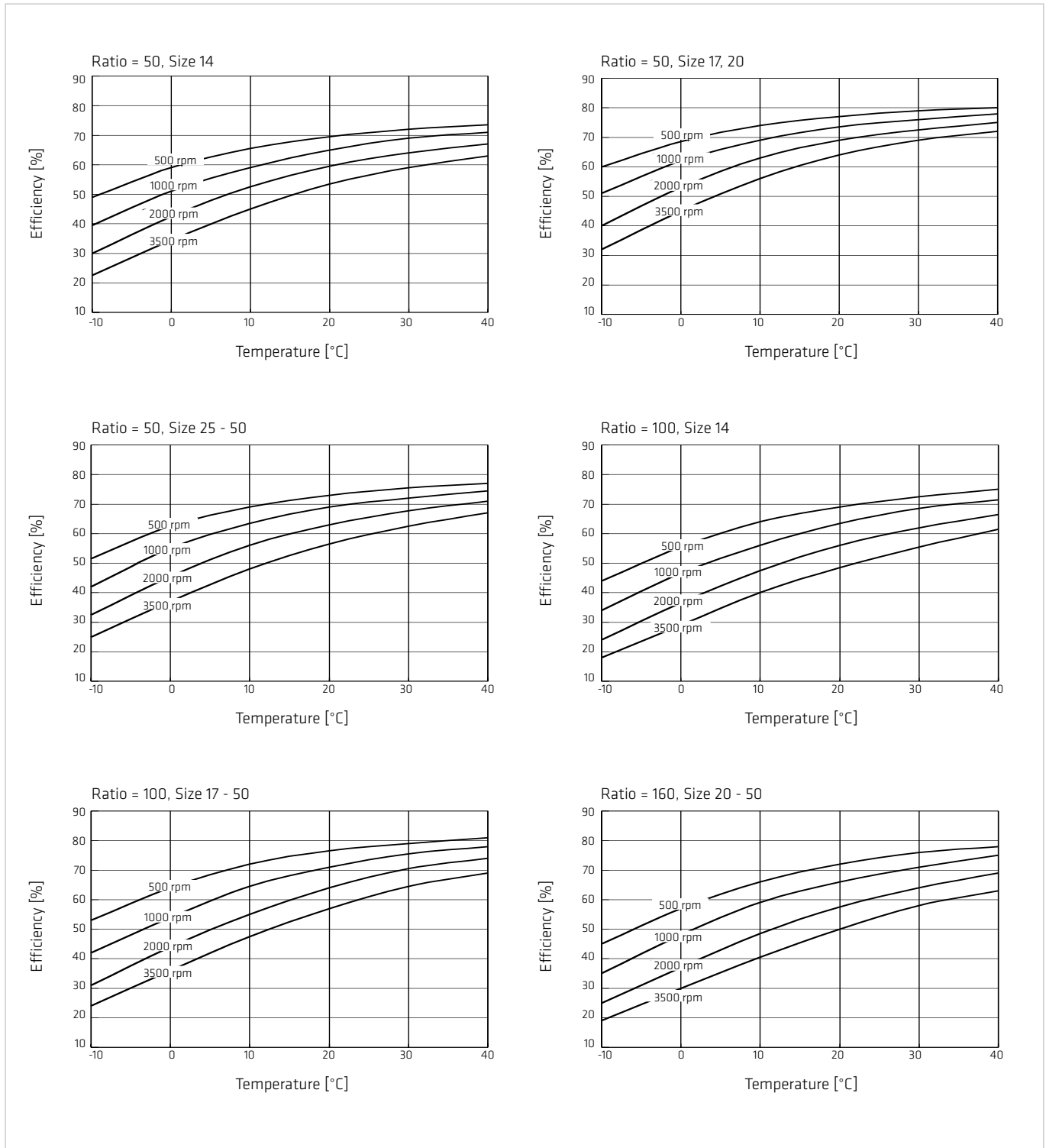


4.3.2 Efficiency Tables

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

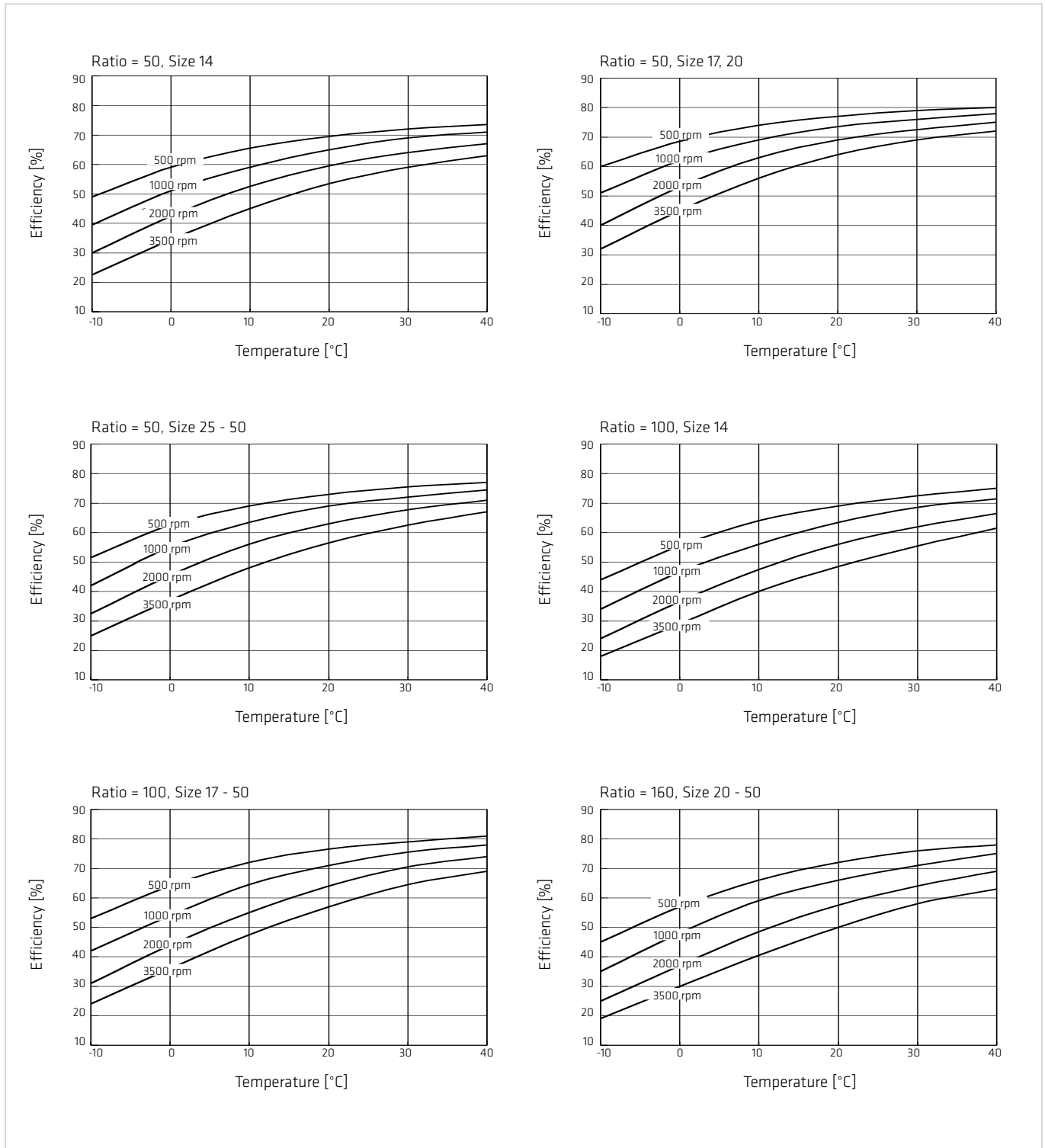
CSD-2UH

Illustration 30.1



CSD-2UF

Illustration 31.1



4.4 Free Load Torques

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

CSD-2UH

Illustration 32.1

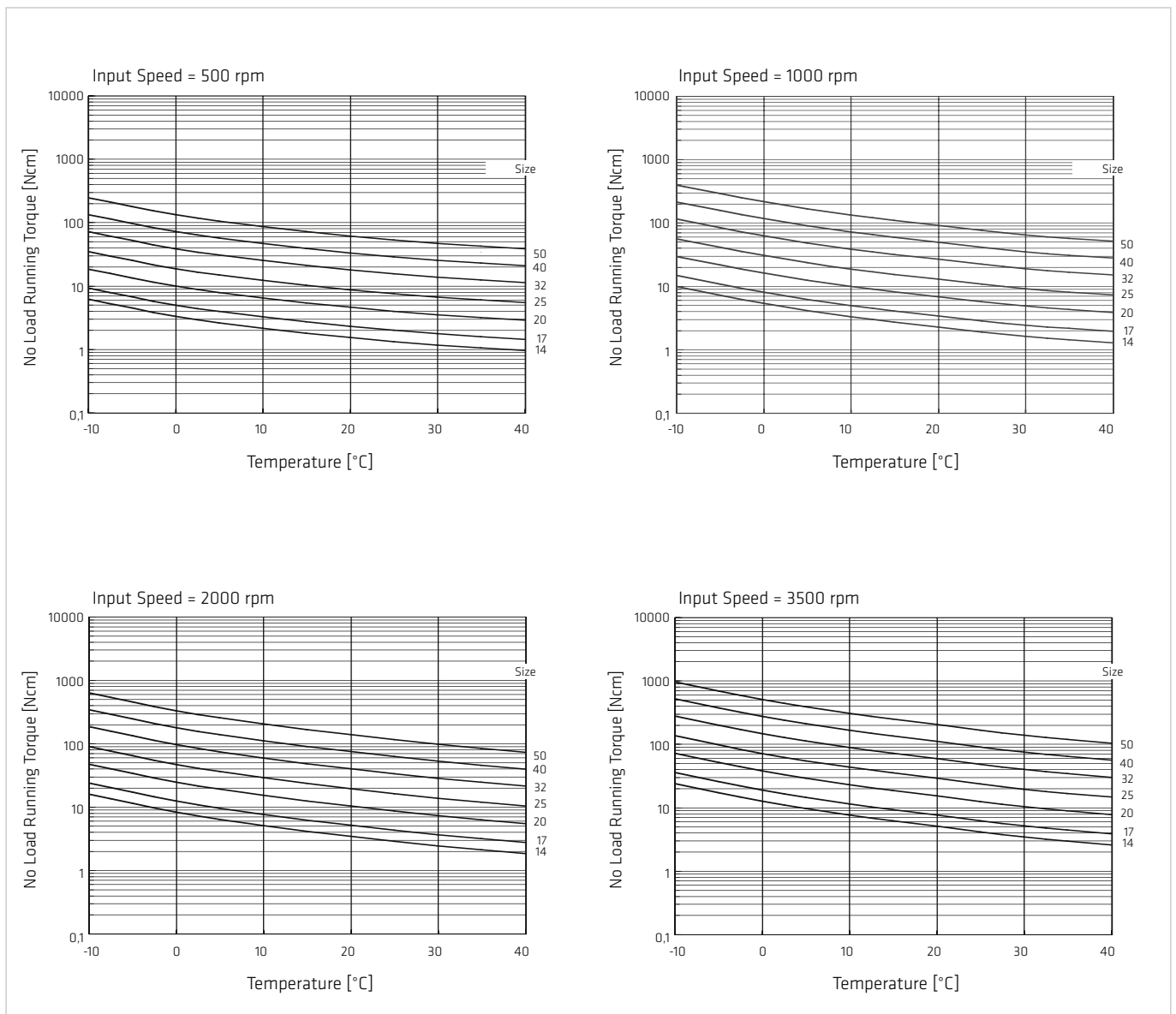
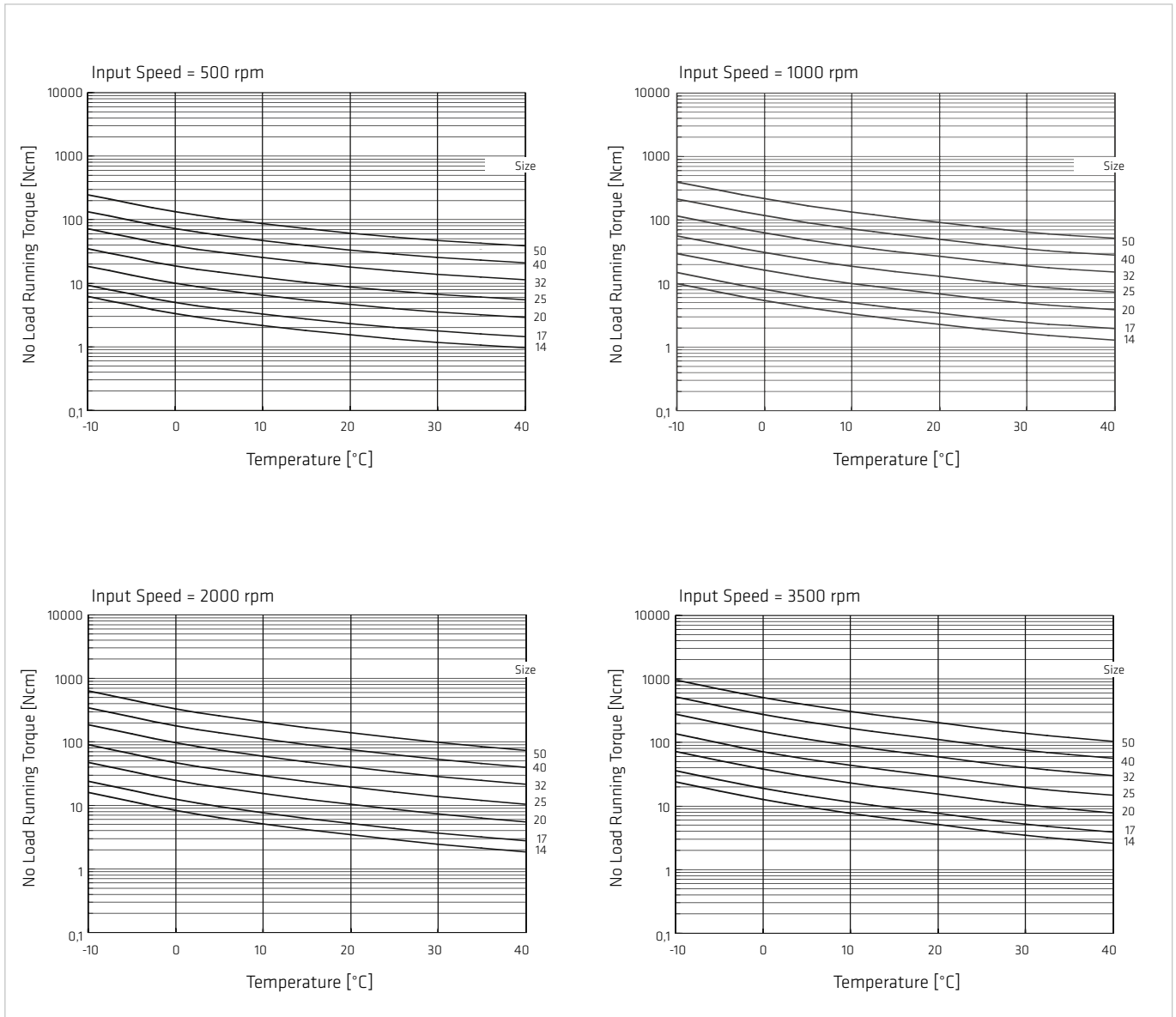


Illustration 33.1



Compensation Values for No Load Running Torque CSD-2UH

Table 34.1

[Ncm]

Ratio	Size						
	14	17	20	25	32	40	50
50	0,93	1,5	2,3	3,8	7,3	12	22
160	-	-	-0,7	-1,2	-2,2	-3,6	-6,4

Compensation Values for No Load Running Torque CSD-2UF

Table 34.2

[Ncm]

Ratio	Size						
	14	17	20	25	32	40	50
50	1,4	1,8	2,6	4,3	8,2	14	
160	-	-	-84	-1,3	-2,5	-4,2	

4.4.2 No Load Starting Torque

No Load Starting Torque CSD-2UH

Table 34.3

[Ncm]

Ratio	Size						
	14	17	20	25	32	40	50
50	4,4	6,7	8,9	16	32	55	102
100	2,8	3,8	5,1	9,1	20	32	60
160	-	-	3,9	7,2	15	26	47

No Load Starting Torque CSD-2UF

Table 34.4

[Ncm]

Ratio	Size						
	14	17	20	25	32	40	50
50	5,3	7,5	9,7	17	34	58	
100	3,2	4,2	5,5	9,6	21	33	
160	-	-	4,1	7,4	16	27	

4.4.3 No Load Back Driving Torque

No Load Back Driving Torque CSD-2UH

Table 34.5

[Nm]

Ratio	Size						
	14	17	20	25	32	40	50
50	2,9	4,3	5,2	9,5	19	33	61
100	3,5	4,6	6,0	11	23	38	71
160	-	-	7,4	13	30	48	89

No Load Back Driving Torque CSD-2UF

Table 34.6

[Nm]

Ratio	Size						
	14	17	20	25	32	40	50
50	3,3	4,7	5,6	10	20	34	
100	3,9	5,0	6,4	11	24	39	
160	-	-	7,8	14	31	49	

4.5 Life for Continuous Operation

The operating life of the output bearing can be calculated using equation 35.1.

Equation 35.1

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

with:

- L_{10} [h] = Operating life
- n_{av} [rpm] = Average output speed (equation 35.2)
- C [N] = Dynamic load rating see table "Output Bearing Ratings"
- P_c [N] = Dynamic equivalent load (equation 36.1)
- f_w = Operating factor (table 35.3)
- B = Bearing type (table 35.4)

Average Output Speed

Equation 35.2

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

Table 35.3

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 35.4

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

Dynamic Equivalent Load

Equation 36.1

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

with:

F_{rav} [N] = Radial force (equation 36.2)

x = Radial load factor (table 34.4)

F_{aav} [N] = Axial force (equation 36.3)

y = Axial load factor (table 34.4)

d_p [m] = Pitch circle (see capital 3.3.5)

M = Tilting moment

Equation 36.2

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

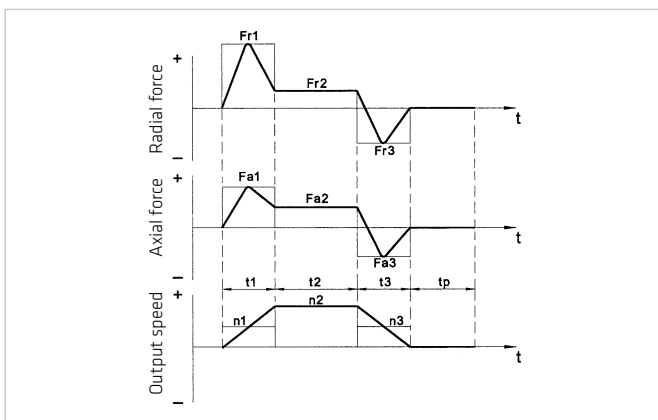
Equation 36.3

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

Table 36.4

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 36.5



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 37.1

Equation 37.1

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

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 18.1)

P_c [N] = Dynamic equivalent load (equation 36.1)

φ [deg] = Oscillating angle

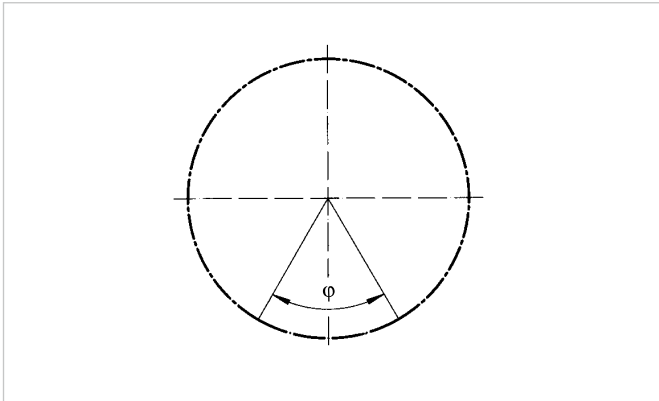
f_w = Operating factor (table 35.3)

* one oscillation means 2φ

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 37.2



4.6 Permissible Static Tilting Moment

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

Equation 38.1

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

and so

Equation 38.2

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

f_s = Static load safety factor

($f_s = 1.5 \dots 3$) (table 38.3)

C_0 = Static load rating

$F_r = F_a = 0$

$x_0 = 1$

$y_0 = 0.44$

P_0 = Static equivalent load

d_p = Pitch circle diameter of the output bearing

M = Moment acting

M_0 = Allowable static overturning moment

Table 38.3

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

4.7 Angle of Inclination

The angle of inclination of the output flange, as a function of the tilting moment acting on the output bearing, can be calculated by means of equation 38.4:

Equation 38.4

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

with:

γ [arcmin] = Angle of inclination of the output flange

M [Nm] = Tilting moment acting on the output bearing

K_B [Nm/arcmin] = Moment stiffness of the output bearing

4.8 Lubrication

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.

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 39.1

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 39.2

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 40.1 gives some important information regarding Harmonic Drive® lubricating greases.

Table 40.1

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

Notes:

+ = Good

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

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

Special Operating Demands

Table 54.1 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 41.1

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 41.2

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

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 42.1

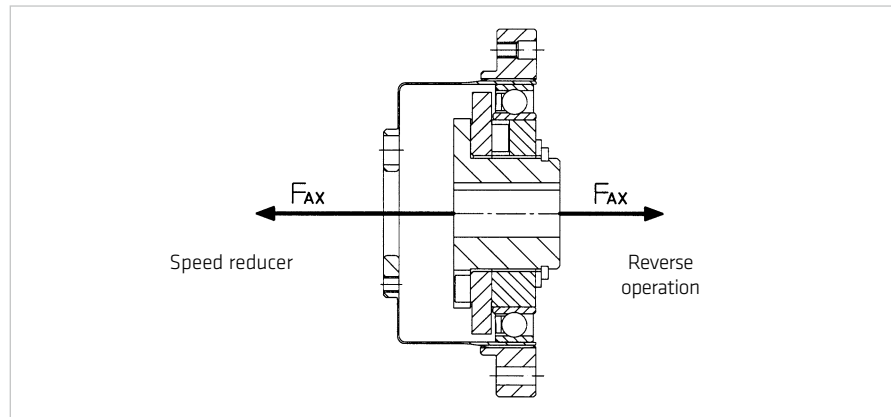


Table 42.2

Ratio		
30	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 32^\circ$	[Equation 42.3]
50	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 30^\circ + 2\mu PF$	[Equation 42.4]
80...160	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 20^\circ + 2\mu PF$	[Equation 42.5]

with:

- F_{AX} = Axial force [N]
- D = (Size) · 0.00254 [m]
- T = Torque at the output [Nm]
- μ = 0.07 Coefficient of friction
- $2\mu PF$ = Additional force (only CSD) [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 42.6

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 and refer to table 7 for allowed oil types. 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 full features of Harmonic Drive® Units to be exploited fully, it is essential that the tolerances according to table 44.2 are observed for the input assembly.

Illustration 44.1

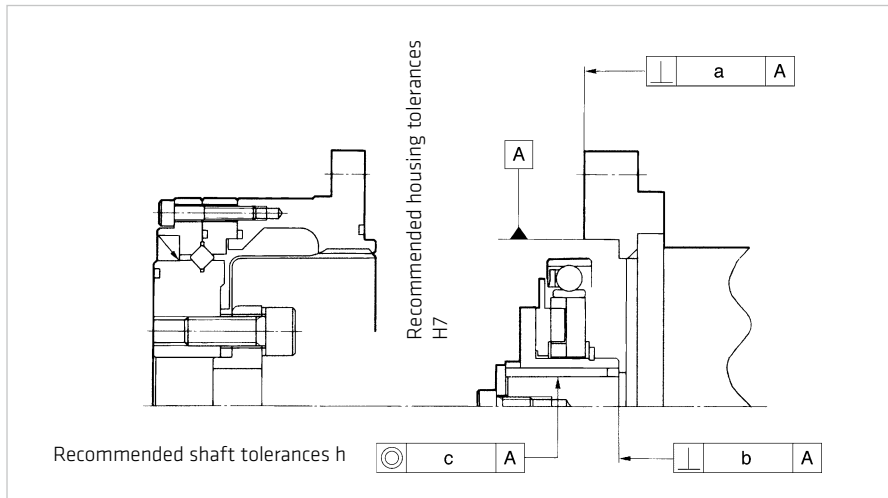


Table 44.2

[mm]

Sizes	14	17	20	25	32	40	50
a	0.011	0.015	0.017	0.024	0.026	0.026	0.028
b	0.008	0.010	0.010	0.012	0.012	0.012	0.015
c	0.016	0.018	0.019	0.022	0.022	0.024	0.030

For the direct mounting of a Wave Generator without Oldham coupling (optional) on a motor shaft, the shaft tolerances should fulfill the DIN 42955 R standard.

5.5 Lubrication

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 Reservoir

For assembly please ensure that the grease reservoir is filled up with grease (dimension c and $\varnothing d$ in illustration 45.1 and table 45.2).

Illustration 45.1

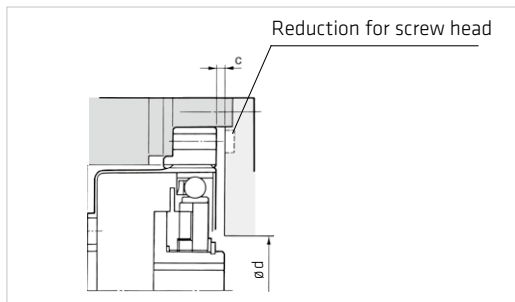


Table 45.2

Size	14	17	20	25	32	40	50
c*	1	1	1.5	1.5	2	2.5	3.5
c**	3	3	4.5	4.5	6	7.5	7.5
ø d	16	26	30	37	37	45	45

c* Horizontal and vertical - Wave Generator below

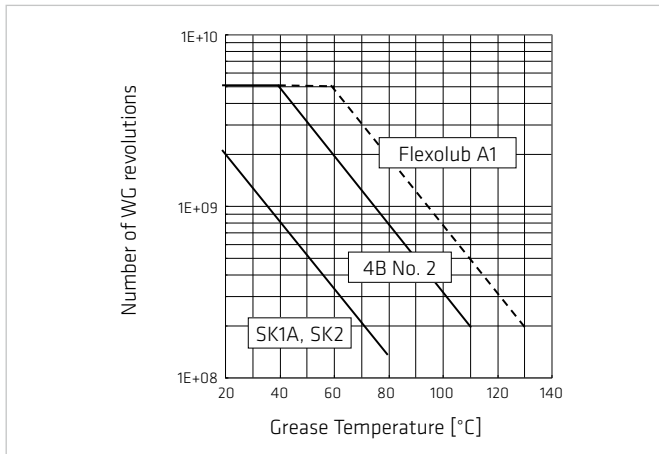
c** Vertical - Wave Generator above

5.5.2 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 46.3, 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. 8.5×10^8 revolutions of the input shaft. All grease change data refers to rated speed and rated torque.

Illustration 46.1



Equation 46.3

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

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

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

5.7.1 Motor Assembly

The Units have been designed for simple motor assembly. This means that the Wave Generator is mounted directly on the motor shaft. When ordering, please indicate which motor type is to be used, so that the Wave Generator can be manufactured to match. If required, units can be provided including the motor adaptor flange or with a ready assembled motor. In addition to the correct dimensioning of the motor, particular attention must be paid to the geometric tolerances of the motor output flange and motor shaft. The shaft and flange tolerances of the motor should fulfill the requirements of the DIN 42955 standard. To fully exploit the excellent performance characteristics of the units we recommend the use of motors fulfilling DIN 42955 R tolerances.

Adaptor Flange

The transmission accuracy of the gearbox is dependent on the manufacturing accuracy of the motor adaptor flange. Please also note section 5.6.3.

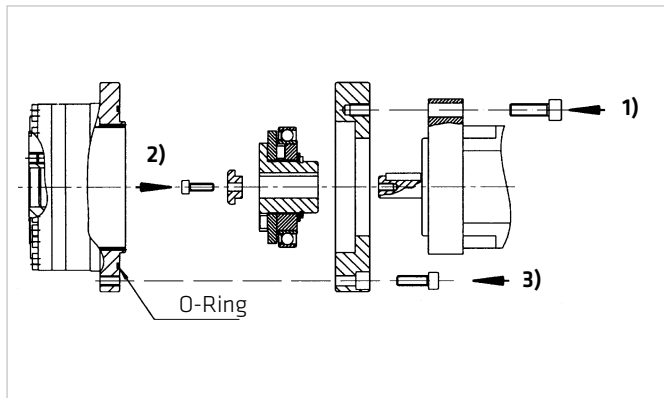
Assembly

As shown in illustration 47.2 and 47.3, there are two basic methods of assembly. Table 47.1 provides recommendations concerning the appropriate assembly procedure.

Table 47.1

Size	14	17	20	25	32	40	50	Assembly according to illustration
Motor-Centering- \varnothing	<35.5	<43.5	<50.0	<62.5	<81.5	<100.0	<124.5	47.2
	≥ 35.5	≥ 43.5	≥ 50.0	≥ 62.5	≥ 81.5	≥ 100.0	≥ 124.5	47.3

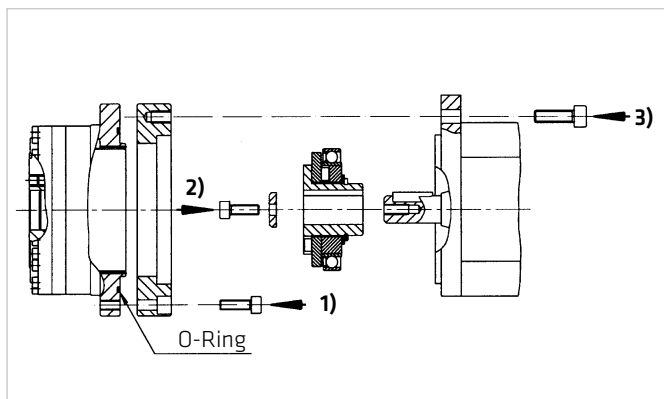
Illustration 47.2



Assembly procedure according to illustration 47.2:

- 1) Attachment of the adaptor flange to the motor.
- 2) Attachment of the Wave Generator to the motor shaft.
- 3) Attachment of the adaptor flange and motor to the unit.

Illustration 47.3



Assembly procedure according to illustration 47.3:

- 1) Attachment of the adaptor flange to the unit.
- 2) Attachment of the Wave Generator to the motor shaft.
- 3) Attachment of the motor to the adaptor flange and gearbox.

5.7.2 Assembly of the Wave Generator

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 48.2. When the Wave Generator hub is glued to the input shaft please consider section 5.7.

Illustration 48.1

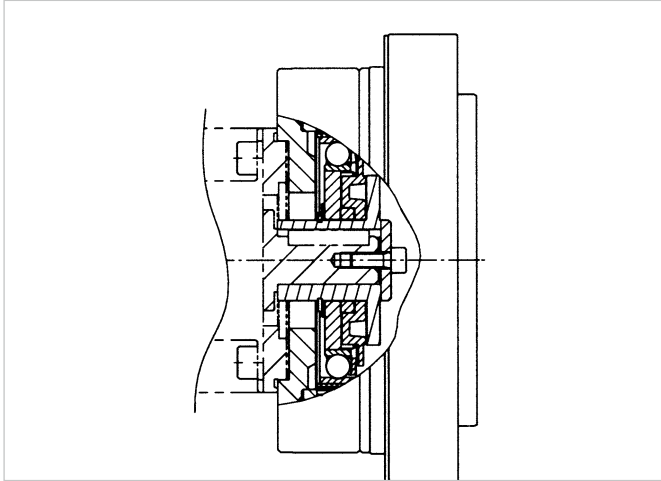
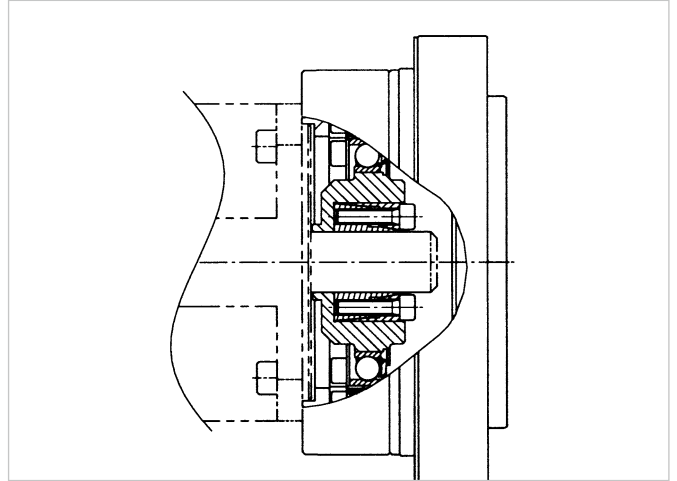


Illustration 48.2



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 59.3. When the gear is oil lubricated, fill in the prescribed oil quantity.

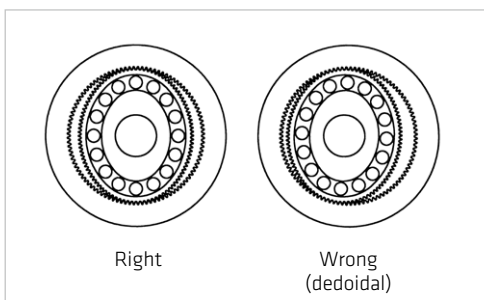
5.7.4 Assembly Control

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 48.3



5.7.5 Output Flange Assembly

In the case of the HFUS-2UH and -2UJ Units the load is connected to the output bearing by means of a flange.

Table 49.1

Size	14	17	20	25	32	40	50
Number of Bolts	6	8	12	12	12	12	12
Bolt Size	M3	M3	M3	M3	M4	M5	M6
Pitch circle diameter [mm]	44	54	62	75	100	120	150
Tightening torque [Nm]	2	2	2	2	4.5	9	15.3
Torque transmitting capacity [Nm]	55	90	155	188	422	810	1434

5.7.6 Housing Flange Assembly

Table 49.2

Size	CSD - 2A							CSD - 2A - BB				
	14	17	20	25	32	40	50	20	25	32	40	50
Number of Bolts	9	8	9	9	11	10	11	12	12	14	14	14
Bolt Size	M3	M4	M4	M5	M6	M8	M10	M3	M4	M5	M6	M8
Pitch circle diameter [mm]	17	19.5	24	30	41	48	62	26	32	42	52	65
Screw tightening torque [Nm]	2.0	4.5	4.5	9	15.3	37	74	2	4.5	9	15.3	37
Torque transmitting capacity [Nm]	32	55	76	152	359	696	1560	64	135	331	578	1320

- Friction coefficient $\mu = 0.15$
- To obtain good friction between the mating surfaces, clean and degrease the surfaces thoroughly. Keep the surfaces completely dry.
- Apply Loctite No. 243 to the threads of bolts.
- Steel or cast iron is preferred for the female thread.
- 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]

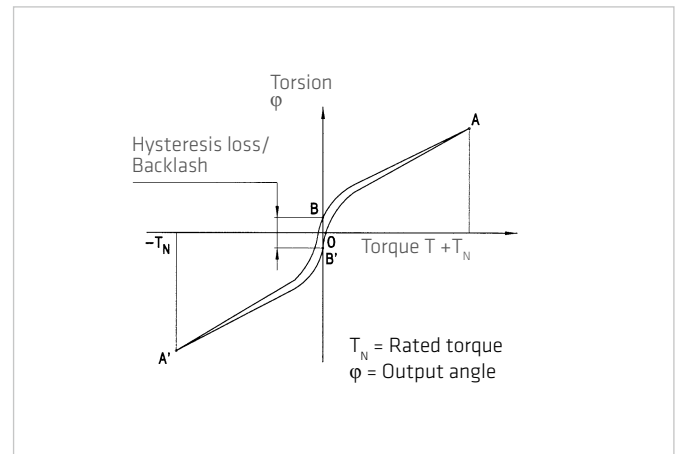
Maximum permissible average gear input speed for oil lubrication.

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 τ_e [s]

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

Hollow shaft diameter d_H [mm]

Free inner diameter of the continuous axial hollow shaft.

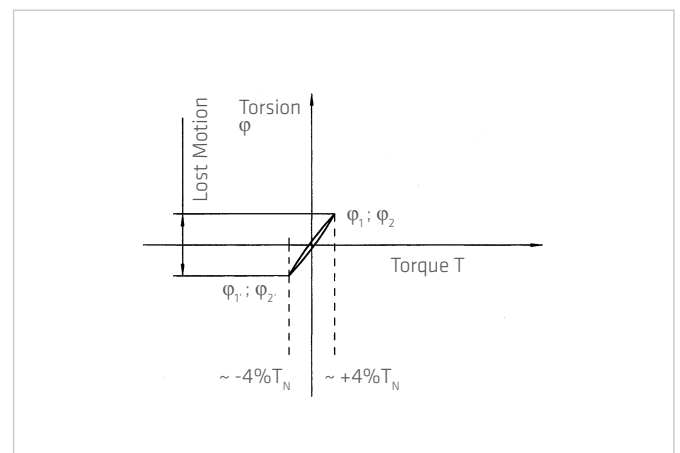
Inductance (L-L) L_{L-L} [mH]

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

Lost Motion (Harmonic Drive® Gearing) [arcmin]

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

The illustration shows the angle of rotation ϕ measured against the applied output torque as a hysteresis curve, with the Wave Generator locked. The lost motion measurement of the gear is taken with an output torque of about $\pm 4\%$ 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 τ_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 [kgm²]

Mass moment of inertia at motor side.

Moment of inertia J_{in} [kgm²]

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

Moment of inertia J_{out} [kgm²]

Mass moment of inertia with respect to the output.

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

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

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.

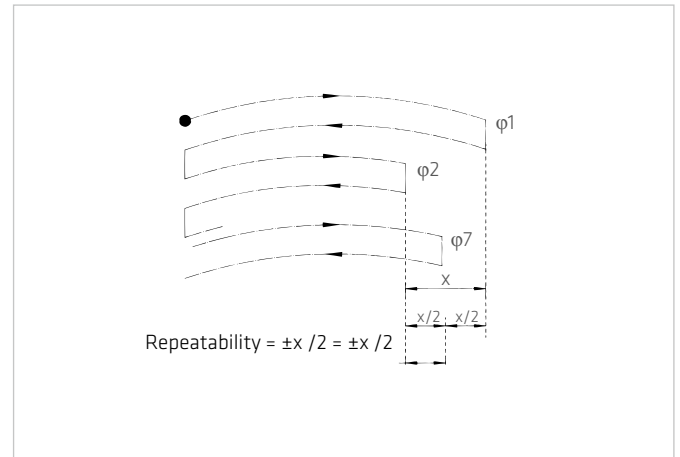
Ratio $i []$

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} [Ω]

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

Size

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

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

2) CHM Servo motor series

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

3) Direct drives from the TorkDrive® series

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

Static load rating C_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_{rms}]

Quotient of stall torque and stall current.

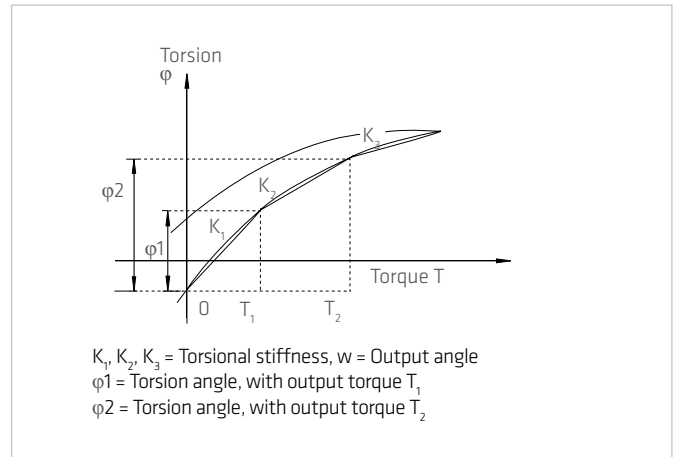
Torque constant (output) k_{Tout} [Nm/A_{rms}]

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

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

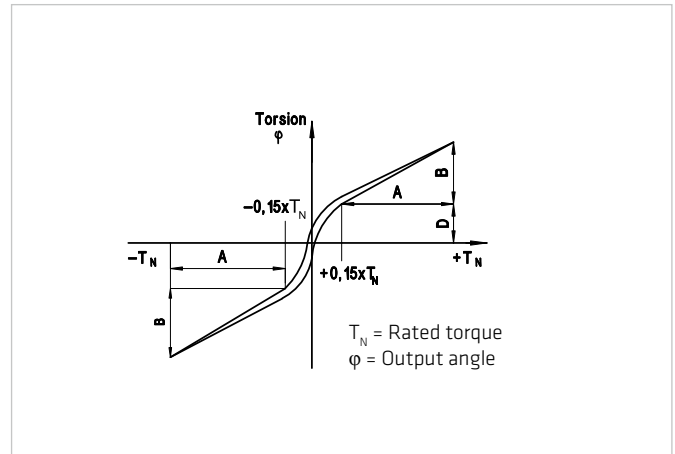
The amount of elastic rotation at the output for a given torque and the Wave Generator blocked. The torsional stiffness K_3 describes the stiffness above a defined reference torque where the stiffness is almost linear. Values below this torque can be requested or found on our web site.

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



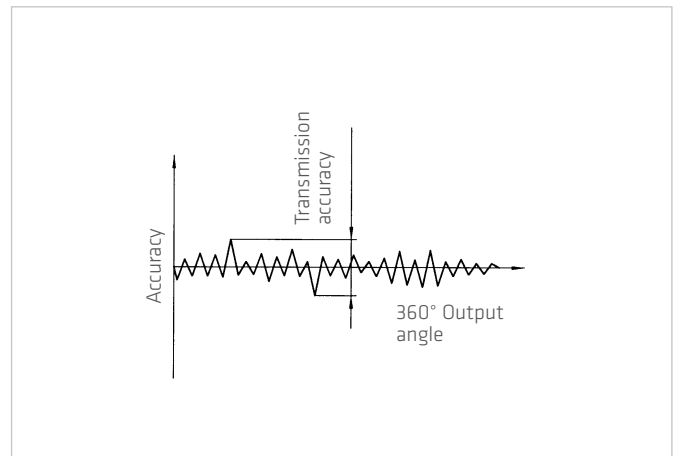
Torsional stiffness (Harmonic Planetary gears) K [Nm/rad]

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