Engineering Data
CPU-M/H/S Units

Harmonic Drive AG

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...just move it!

Contents

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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65555 Limburg / Lahn
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1.1 Description of Safety Alert Symbols

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

1.2 Disclaimer and Copyright

We have checked the contents of this document. Since errors cannot be ruled out entirely, we do not accept liability for mistakes which may have occurred. Notification of any mistake or suggestions for improvements will be gratefully received and any necessary correction will be included in subsequent editions.

2. Safety and Installation Instructions

Please take note of the information and instructions in this document. Specialy designed models may differ in technical detail. If in doubt, we strong recommend that you contact the manufacturer, giving the type designation and serial number for clarification.

2.1 Hazards

⚠ DANGER

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

Observing the five safety rules:
- Disconnect mains
- Prevent reconnection
- Test for absence of harmful voltages
- Ground and short circuit
- Cover or close off nearby live parts

The measures taken above must only be withdrawn when the work has been completed and the device is fully assembled.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

⚠ DANGER

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

⚠ DANGER

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

⚠ WARNING

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

⚠ ATTENTION

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

ADVICE

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

ADVICE

Cables must not come into direct contact with hot surfaces.

INFORMATION

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

2.2 Intended Purpose

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

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

The products may only be operated within the operating ranges and environmental conditions shown in the documentation (altitude, degree of predection, temperature range etc).
Before plant and machinery which have Harmonic Drive® products built into them are commissioned, the compliance must be established with the Machinery Directive, Low Voltage Directive and EMC guidelines.

Plant and machinery with inverter driven motors must satisfy the predection requirements in the EMC guidelines. It is the responsibility of the installer to ensure that installation is undertaken correctly.
Signal and power lines must be shielded. The EMC instructions from the inverter manufacturer must be observed in order that installation meets the EMC regulations.

2.3 Non Intended Purpose

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

ADVICE

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

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

2.4 Declaration of Conformity

Harmonic Drive® gears are components for installation in machines as defined by the machine directive 89/392/EWG. Commissioning is prohibited until such time as the end product has been proved to conform to the provisions of this directive.

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

3.1 Product Description

Increased precision output bearing and flexible connectivity

The CPU Series Units are available in nine sizes with gear ratios of 30, 50, 80, 100, 120 and 160:1 offering repeated peak torques from 9 to 1840 Nm.

The precision output bearing with high tilting capacity often allows direct attachment of heavy payloads without the need for further support, thereby providing simple and space saving design installations.

The CPU Series is available in three versions: the CPU-M Unit for direct mounting of any servo motor, the CPU-H Unit with hollow shaft to feed through supply lines for further drive systems and the CPU-S Unit with stainless steel input shaft enabling flexible integration into your design.

If required, the Units are available as specific configurations tailored to your application, or with particularly high corrosion protection. The high capacity output bearing with maximum tilting rigidity and precision means that the Units can quickly and easily absorb high payloads and feature long service life. The Units are fully sealed and thus ideally suited for use in harsh ambient conditions. The Units accurate positioning guarantees stable machine characteristics with short cycle times guaranteed.

3.2 Ordering Code

Table 9.1

Series	Sizes	Ratio [2)]						Version	Code for motor adaptation	Special design
CPU	14A	30	50	80	100			M H S	Depending on motor type	According to customer requirements
	17A	30	50	80	100	120				
	20A	30	50	80	100	120	160			
	25A	30	50	80	100	120	160			
	32A	30	50	80	100	120	160			
	40A		50	80	100	120	160			
	45A		50	80	100	120	160			
	50A		50[1)]	80	100	120	160			
	58A		50[1)]	80	100	120	160			
Ordering code										
CPU	**- 25A**	**-**		**100**				**M**	**19.22**	**SP**

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

Table 9.2

Version	
Ordering code	**Description**
M	Unit for motor assembly
H	Unit with hollow shaft
S	Unit with solid input shaft

Clarification of the technical data can be found in the Glossary

3.3 Technical Data

3.3.1 General Technical Data

Table 10.1

	Unit	CPU-14			
Ratio	i [ ]	30	50	80	100
Repeated peak torque	T_R [Nm]	9.0	18	23	28
Average torque	T_A [Nm]	6.8	6.9	11	11
Rated torque	T_N [Nm]	4.0	5.4	7.8	7.8
Momentary peak torque	T_M [Nm]	17	35	47	54
Maximum input speed	$n_{in\ (max)}$ [rpm]	8500			
Average input speed	$n_{av\ (max)}$ [rpm]	3500/3000[1)]			
Moment of inertia CPU-M	J_{in} [$x10^{-4}$ kgm^2]	0.033			
Moment of inertia CPU-H	J_{in} [$x10^{-4}$ kgm^2]	0.091			
Moment of inertia CPU-S	J_{in} [$x10^{-4}$ kgm^2]	0.025			
Weight CPU-M	m [kg]	0.54			
Weight CPU-H	m [kg]	0.67			
Weight CPU-S	m [kg]	0.64			

[1)] Valid for CPU-H

Table 10.2

	Unit	CPU-17				
Ratio	i [ ]	30	50	80	100	120
Repeated peak torque	T_R [Nm]	16	34	43	54	54
Average torque	T_A [Nm]	12	26	27	39	39
Rated torque	T_N [Nm]	8.8	16	22	24	24
Momentary peak torque	T_M [Nm]	30	70	87	110	86
Maximum input speed	$n_{in\ (max)}$ [rpm]	8500				
Average input speed	$n_{av\ (max)}$ [rpm]	3500/3000[2)]				
Moment of inertia CPU-M	J_{in} [$x10^{-4}$ kgm^2]	0.079				
Moment of inertia CPU-H	J_{in} [$x10^{-4}$ kgm^2]	0.193				
Moment of inertia CPU-S	J_{in} [$x10^{-4}$ kgm^2]	0.059				
Weight CPU-M	m [kg]	0.79				
Weight CPU-H	m [kg]	1.0				
Weight CPU-S	m [kg]	0.95				

[2)] Valid for CPU-H

3.3.2 Dimensions

Illustration 11.1 CPU-14-M [mm]

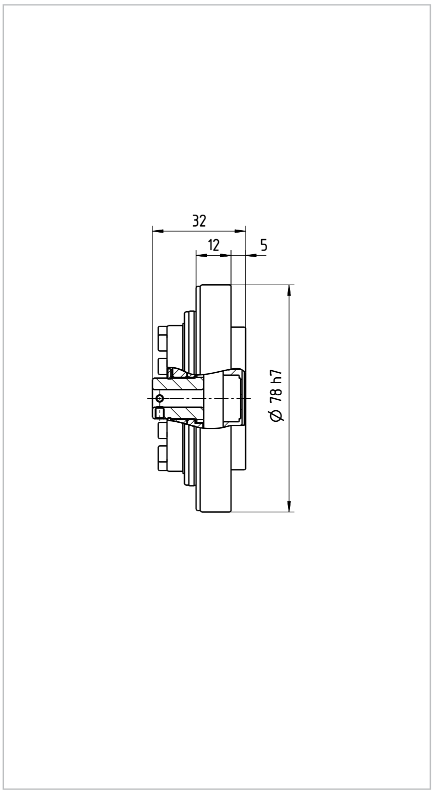

Illustration 11.2 CPU-14-H [mm]

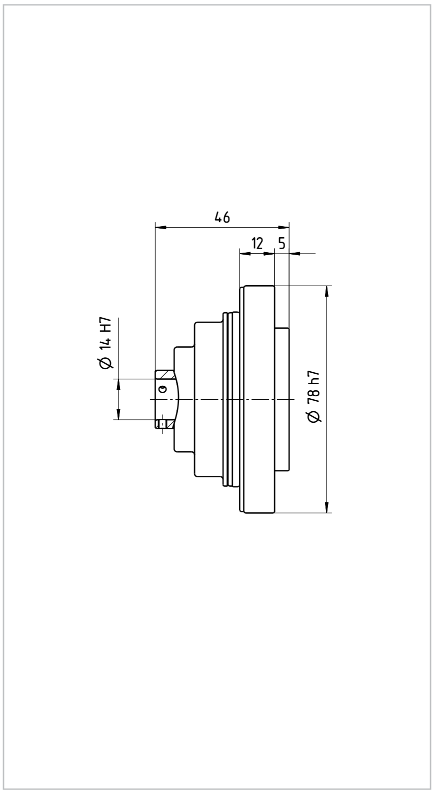

Illustration 11.3 CPU-14-S [mm]

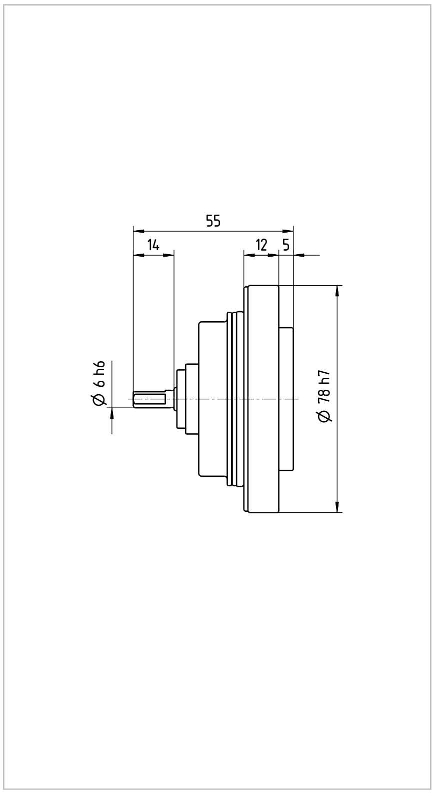

Illustration 11.4 CPU-17-M [mm]

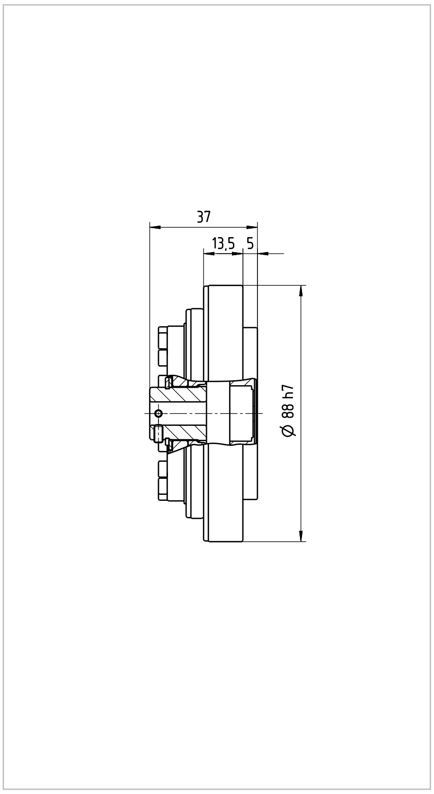

Illustration 11.5 CPU-17-H [mm]

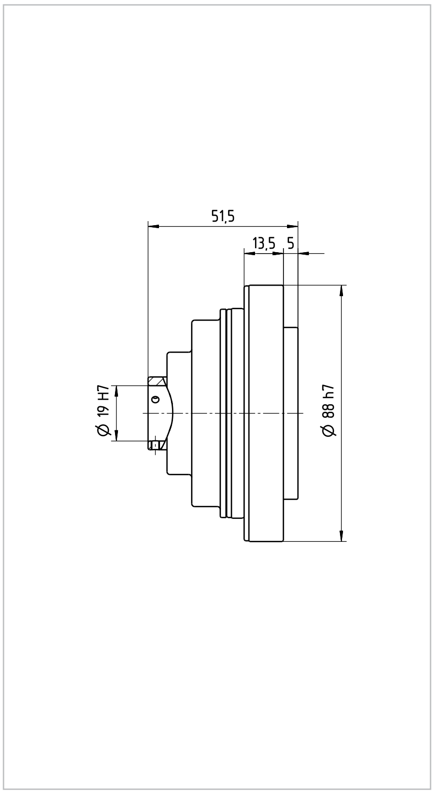

Illustration 11.6 CPU-17-S [mm]

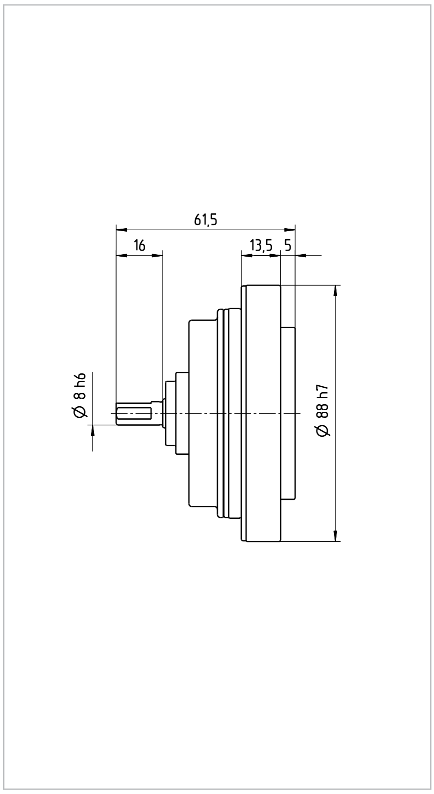

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Table 12.1

	Unit	CPU-20					
Ratio	i [ ]	30	50	80	100	120	160
Repeated peak torque	T_R [Nm]	27	56	74	82	87	92
Average torque	T_A [Nm]	20	34	47	49	49	49
Rated torque	T_N [Nm]	15	25	34	40	40	40
Momentary peak torque	T_M [Nm]	50	98	127	147	147	147
Maximum input speed	$n_{in\ (max)}$ [rpm]	6500					
Average input speed	$n_{av\ (max)}$ [rpm]	3500/3000[1)]					
Moment of inertia CPU-M	J_{in} [$x10^{-4}$ kgm^2]	0.193					
Moment of inertia CPU-H	J_{in} [$x10^{-4}$ kgm^2]	0.404					
Moment of inertia CPU-S	J_{in} [$x10^{-4}$ kgm^2]	0.137					
Weight CPU-M	m [kg]	1.3					
Weight CPU-H	m [kg]	1.55					
Weight CPU-S	m [kg]	1.4					

[1)] Valid for CPU-H

Table 12.2

	Unit	CPU-25					
Ratio	i [ ]	30	50	80	100	120	160
Repeated peak torque	T_R [Nm]	50	98	137	157	167	176
Average torque	T_A [Nm]	38	55	87	108	108	108
Rated torque	T_N [Nm]	27	39	63	67	67	67
Momentary peak torque	T_M [Nm]	95	186	255	284	304	314
Maximum input speed	$n_{in\ (max)}$ [rpm]	5600					
Average input speed	$n_{av\ (max)}$ [rpm]	3500/2575[2)]					
Moment of inertia CPU-M	J_{in} [$x10^{-4}$ kgm^2]	0.41					
Moment of inertia CPU-H	J_{in} [$x10^{-4}$ kgm^2]	1.07					
Moment of inertia CPU-S	J_{in} [$x10^{-4}$ kgm^2]	0.32					
Weight CPU-M	m [kg]	1.95					
Weight CPU-H	m [kg]	2.4					
Weight CPU-S	m [kg]	2.5					

[2)] Valid for CPU-H

Illustration 13.1 CPU-20-M [mm]

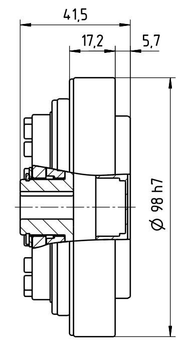

Illustration 13.2 CPU-20-H [mm]

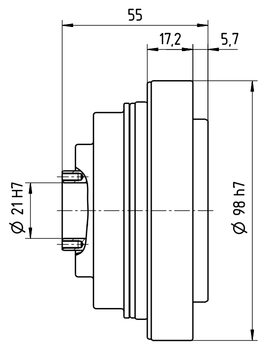

Illustration 13.3 CPU-20-S [mm]

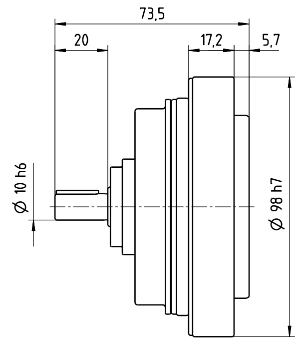

Illustration 13.4 CPU-25-M [mm]

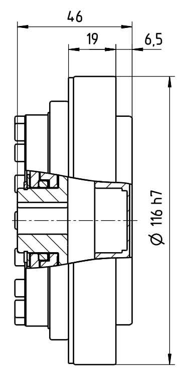

Illustration 13.5 CPU-25-H [mm]

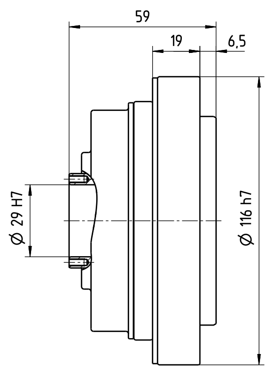

Illustration 13.6 CPU-25-S [mm]

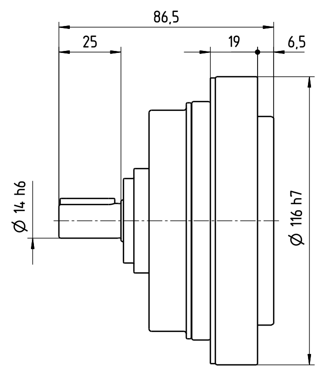

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Table 14.1

	Unit	CPU-32					
Ratio	i [ ]	30	50	80	100	120	160
Repeated peak torque	T_R [Nm]	100	216	304	333	353	372
Average torque	T_A [Nm]	75	108	167	216	216	216
Rated torque	T_N [Nm]	54	76	118	137	137	137
Momentary peak torque	T_M [Nm]	200	382	568	647	686	686
Maximum input speed	$n_{in\ (max)}$ [rpm]	4800					
Average input speed	$n_{av\ (max)}$ [rpm]	3500/1980[1)]					
Moment of inertia CPU-M	J_{in} [$x10^{-4}$ kgm^2]	1.69					
Moment of inertia CPU-H	J_{in} [$x10^{-4}$ kgm^2]	2.85					
Moment of inertia CPU-S	J_{in} [$x10^{-4}$ kgm^2]	1.20					
Weight CPU-M	m [kg]	3.9					
Weight CPU-H	m [kg]	5.0					
Weight CPU-S	m [kg]	5.4					

[1)] Valid for CPU-H

Table 14.2

	Unit	CPU-40				
Ratio	i [ ]	50	80	100	120	160
Repeated peak torque	T_R [Nm]	402	519	568	617	647
Average torque	T_A [Nm]	196	284	372	451	451
Rated torque	T_N [Nm]	137	206	265	294	294
Momentary peak torque	T_M [Nm]	686	980	1080	1180	1180
Maximum input speed	$n_{in\ (max)}$ [rpm]	4000				
Average input speed	$n_{av\ (max)}$ [rpm]	3000/1300[2)]				
Moment of inertia CPU-M	J_{in} [$x10^{-4}$ kgm^2]	4.5				
Moment of inertia CPU-H	J_{in} [$x10^{-4}$ kgm^2]	9.28				
Moment of inertia CPU-S	J_{in} [$x10^{-4}$ kgm^2]	3.41				
Weight CPU-M	m [kg]	6.9				
Weight CPU-H	m [kg]	8.8				
Weight CPU-S	m [kg]	8.8				

[2)] Valid for CPU-H

Illustration 15.1 CPU-32-M [mm]

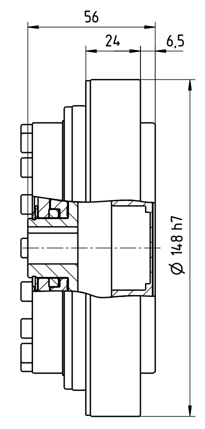

Illustration 15.2 CPU-32-H [mm]

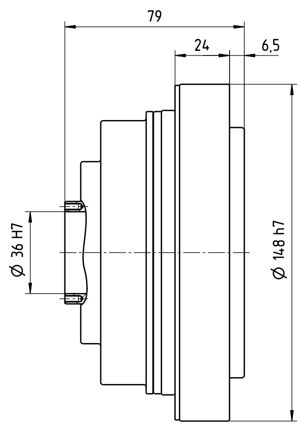

Illustration 15.3 CPU-32-S [mm]

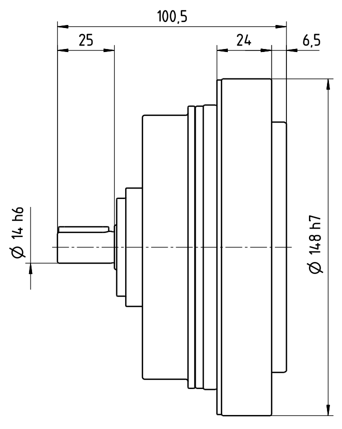

Illustration 15.4 CPU-40-M [mm]

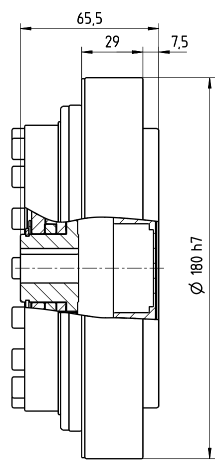

Illustration 15.5 CPU-40-H [mm]

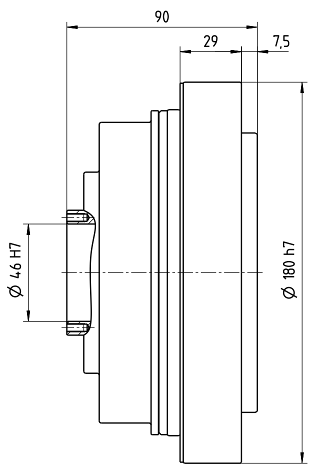

Illustration 15.6 CPU-40-S [mm]

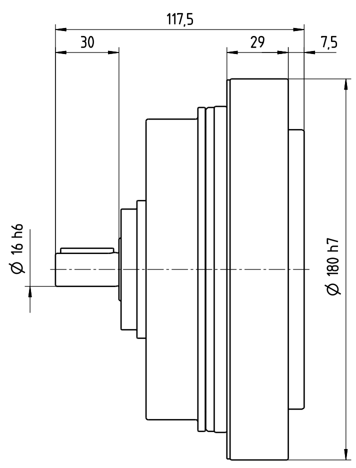

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Table 16.1

	Unit	CPU-45				
Ratio	i [ ]	50	80	100	120	160
Repeated peak torque	T_R [Nm]	500	706	755	823	882
Average torque	T_A [Nm]	265	390	500	620	630
Rated torque	T_N [Nm]	176	313	353	402	402
Momentary peak torque	T_M [Nm]	950	1270	1570	1760	1910
Maximum input speed	$n_{in\ (max)}$ [rpm]	3800				
Average input speed	$n_{av\ (max)}$ [rpm]	3000/1250[1]				
Moment of inertia CPU-M	J_{in} [$x10^{-4}$ kgm²]	8.7				
Moment of inertia CPU-H	J_{in} [$x10^{-4}$ kgm²]	13.8				
Moment of inertia CPU-S	J_{in} [$x10^{-4}$ kgm²]	5.80				
Weight CPU-M	m [kg]	9.6				
Weight CPU-H	m [kg]	12.1				
Weight CPU-S	m [kg]	11.8				

[1] Valid for CPU-H

Table 16.2

	Unit	CPU-50				
Ratio	i [ ]	50	80	100	120	160
Repeated peak torque	T_R [Nm]	715	941	980	1080	1180
Average torque	T_A [Nm]	122	519	666	813	843
Rated torque	T_N [Nm]	245	372	470	529	529
Momentary peak torque	T_M [Nm]	1430	1860	2060	2060	2450
Maximum input speed	$n_{in\ (max)}$ [rpm]	3500				
Average input speed	$n_{av\ (max)}$ [rpm]	2500/1200[1]				
Moment of inertia CPU-M	J_{in} [$x10^{-4}$ kgm²]	12.6				
Moment of inertia CPU-H	J_{in} [$x10^{-4}$ kgm²]	25.2				
Moment of inertia CPU-S	J_{in} [$x10^{-4}$ kgm²]	9.95				
Weight CPU-M	m [kg]	12.6				
Weight CPU-H	m [kg]	16.0				
Weight CPU-S	m [kg]	15.0				

[1] Valid for CPU-H

Illustration 17.1 CPU-45-M [mm]

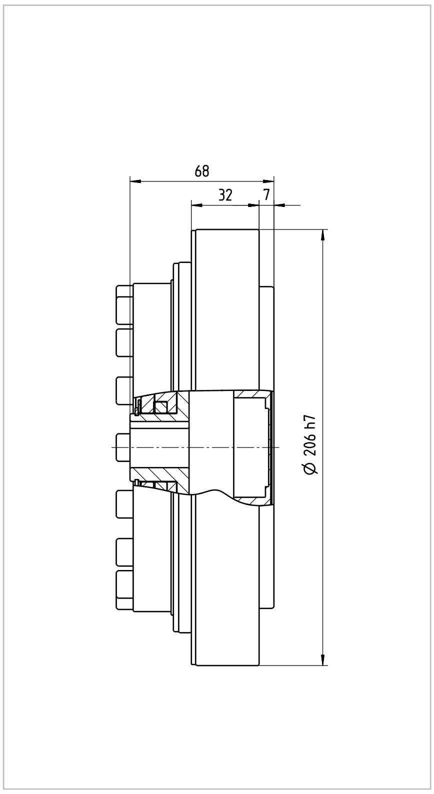

Illustration 17.2 CPU-45-H [mm]

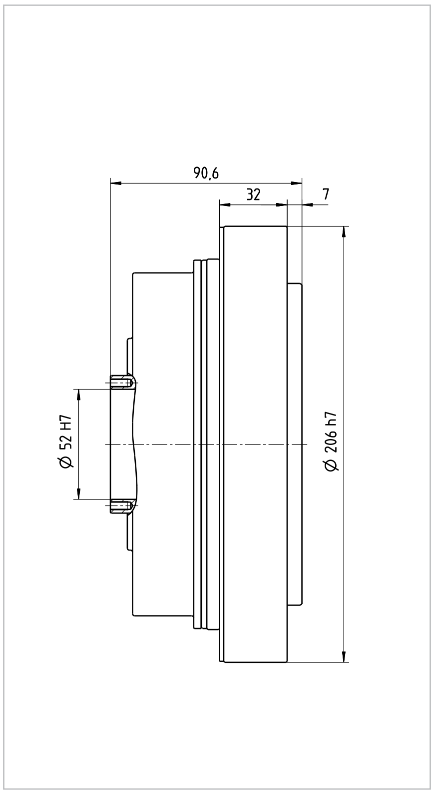

Illustration 17.3 CPU-45-S [mm]

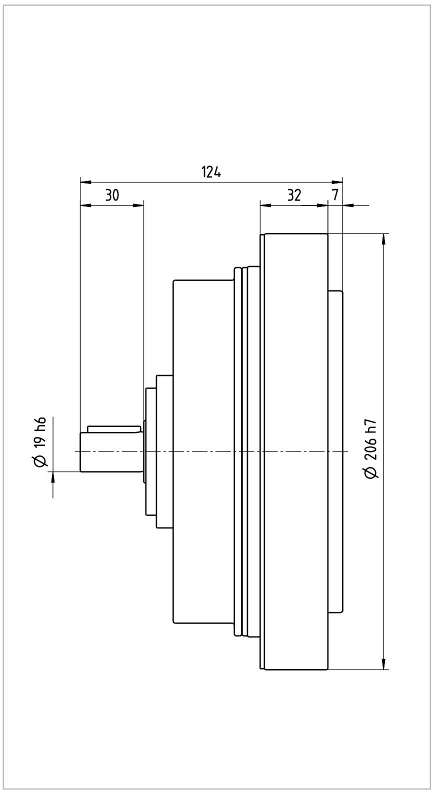

Illustration 17.4 CPU-50-M [mm]

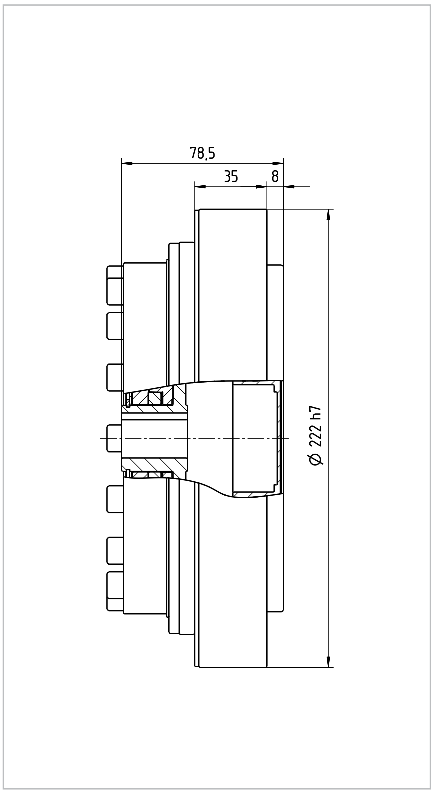

Illustration 17.5 CPU-50-H [mm]

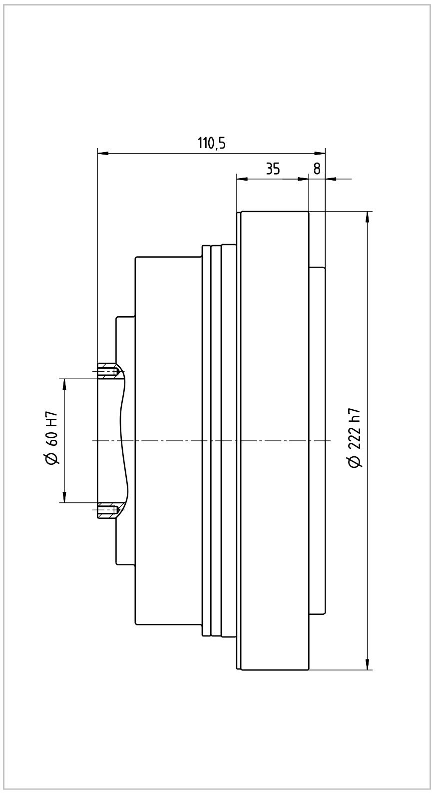

Illustration 17.6 CPU-50-S [mm]

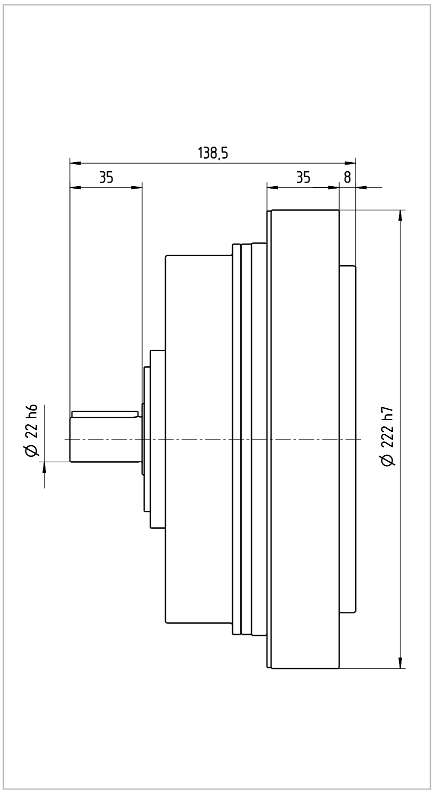

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Table 18.1

	Unit	CPU-58				
Ratio	i [ ]	50	80	100	120	160
Repeated peak torque	T_R [Nm]	1020	1480	1590	1720	1840
Average torque	T_A [Nm]	177	770	1060	1190	1210
Rated torque	T_N [Nm]	353	549	696	745	745
Momentary peak torque	T_M [Nm]	1960	2450	3180	3330	3430
Maximum input speed	$n_{in\,(max)}$ [rpm]	3000				
Average input speed	$n_{av\,(max)}$ [rpm]	2200/1100[1]				
Moment of inertia CPU-M	J_{in} [$x10^{-4}$ kgm²]	27.3				
Moment of inertia CPU-H	J_{in} [$x10^{-4}$ kgm²]	49.5				
Moment of inertia CPU-S	J_{in} [$x10^{-4}$ kgm²]	20.5				
Weight CPU-M	m [kg]	17.8				
Weight CPU-H	m [kg]	22.8				
Weight CPU-S	m [kg]	22.1				

[1] Gültig für CPU-H

Illustration 18.2 CPU-58-M [mm]

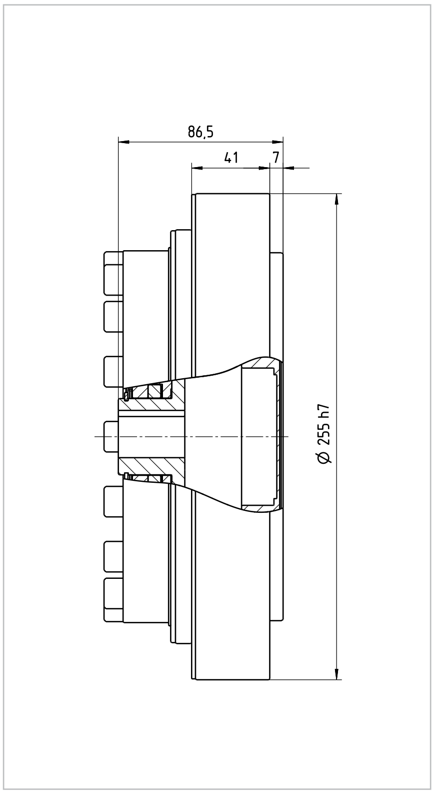


Illustration 18.3 CPU-58-H [mm]

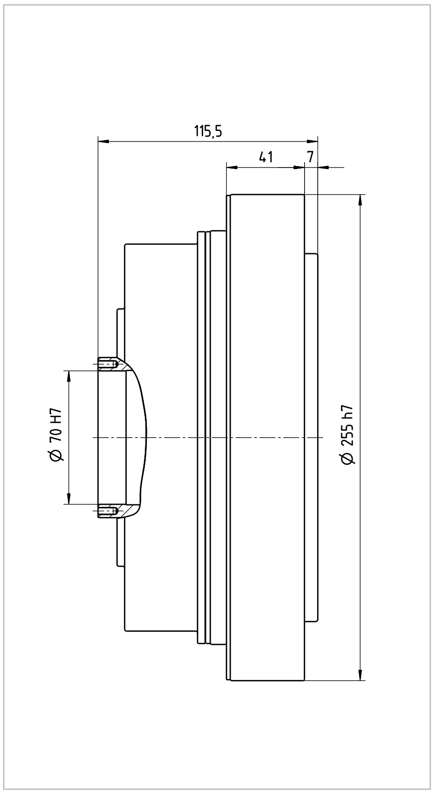
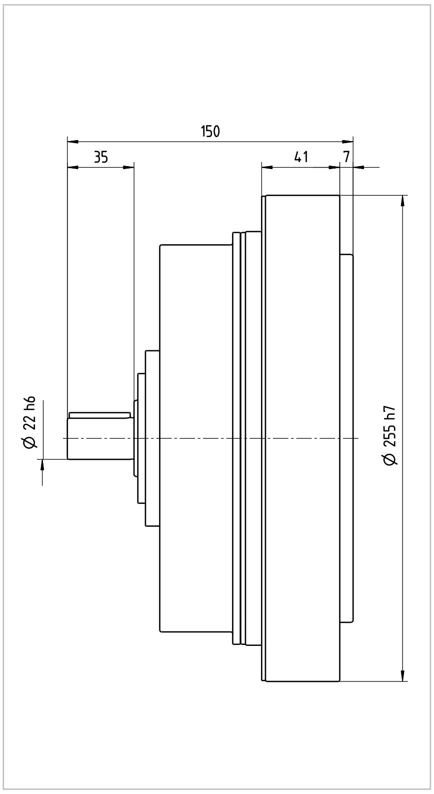


Illustration 18.4 CPU-58-S [mm]



QUICKLINK
www.harmonicdrive.de/CAD2041

QUICKLINK
www.harmonicdrive.de/CAD2042

QUICKLINK
www.harmonicdrive.de/CAD2043

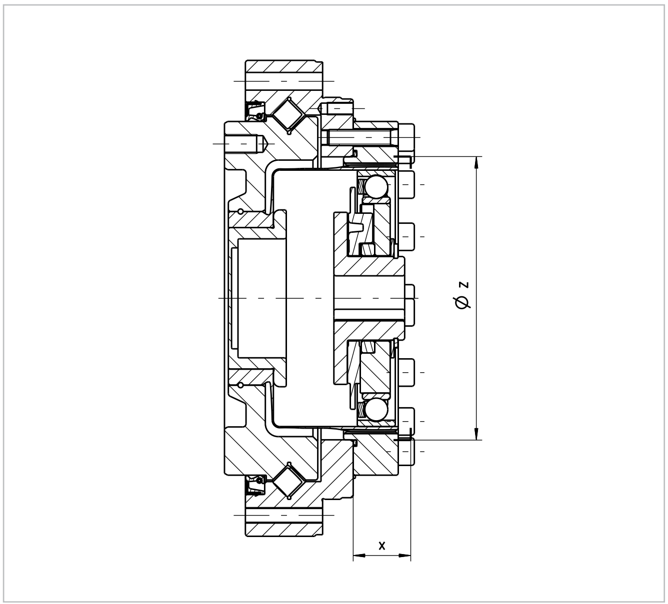
3.3.3 Minimum Housing Clearance

Table 19.1

CPU-M [mm]

Sizes	14	17	20	25	32	40	45	50	58
ØZ	38	45	53	66	86	106	119	133	154
X	7.0	7.5	9.0	11.5	15.5	19.0	21.0	24.0	27.5

Illustration 19.2



3.3.4 Accuracy

Table 20.1 [arcmin]

Sizes		14 – 17			20 – 32			>=40	
Ratio		30	50	>50	30	50	>50	50	>50
Transmission accuracy[1)]	CPU-H CPU-S	< 2	< 1.2	< 1	< 1.5	< 1	< 0.8	< 0.7	< 0.5
	CPU-M with Wave Generator and Oldham Coupling or solid Wave Generator with adjustment assembly	< 2	< 1.2	< 1	< 1.5	< 1	< 0.8	< 0.7	< 0.5
	CPU-M with solid Wave Generator and standard assembly	< 2	< 1.5	< 1.5	< 1.5	< 1	< 1	< 1	< 1
Hysteresis loss		< 3	< 1	< 1	< 3	< 1	< 1	< 1	< 1
Lost motion		< 1							
Repeatability		< ± 0.1							

1) Higher accuracy on request

3.3.5 Torsional Stiffness

Table 20.2

Sizes		14	17	20	25	32	40	45	50	58
T_1 [Nm]		2	3.9	7	14	29	54	76	108	168
T_2 [Nm]		6.9	12	25	48	108	196	275	382	598
i = 30	K_3[x10^3 Nm/rad]	3.4	6.7	11	21	49	–	–	–	–
	K_2[x10^3 Nm/rad]	2.4	4.4	7.1	13	30	–	–	–	–
	K_1[x10^3 Nm/rad]	1.9	3.4	5.7	10	24	–	–	–	–
i = 50	K_3[x10^3 Nm/rad]	5.7	13	23	44	98	180	260	340	540
	K_2[x10^3 Nm/rad]	4.7	11	18	34	78	140	200	280	440
	K_1[x10^3 Nm/rad]	3.4	8.1	13	25	54	100	150	200	310
i > 50	K_3[x10^3 Nm/rad]	7.1	16	29	57	12	230	330	440	710
	K_2[x10^3 Nm/rad]	6.1	14	25	50	11	200	290	400	610
	K_1[x10^3 Nm/rad]	4.7	10	16	31	67	130	180	250	400

3.3.6 Storage

Output Bearing

CPU units incorporate a high stiffness cross roller or four-point 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 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 21.1 lists ratings and important dimensions for the output bearings.

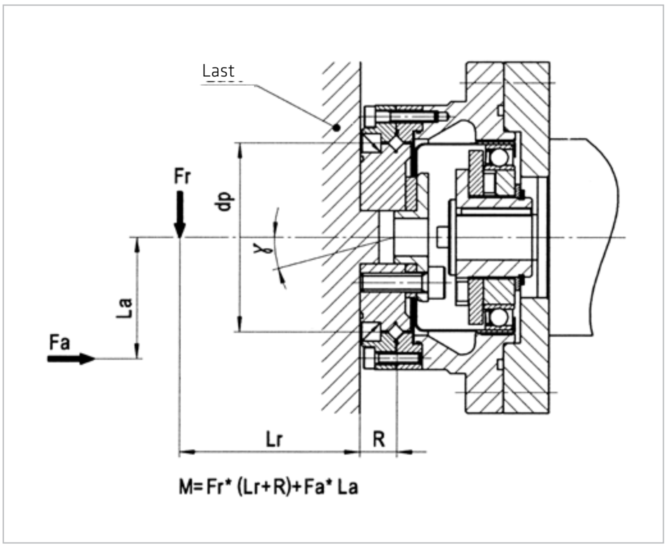
Table 21.1

Sizes		14	17	20	25	32	40	45	50	58
Bearing type		C/F	C/F	C	C	C	C	C	C	C
Pitch circle ø	d_p [m]	0.0465	0.059	0.070	0.088	0.114	0.134	0.150	0.171	0.192
Offset [2]	R [m]	0.014	0.014	0.016	0.018	0.020	0.026	0.024	0.028	0.029
Dynamic load rating	C [N]	8250	10700	21000	21800	34500	43300	77600	81600	87400
Static load rating	C_0 [N]	11400	14800	27000	35800	59000	81600	135000	149000	171000
Permissible dynamic tilting moment [3]	M [Nm]	73	114	172	254	578	886	1253	1558	2222
Permissible static tilting moment [4]	M_0 [Nm]	155	276	603	1050	2242	3645	6750	8493	10944
Tilting moment stiffness [6]	K_B [Nm/arcmin]	23	40	70	114	350	522	749	1020	1550
Permissible axial load [5]	F_a [N]	2880	4600	15800	19200	22300	42000	52300	56100	37300
Permissible radial load [5]	F_r [N]	1450	2300	8600	12700	14600	27500	34600	37300	38400

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

1) F = Four-point bearing, C = Cross roller bearing
2) See illustration 21.2
3) These values are valid for moving gears. They are not based on the equation for lifetime calculation of the output bearing but on the maximum allowable deflection of the Harmonic Drive® component set. The values indicated in the table must not be exceeded even if the lifetime equation of the bearing permits higher values.
4) These values are valid for gears at a standstill and for a static load safety factor f_s = 1.8 for # 14-20 and 1,5 for # 25-58. For other values of f_s, please refer to capital 4.7.
5) These data are valid for n = 15 rpm and L_{10}=15000h
3) 4) 5) These data are only valid if the following conditions are fulfilled: For: M, M_0 : F_a = 0, F_r = 0 | F_a : M = 0; F_r = 0 | F_r : M = 0, F_a = 0
6) Average value

Illustration 21.2



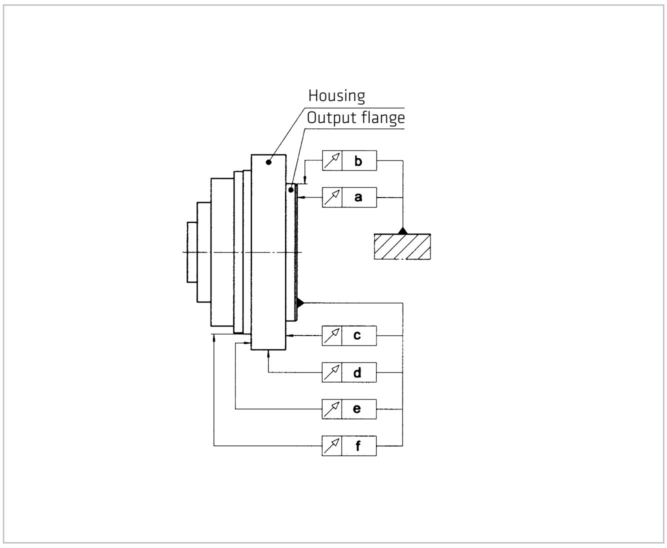
Output Bearing and Housing Tolerances CPU Units

The following data are valid for a rotating output flange.

Table 22.1 [mm]

Sizes	14	17	20	25	32	40	45	50	58
a	0.010	0.010	0.010	0.010	0.012	0.012	0.012	0.015	0.015
b	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
c	0.010	0.010	0.010	0.010	0.012	0.012	0.012	0.015	0.015
d	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
e	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
f	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015

Illustration 22.2



Input Bearing CPU-H

The input shaft of the CPU-H unit is supported by two single row deep groove ball bearings. Illustration 23.2 shows the points ofapplication of force of the radial and axial loads given in table 23.1 and illustration 23.3.

Example: If the input shaft of a CPU-58-H unit is subjected to an axial load of 900 N, then the maximum permissible radial force will be 1400 N, see illustration 23.3.

The technical data given on this page are valid for an average input speed of 2000 rpm and a mean bearing life of L_{50} = 35000 h.

Table 23.1

Sizes		**14**	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**
Offset	B [mm]	6.5	6.5	5	5	7	8	8	9	10
Max. permissible radial load	F_r [N]	204	235	271	306	918	1113	1220	1812	2358

Illustration 23.2

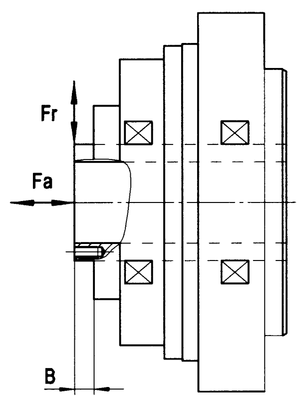
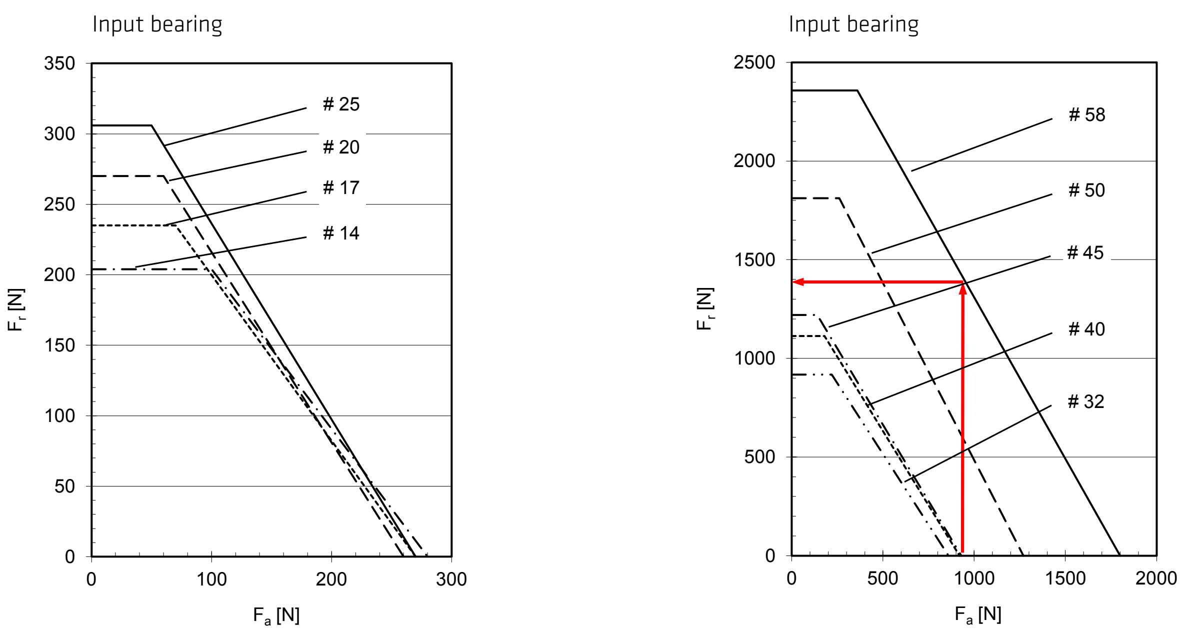


Illustration 23.3



Input Bearing CPU-S

The input shaft of the CPU-S unit is supported by two single row deep groove ball bearings. illustration 24.2 shows the points of application of force of the radial and axial loads given in table 24.1 and illustration 24.3.

Example: If the input shaft of a CPU-58-H unit is subjected to an axial load of 900 N, then the maximum permissible radial force will be 1400 N, see illustration 24.3.

The technical data given on this page are valid for an average input speed of 2000 rpm and a mean bearing life of L_{50} = 35000 h.

Table 24.1

Sizes		14	17	20	25	32	40	45	50	58
Offset	B [mm]	7	8	10	12.5	12.5	15	15	17.5	17.5
Max. permissible radial load	F_r [N]	118	145	232	342	567	825	1264	1745	2027

Illustration 24.2

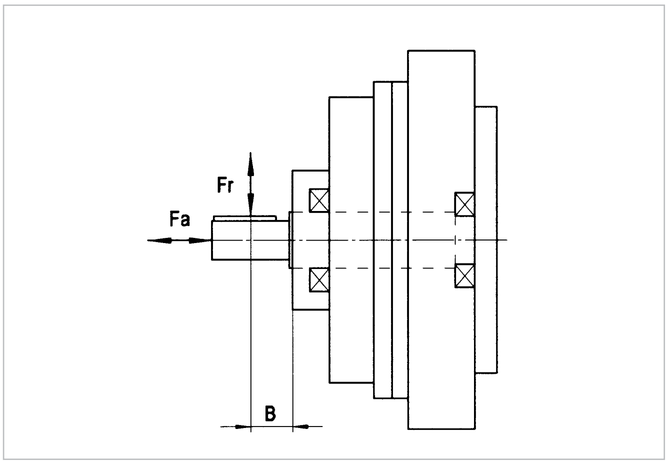
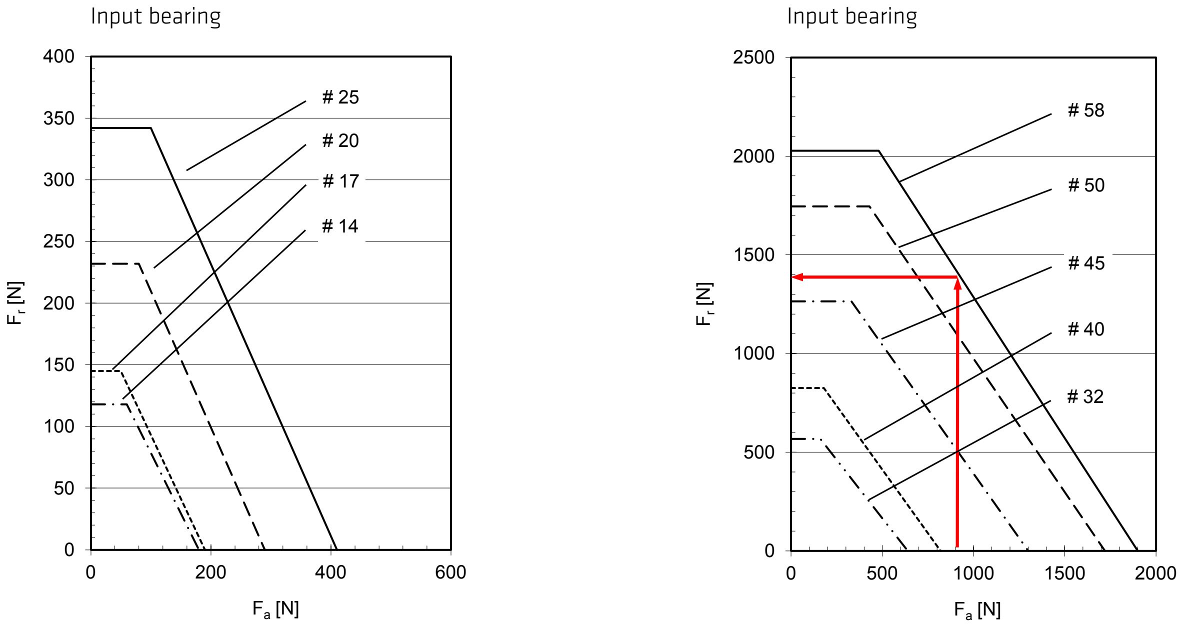


Illustration 24.3



3.3.7 Materials used

The surrounding medium should not have any corrosive effects on the materials listed below.

CPU-H and CPU-S Units
Corrosion protected steel, stainless steel.
Output bearing: browned
Screws provided with anti-corrosion coating.

CPU-M Units
Please refer to the notes above regarding CPU-H/-S Units
Adapter flange material, if supplied by Harmonic Drive AG:
high-tensile aluminium or steel.

4. Driving Arrangements

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

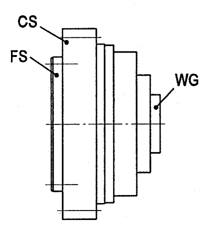
Equation 26.1

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

Overview Harmonic Drive® Products

The three main components of the Harmonic Drive® units, Circular Spline (CS), Flexspline (FS) and Wave Generator (WG) can be seen in the illustration 26.2.

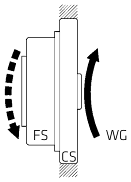
Illustration 26.2



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

Ratio

1)



Reduction gearing

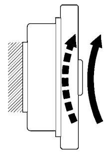
CS	Fixed
WG	Input
FS	Output

Equation 27.1

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

Input and output rotate in opposite directions.

2)



Reduction gearing

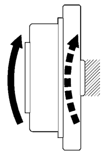
FS	Fixed
WG	Input
CS	Output

Equation 27.2

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

Input and output rotate in same direction.

3)



Reduction gearing

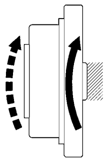
WG	Fixed
FS	Input
CS	Output

Equation 27.3

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

Input and output rotate in same direction.

4)



Speed increaser gearing

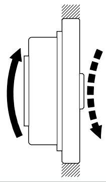
WG	Fixed
CS	Input
FS	Output

Equation 27.4

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

Input and output rotate in same direction.

5)



Speed increaser gearing

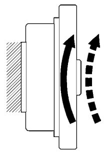
CS	Fixed
FS	Input
WG	Output

Equation 27.5

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

Input and output rotate in opposite directions.

6)



Speed increaser gearing

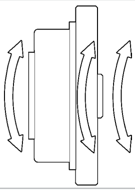
FS	Fixed
CS	Input
WG	Output

Equation 27.6

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

Input and output rotate in same direction.

7)



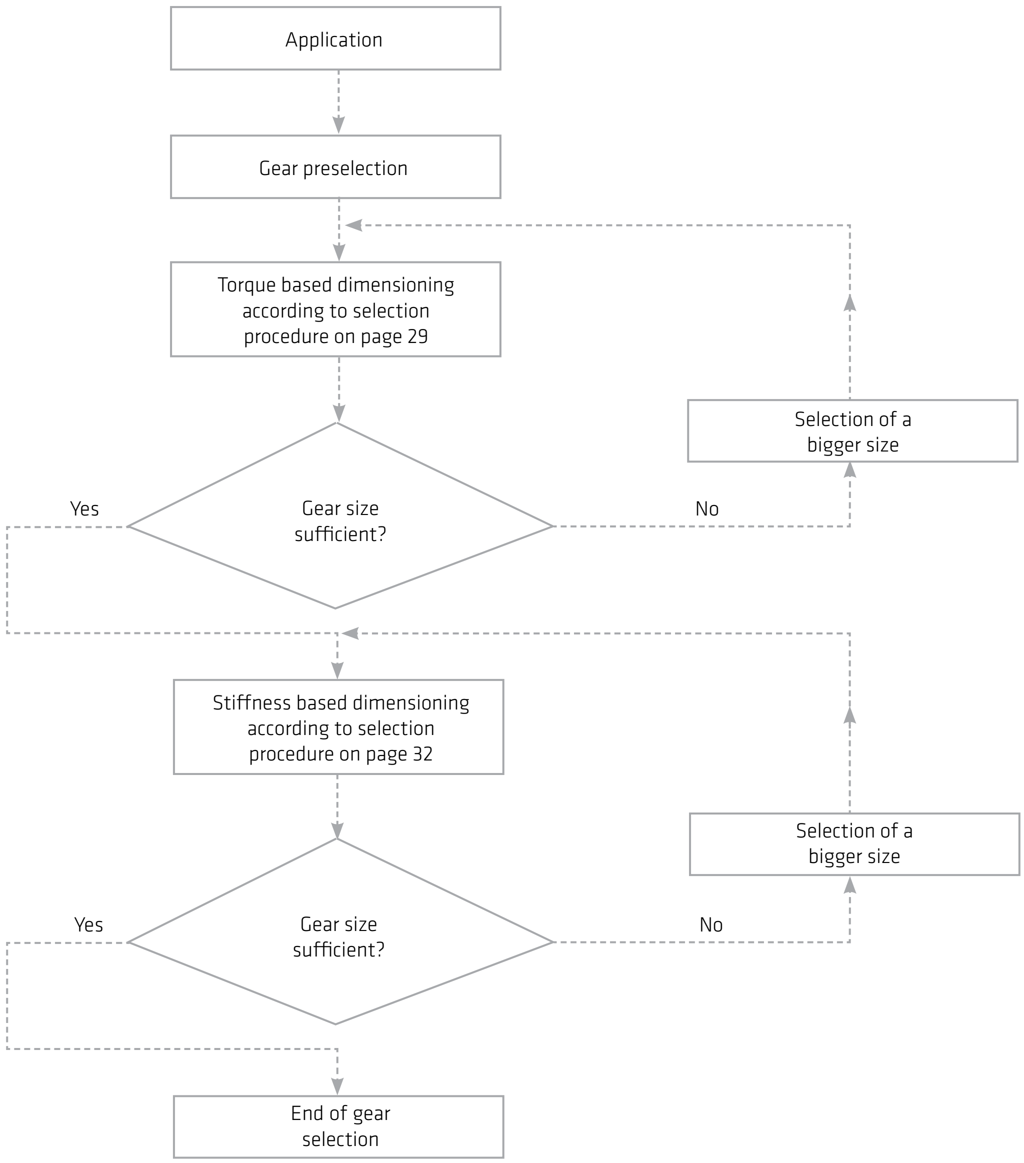
Differential gear

WG	Control input
CS	Main drive input
FS	Main drive output

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

4.1 Selecting Harmonic Drive® Gears

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

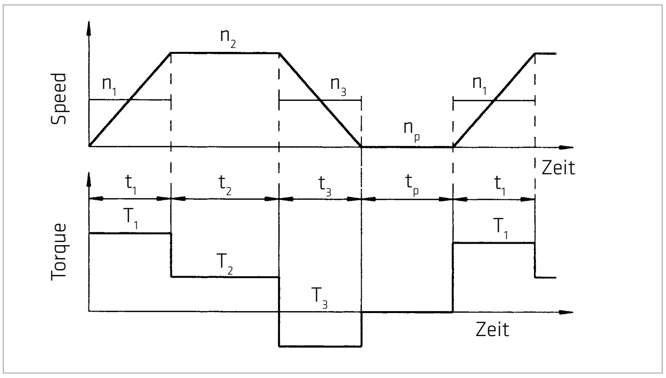


4.1.1 Torque Based Dimensioning

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 29.1



Equation 29.2

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

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

Equation 29.3

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

No

Selection of a bigger size

Equation 29.4

Calculation of the average output speed

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

Equation 29.5

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

Equation 29.6

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

Equation 29.7

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

Equation 29.8

Load limit 2, T_R

$T_{max} \leq T_R$

Equation 29.9

Load limit 3, T_M

$T_k \leq T_M$

Equation 29.10

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 29.11

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 31.1

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

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

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

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

T_{av} = 319 Nm ≤ T_A = 451 Nm

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

Calculation of the average output speed

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

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

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

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

Load limit 2, T_R

T_{max} = 400 Nm ≤ T_R = 617 Nm

Load limit 3, T_M

T_k = 500 Nm ≤ T_M = 1180 Nm

Allowable number of momentary peak torques

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

Operating life

HFUC-40-120-2A-GR:

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

L_{50} = 38054 h > 30000 h

4.1.2 Life of the Wave Generator Bearing

Given that the Harmonic Drive® Gear is rated to provide infinite fatigue life for the Flexspline, the life expectancy is based on the average life of the Wave Generator bearing. The rated torque at the rated speed given in the rating table is based on the mean L_{50} bearing life. The life expectancy of a component set or an unit operating at an input speed n (rpm) and output torque T (Nm) may be estimated from equation 31.2.

Table 31.1

[h]

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

Equation 31.2

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

Equation 31.3

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

n_N = Rated input speed [rpm]
$n_{in\ av}$ = Average input speed [rpm] (equation 29.5)
T_N = Rated output torque at rated speed [Nm]
T_{av} = Average output torque [Nm] (equation 29.2)
L_n = See table 31.1

4.1.3 Stiffness Based Dimensioning

In addition to the “Torque Based Dimensioning” stated on page 29, we recommend that you carry out a selection based on stiffness. For this, the values provided in table 32.1 for the individual resonance frequencies recommended for each application should be taken into account.

Table 32.1 [Hz]

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

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

Selection Example: Stiffness Based Dimensioning

Resonance Frequency (Gear Output)

The formula

Equation 33.1

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

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

allows the calculation of the resonance frequency at the gear output from the given torsional stiffness, K1, of the Harmonic Drive® gear and the load's moment of inertia. The calculated frequency should correspond with the value provided in table 32.1. The higher the load's moment of inertia, the more influence the application has on the gear selection. If the moment of inertia = 0, the selected application has no numerical influence on the selection result.

Resonance Speed (Gear Input)

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

$n_n = f_n * 30$ [rpm]

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

Selection Example

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

Intended application: milling head for woodworking
Moment of inertia at the gear output: 7 kgm^2. Recommended resonance frequency from table 32.1: ≥ 30 Hz.
Resonance frequency using the preselected gear
HFUC-40-120-2A-GR:

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

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

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

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

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

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

4.2 Calculation of the Torsion Angle

Calculation of the Torsion Angle φ at Torque T:

Equation 34.1

$$T \leq T_1$$

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

Equation 34.2

$$T_1 < T \leq T_2$$

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

Equation 34.3

$$T > T_2$$

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

φ = Angle [rad]
T = Torque [Nm]
K = Stiffness [Nm/rad]

Example: HFUC-32-100-2UH

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

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

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

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

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

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

Equation 34.4

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

4.3 Accuracy of the Oldham Coupling CPU-M

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

In the region of tooth engagement Harmonic Drive® gears have no backlash. If an Oldham coupling is used for the compensation of eccentricity errors of the motor shaft, a small backlash in the range of a few seconds of arc can occur at the output shaft, as listed in table 34.5.

Table 34.5 [arcsec]

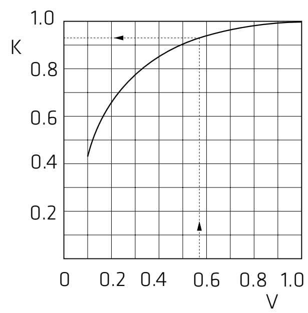
Sizes		**14**	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**
Ratio	30	60	33	28	28	23	–	–	–	–
	50	36	20	17	17	14	14	12	12	10
	80	23	13	11	11	9	9	8	8	6
	100	18	10	9	9	7	7	6	6	5
	120	–	8	8	8	6	6	5	5	4
	160	–	–	6	6	5	5	4	4	3

4.4 Efficiency Versus Load

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

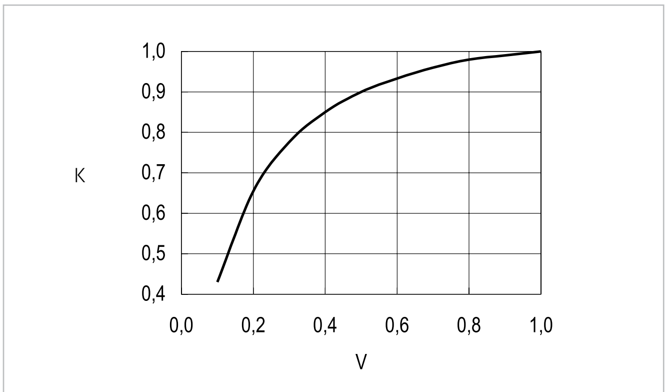
4.4.1 Efficiency Calculations CPU-M Units

Table 35.1

Calculation Procedure	Example
	Efficiency of HFUC-20-80-2A-GR with input speed n=1000 rpm ouput torque T= 19.6 Nm at 20° C ambient temperature. Lubrication: Oil
The efficiency may be determined using the efficiency graphs.	From matching chart η = 78 %
Calculate the torque factor V. $V = \frac{T_{av}}{T_N}$ [Equation 35.2] 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 35.4	
Efficiency $\eta_L = \eta \cdot K$ [Equation 35.3]	η_L = 78 · 0.93 = 73 %

Calculating Factor K

Illustration 35.4



4.4.2 Efficiency Calculations CPU-H und -S Units

Calculation of total efficiency η_L

Equation 36.1

$$\eta_L = K \cdot (\eta_R + \eta_e)$$

with:

K = Correction factor from illustration 36.3 and 36.5

K = 1; for $T > T_N$

η_R = Efficiency at rated torque, see 40.1 and 41.1

η_e = Correction value to reflect the influence of the rotary shaft seals at the input side, see illustration 36.4 and 36.6

Calculation of torque factor V

Equation 36.2

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

with:

T = Actual torque

T_N = Rated torque at rated speed

Correction factor/value CPU-H

Illustration 36.3

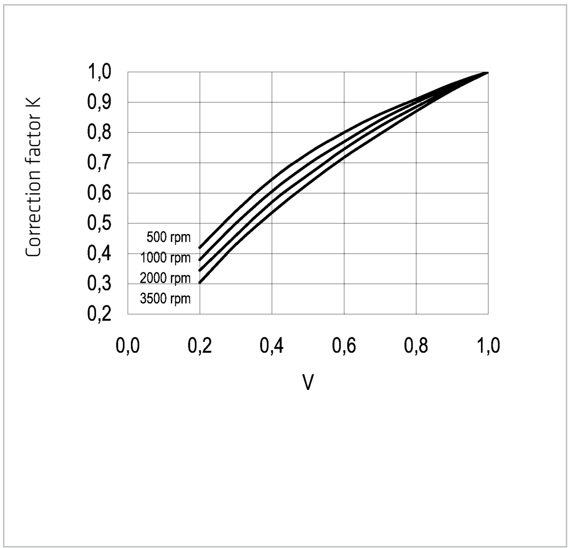
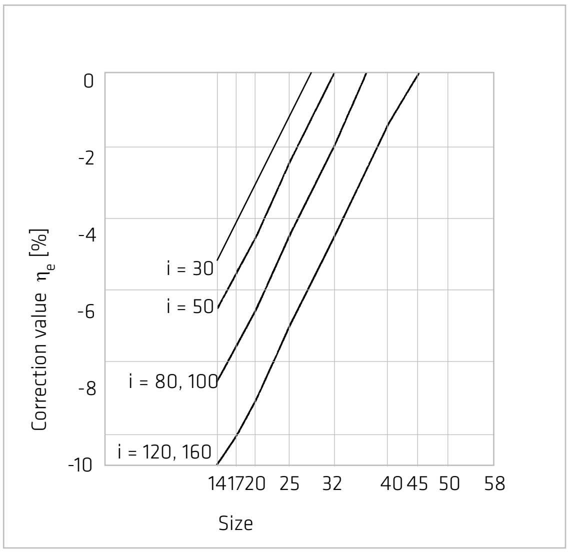


Illustration 36.4



Correction factor/value CPU-S

The calculation of the total efficiency for CPU-S series is analogous to that of CPU-H series gears. In contrast to the CPU-H series, the CPU-S series gears are not subject to any limitations concerning continuous operation.

Illustration 36.5

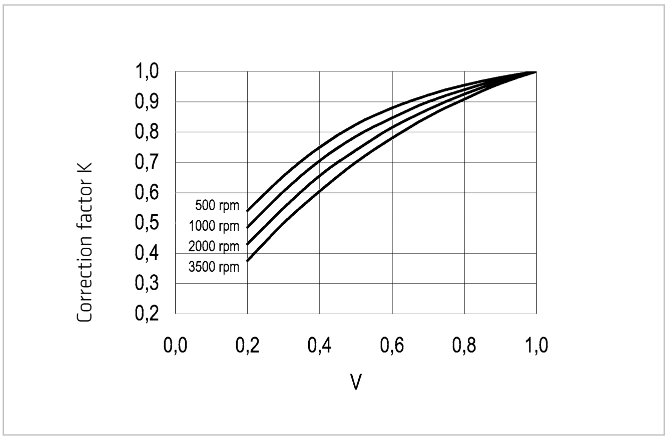
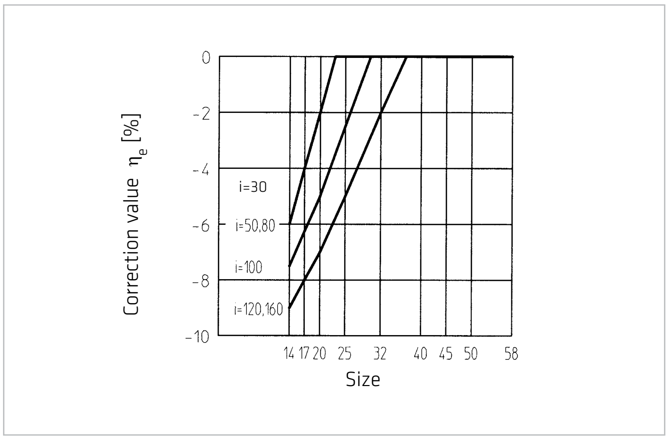


Illustration 36.6



Example: Efficiency Calculations CPU-H und CPU-S

The calculation of the total efficiency for CPU-S series is analogous to that of CPU-H series gears. In contrast to the CPU-H series, the CPU-S series gears are not subject to any limitations concerning continuous operation.

Table 37.1

Calculation Procedure	Example
CPU-25-100-H Input speed n = 1000 rpm Output torque T = 60 Nm Ambient temperature = 20° C	
1. The efficiency may be determined using illustration 40.1	η_R = 65 %
2. Calculate the torque factor V	$V = \frac{T}{T_N} = \frac{60}{67} = 0{,}9$ Equation 37.2
3. The correction factor K may be estimated by means of illustration 36.3	K = 0.95
4. The correction value ηe may be taken from illustration 36.4	$\delta\eta_e$ = -5 %
5. Total efficiency	$\eta_L = K \cdot (\eta_R + \eta_e)$ $= 0.95 \cdot (65\,\% - 5\,\%)$ $= 57\,\%$ Equation 37.3

4.4.3 Efficiency Tables

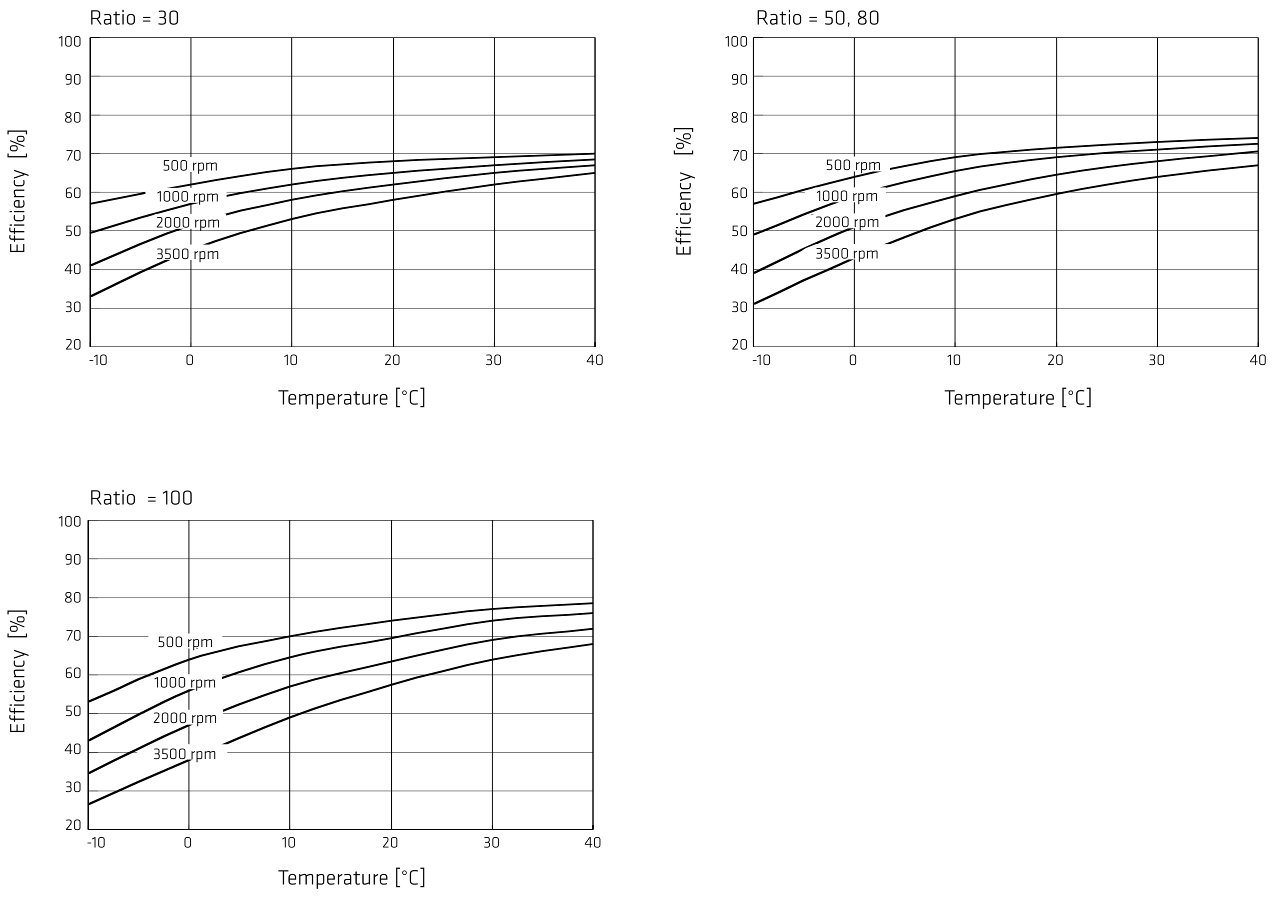
Efficiency for Harmonic Drive® gears varies depending on the output torque. The efficiency curves are for gears operating at rated output torque. Efficiency for a gear operating at a load below the rated torque may be estimated using a compensation curve and equation as shown on pages 35 to 36.

CPU-M

Efficiency for grease lubrication at rated torque

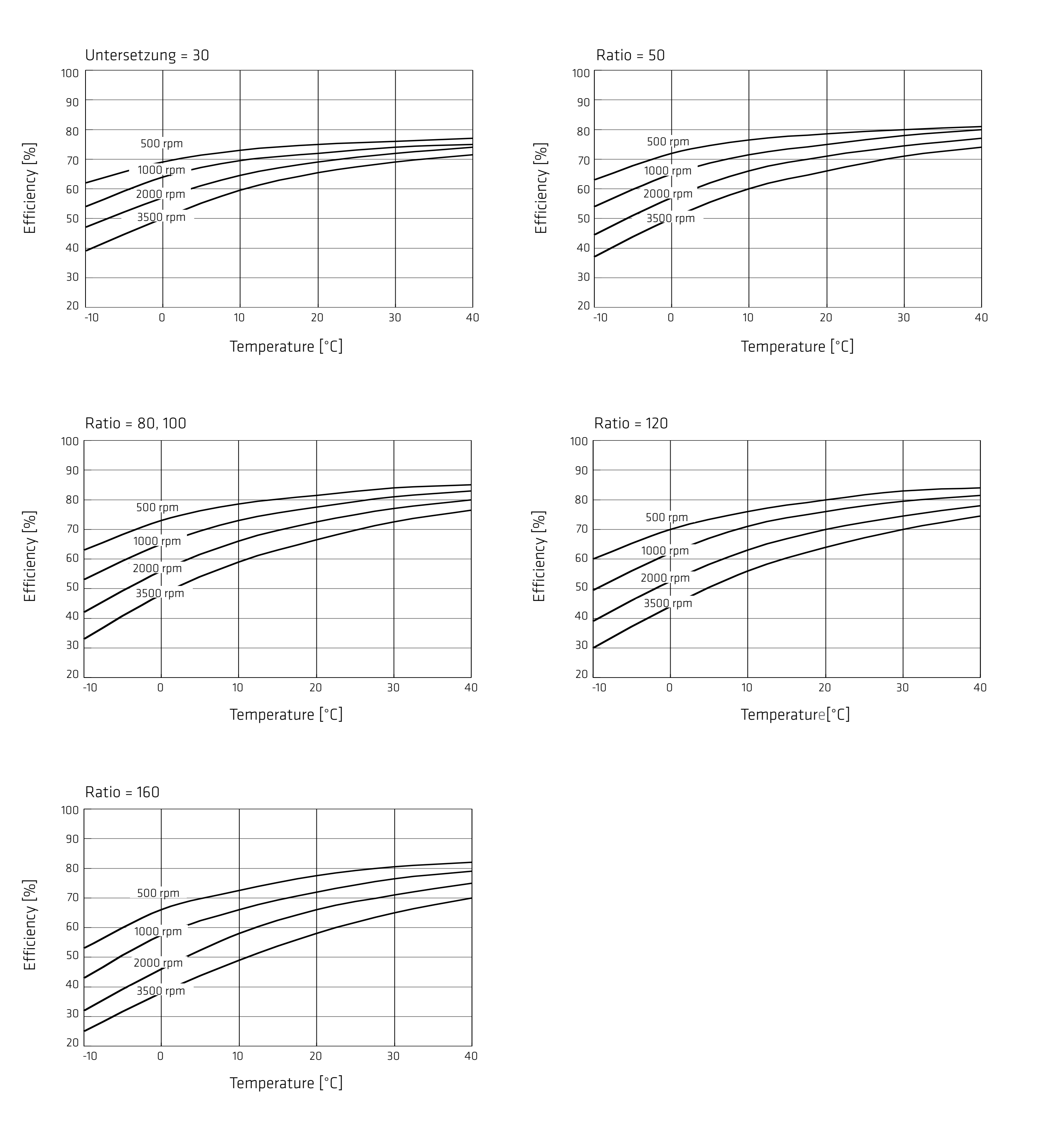
Size 14

Illustration 38.1



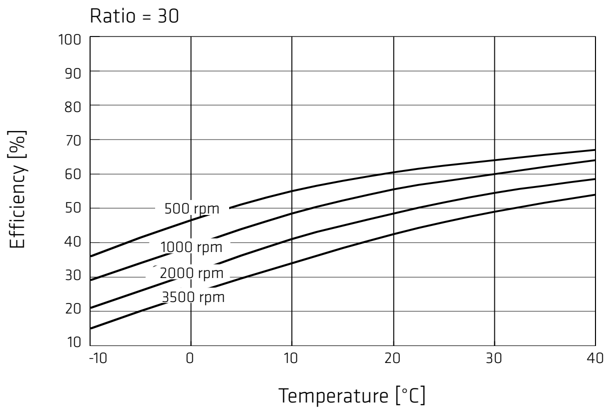
Size 17 - 58

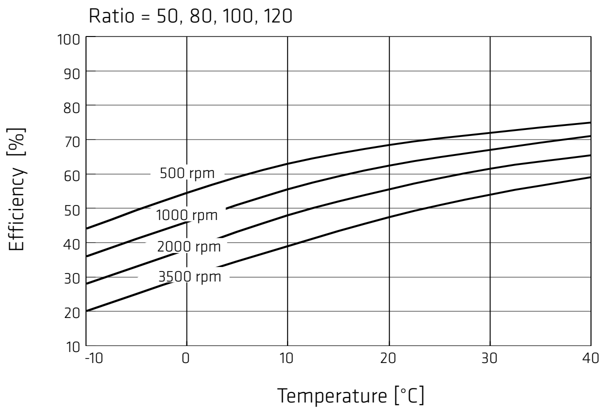
Illustration 39.1

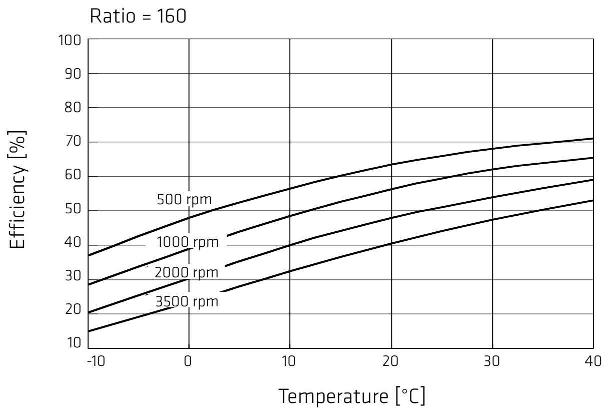


Efficiency for grease lubrication at rated torque

Illustration 40.1

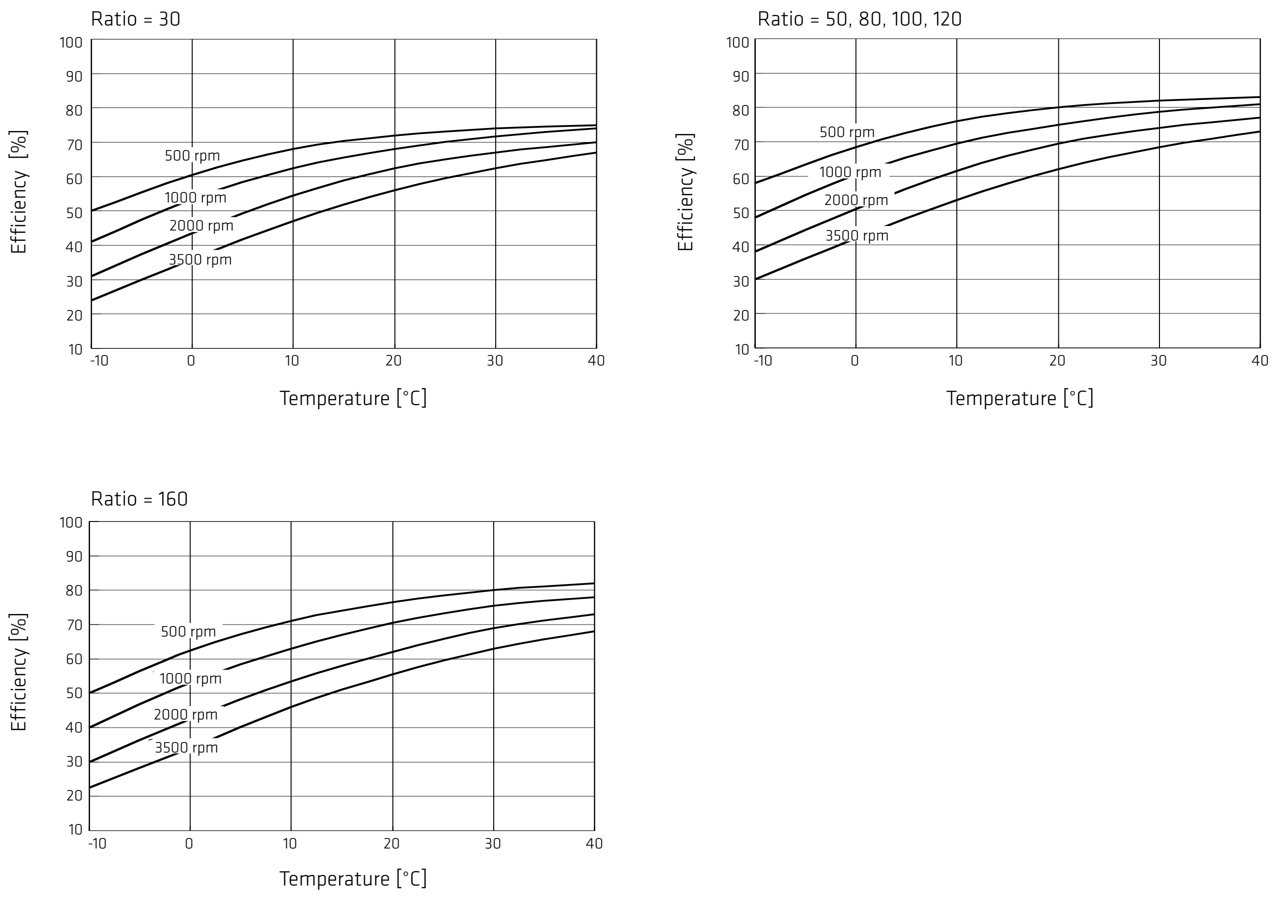






Efficiency for grease lubrication at rated torque

Illustration 41.1



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

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

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

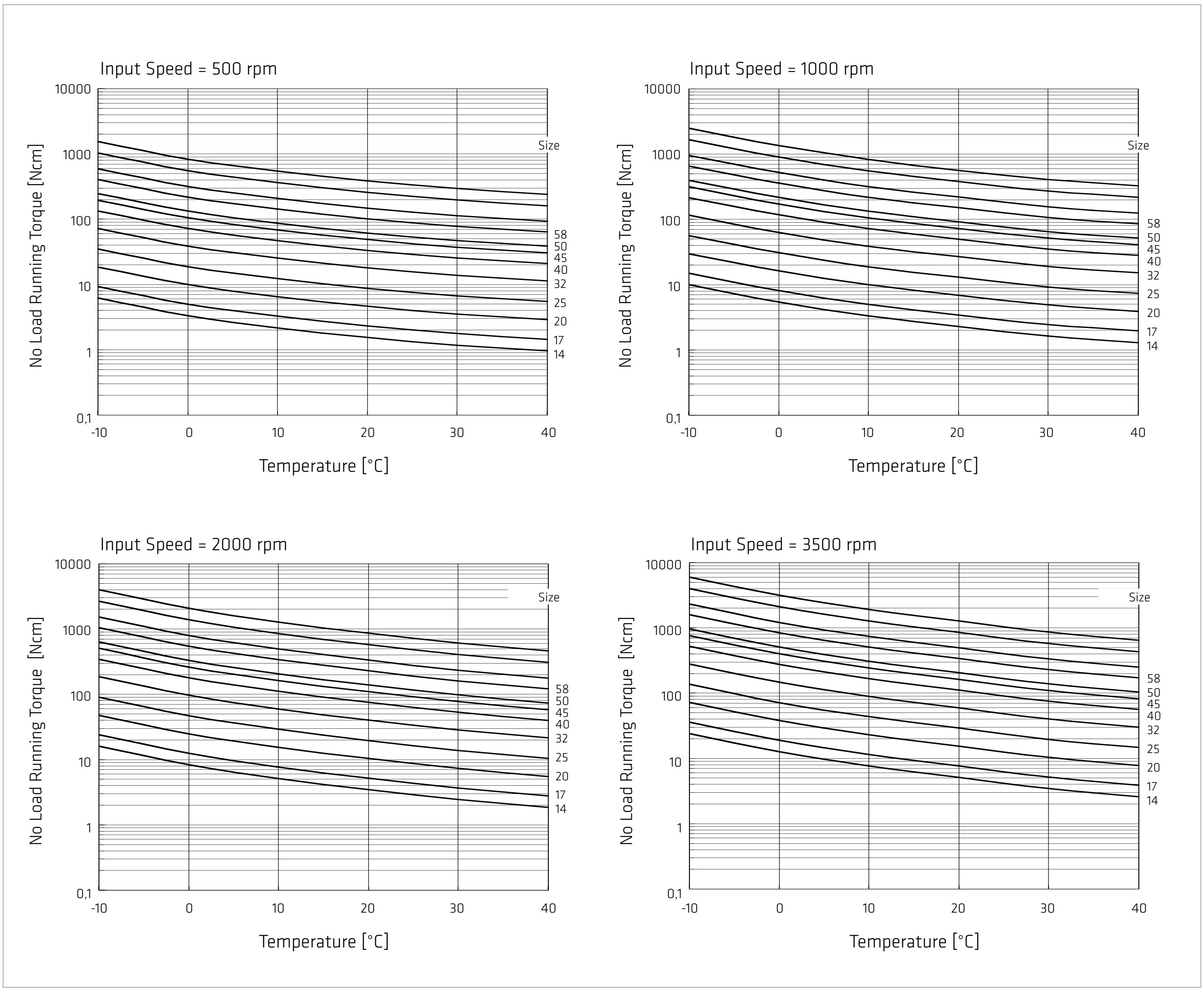
No Load Back Driving Torque
The no load back driving torque is the torque required to commence rotation of the output element (low speed side) with no load applied to the input element (high speed side). The approximate range for no load back driving torque, based on tests of actual production gears,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

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.

4.5.1 No Load Running Torque

No Load Running Torque CPU-M

Illustration 42.1



Compensation Values for No Load Running Torque CPU-M

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

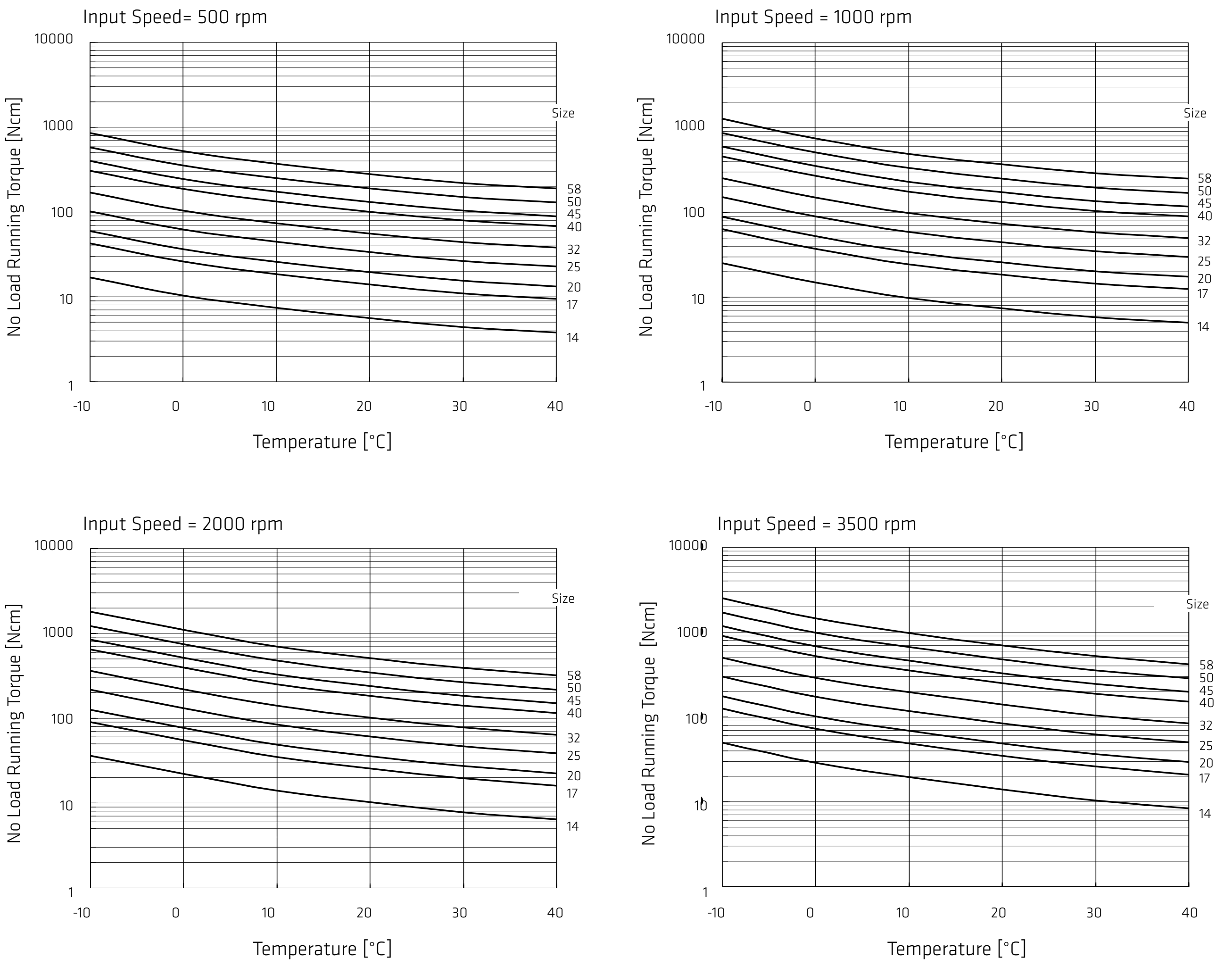
Table 42.2

[Ncm]

Ratio	Sizes								
	14	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**
30	2.5	3.8	5.4	8.8	16.0	–	–	–	–
50	1.1	1.6	2.3	3.8	7.1	12	16	21	30
80	0.2	0.3	0.5	0.7	1.3	2.1	2.9	3.7	5.3
120	–	-0.2	-0.3	-0.5	-0.9	-1.5	-2.1	-2.6	-3.8
160	–	–	-0.8	-1.2	-2.2	-3.5	-4.9	-6.2	-8.9

No Load Running Torque CPU-H

Illustriation 43.1



Compensation Values for No Load Running Torque CPU-H

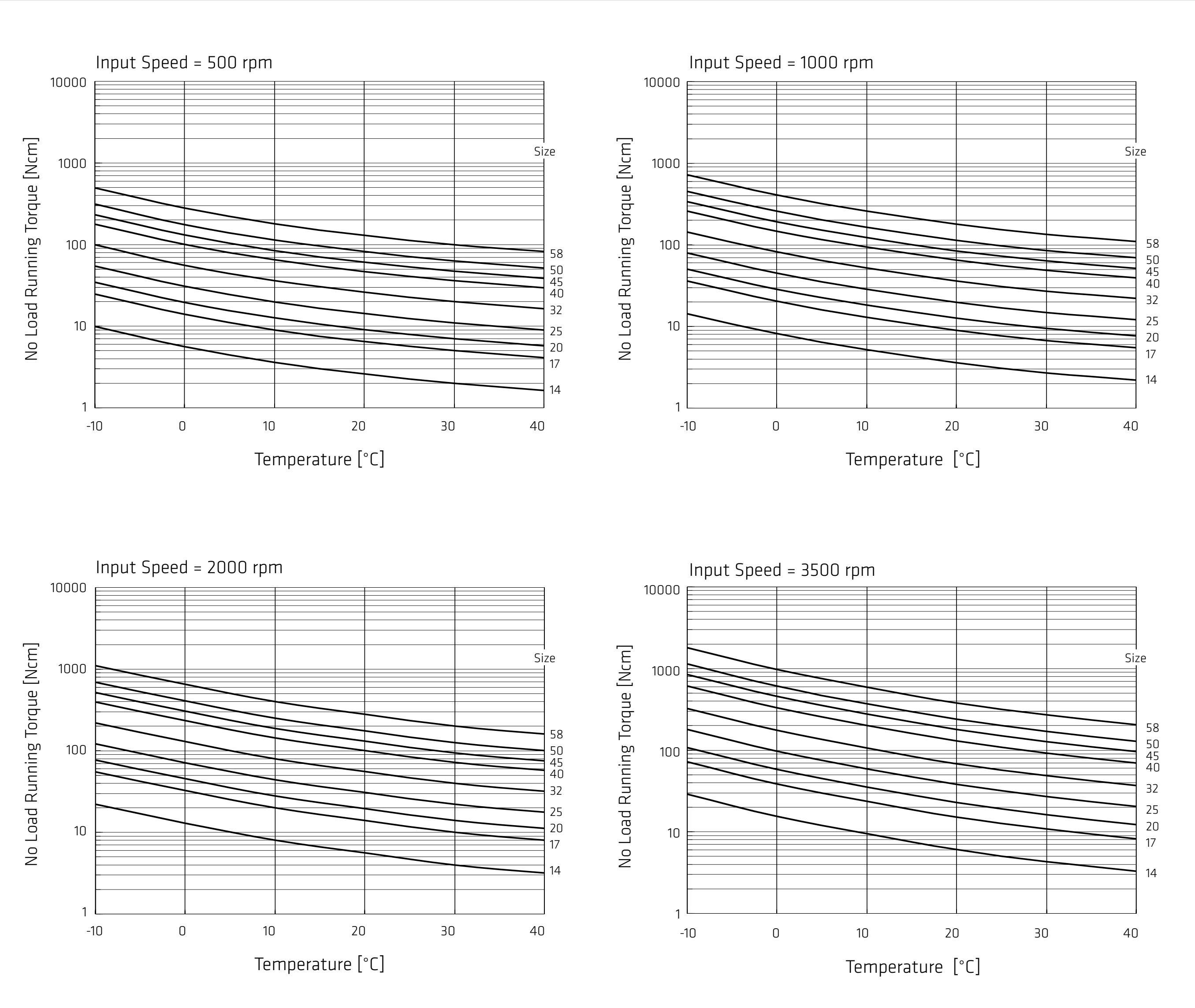
When using gears with ratios other than i ≠ 100, please apply the compensation values from the table to the values taken from the curves.

Table 43.2 [Ncm]

Ratio	Sizes								
	14	17	20	25	32	40	45	50	58
30	2.6	4.1	5.9	9.6	18.3	–	–	–	–
50	1.1	1.8	2.6	4.2	8.0	13.3	18.2	23.9	34.6
80	0.2	0.4	0.5	0.8	1.5	2.4	2.3	4.3	6.2
120	–	-0.2	-0.4	-0.6	-1.1	-1.7	-2.4	-3.1	-4.4
160	–	–	-0.8	-1.3	-2.5	-4.0	-5.5	-7.2	-10.3

No Load Running Torque CPU-S

Illustration 44.1



Compensation Values for No Load Running Torque CPU-S

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

Table 44.2 [Ncm]

Ratio	Sizes								
	14	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**
30	2.6	4.1	5.9	9.6	18.3	–	–	–	–
50	1.1	1.8	2.6	4.2	8.0	13.3	18.2	23.9	34.6
80	0.2	0.4	0.5	0.8	1.5	2.4	2.3	4.3	6.2
120	–	-0.2	-0.4	-0.6	-1.1	-1.7	-2.4	-3.1	-4.4
160	–	–	-0.8	-1.3	-2.5	-4.0	-5.5	-7.2	-10.3

4.5.2 No Load Starting Torque

No Load Starting Torque CPU-M

Table 45.1 [Ncm]

Ratio	Sizes								
	14	17	20	25	32	40	45	50	58
30	6.4	9.3	15	25	54	–	–	–	–
50	4.1	6.1	7.8	15	31	55	77	110	160
80	2.8	4.0	4.9	9.2	19	35	49	66	98
100	2.5	3.4	4.3	8.0	18	31	43	58	88
120	–	3.1	3.8	7.3	15	28	39	52	80
160	–	–	3.3	6.3	14	24	33	45	68

No Load Starting Torque CPU-H

Table 45.2 [Ncm]

Ratio	Sizes								
	14	17	20	25	32	40	45	50	58
30	11	30	43	64	112	–	–	–	–
50	8.8	27	36	56	85	136	165	216	297
80	7.5	25	33	50	74	117	138	179	244
100	6.9	24	32	49	72	112	131	171	231
120	–	24	31	48	68	110	126	165	223
160	–	–	31	47	67	105	122	156	213

No Load Starting Torque CPU-S

Table 45.3 [Ncm]

Ratio	Sizes								
	14	17	20	25	32	40	45	50	58
30	6.8	11	19	26	63	–	–	–	–
50	5.7	9.7	14	22	41	72	94	125	178
80	4.4	7.2	11	15	29	52	68	88	125
100	3.7	6.5	9.9	14	27	47	60	80	113
120	–	6.2	9.3	13	24	44	55	74	105
160	–	–	8.6	12	23	39	50	66	94

4.5.3 No Load Back Driving Torque

No Load Back Driving Torque CPU-M

Table 46.1 [Nm]

Ratio	Sizes								
	14	17	20	25	32	40	45	50	58
30	2.4	3.8	6.2	11	23	–	–	–	–
50	1.6	3.0	4.7	9.0	18	33	47	62	95
80	1.6	3.0	4.8	9.1	19	33	48	63	96
100	1.8	3.3	5.1	9.8	20	36	51	68	110
120	–	3.5	5.5	11	22	39	55	73	110
160	–	–	6.4	13	26	46	64	85	130

No Load Back Driving Torque CPU-H

Table 46.2 [Nm]

Ratio	Sizes								
	14	17	20	25	32	40	45	50	58
30	5.4	17	23	35	57	–	–	–	–
50	5.3	16	22	34	51	82	99	129	178
80	7.2	24	31	48	70	112	133	172	234
100	8.2	29	38	59	86	134	158	205	278
120	–	34	45	69	97	158	182	237	322
160	–	–	59	90	128	201	233	299	408

No Load Back Driving Torque CPU-S

Table 46.3 [Nm]

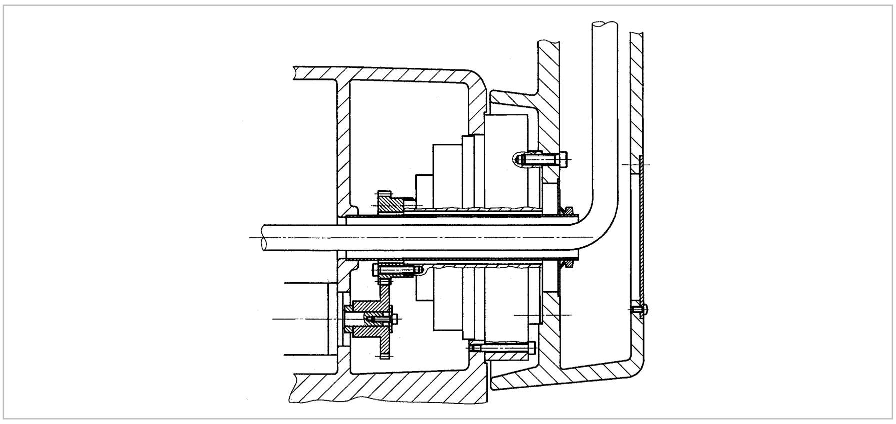
Ratio	Sizes								
	14	17	20	25	32	40	45	50	58
30	3.5	5.9	10	16	31	–	–	–	–
50	3.4	5.8	8.4	13	25	43	56	75	107
80	4.2	6.9	10	15	28	50	65	85	120
100	4.5	7.8	12	17	33	56	72	96	135
120	–	8.9	13	19	34	63	79	106	151
160	–	–	17	23	43	75	96	126	181

4.6 Continuous Operation CPU-H

The friction of the rotary shaft seals at the input side can result in an increased temperature of the hollow shaft units during operation. Therefore the defined "Limit for average input speed" of these units is reduced. For continuous operation at rated speed the max. operating times specified in table 47.2 should not be exceeded.

Alternatively a design according to illustration 47.1 can be used. This application example shows the removal of the rotary shaft seals at the (fast running) input side. For this design, the operating time is not limited. The removal of one or both rotary shaft seals at the input element should only be carried out if other measures have been undertaken to prevent the leakage of grease or oil, or if a leakage can be ruled out due to the installation position.

Illustration 47.1



Max. permissible operating time at continuous operation

Table 47.2 [min]

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

The data mentioned in table 47.2 are valid for:
- Ambient temperature: 25° C
- Input speed: 2000 rpm
- Max. lubrication temperature: 80° C
- Mounting of the unit on a plate with the following dimensions:
- Height of plate: 330 mm
- Thickness of plate: 15 mm for sizes ≤ 32
  30 mm for sizes ≥ 40
- Plate material: Steel
- An additional output flange is not mounted.

4.7 Life for Continuous Operation

The operating life of the output bearing can be calculated using equation 48.1.

Equation 48.1

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

with:

L_{10} [h] = Operating life

n_{av} [rpm] = Average output speed (equation 48.2)

C [N] = Dynamic load rating see table “Output Bearing Ratings”

P_C [N] = Dynamic equivalent load (equation 49.1)

f_W = Operating factor (table 48.3)

B = Bearing type (table 48.4)

Average Output Speed

Equation 48.2

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

Table 48.3

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 48.4

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

Dynamic Equivalent Load

Equation 49.1

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

with:

F_{rav} [N]	=	Radial force (equation 49.2)	x	=	Radial load factor (table 49.4)
F_{aav} [N]	=	Axial force (equation 49.3)	y	=	Axial load factor (table 49.4)
d_p [m]	=	Pitch circle (see capital 3.3.5)	M	=	Tilting moment (illustration 21.2)

Equation 49.2

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

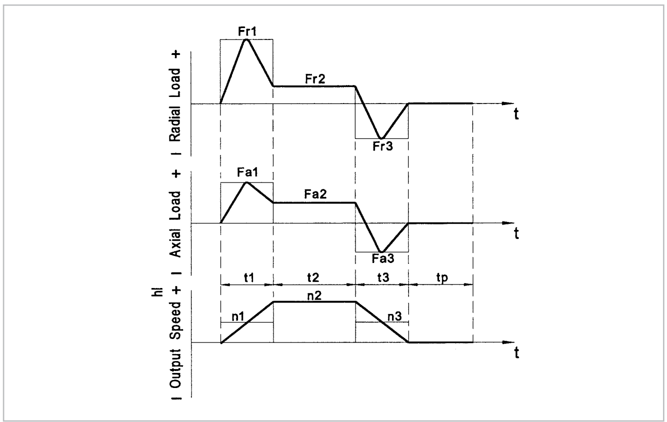
Equation 49.3

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

Table 49.4

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 49.5



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

4.7.1 Output Bearing at oscillating motion

Life for Oscillating Motion

The operating life at oscillating motion can be calculated using equation 50.1

Equation 50.1

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

with:

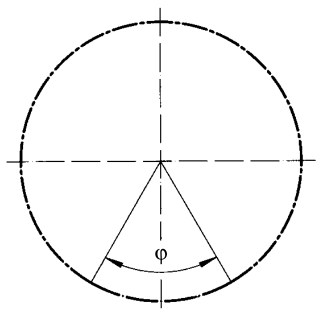
L_{OC} [h]	=	Operating life for oscillating motion
n_1 [cpm]	=	Number of oscillations/minute*
C [N]	=	Dynamic load rating, see table “Output Bearing” in the appropriate product chapter (table 21.1)
P_C [N]	=	Dynamic equivalent load (equation 49.1)
φ [deg]	=	Oscillating angle
f_W	=	Operating factor (Table 48.3)

* one oscillation means 2φ

Oscillating angle

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

Illustration 50.2



4.8 Permissible Static Tilting Moment

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

Equation 51.1

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

and so

Equation 51.2

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

f_s = Static load safety factor
(f_s = 1.5 ... 3) (table 51.3)
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 (illustration 21.2)
M_0 = Allowable static overturning moment

Table 51.3

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

4.9 Angle of Inclination

The angle of inclination of the output flange, as a function of the tilting moment acting on the output bearing, can be calculated by means of equation 51.4:

Equation 51.4

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

with:
γ [arcmin] = Angle of inclination of the output flange
M [Nm] = Tilting moment acting on the output bearing
K_B [Nm/arcmin] = Moment stiffness of the output bearing (table 21.1)

4.10 Lubrication

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

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

4.10.1 Grease lubrication

Application of Harmonic Drive® Lubricating Grease
Depending on product, size and if necessary ratio, the matching Harmonic Drive® grease should be selected. We recommend the application of the Harmonic Drive® lubricating greases according to the data in the tables 52.1 and 52.2.

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 52.1

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

Table 52.2

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

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

Table 53.1 gives some important information regarding Harmonic Drive® lubricating greases.

Table 53.1

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 54.1

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.

4.10.2 Oil Lubrication

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

Table 54.2

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

Please note the information in section 5.5.5.

4.11 Axial Forces at the Wave Generator CPU-M

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 55.1

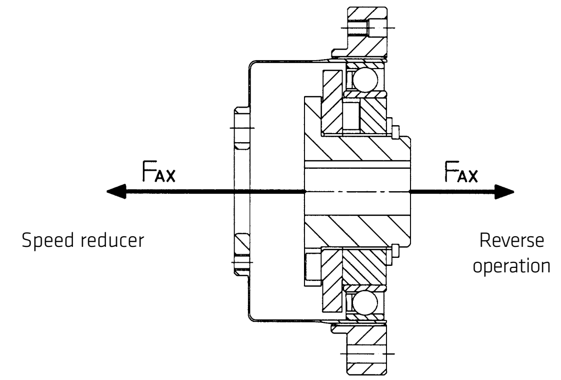


Table 55.2

Ratio		
30	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 32°$	[Equation 55.3]
50	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 30° + 2\mu PF$	[Equation 55.4]
80...160	$F_{AX} = 2 \cdot \frac{T}{D} \cdot \mu \cdot \tan 20° + 2\mu PF$	[Equation 55.5]

with:

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

Example

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

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

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

Table 55.6

Sizes	14	17	20	25	32	40	50
2μPF [N] für CSD und 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 CPU-M

In order for the full features of Harmonic Drive® Units to be exploited fully, it is essential that the tolerances according to table 57.2 are observed for the input assembly.

Illustration 57.1

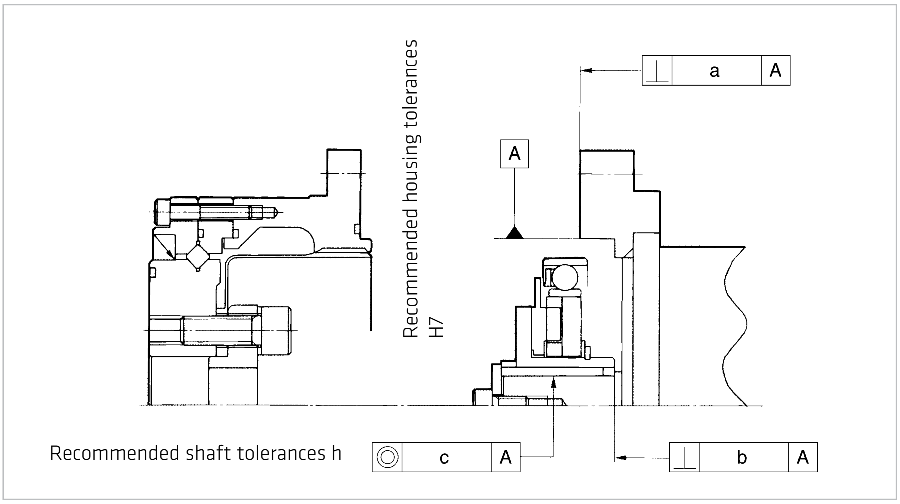


Table 57.2 [mm]

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

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

5.5 Lubrication

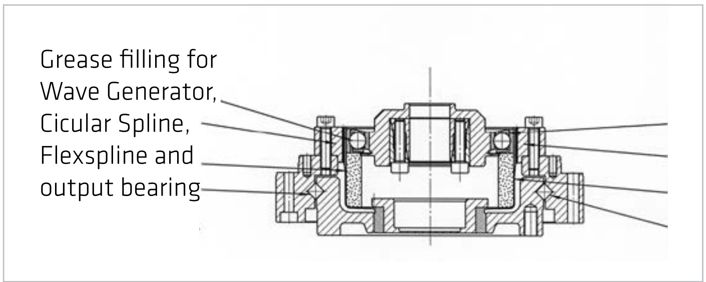
Harmonic Drive® Units are delivered ready for immediate installation. They are supplied with lifetime lubricant which is a high performance grease that meets the specific requirements of the Harmonic Drive® gears. It guarantees constant accuracy of the gears for their whole life. A re-lubrication of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

5.5.1 Grease Lubrication CPU-M

For the lubrication of the gear in sizes 14-58, we recommend the specially developed Harmonic Drive® grease Flexolub®-A1.

Units are supplied with grease lubricant as standard. Illustration 58.1 shows the sections where lubrication is required and which are filled with grease lubrication at the time of delivery. If no special arrangements are made the specially developed high perfomance grease Flexolub-A1 is used. If any other grease is used this will be indicated on the customer drawing.

Illustration 58.1

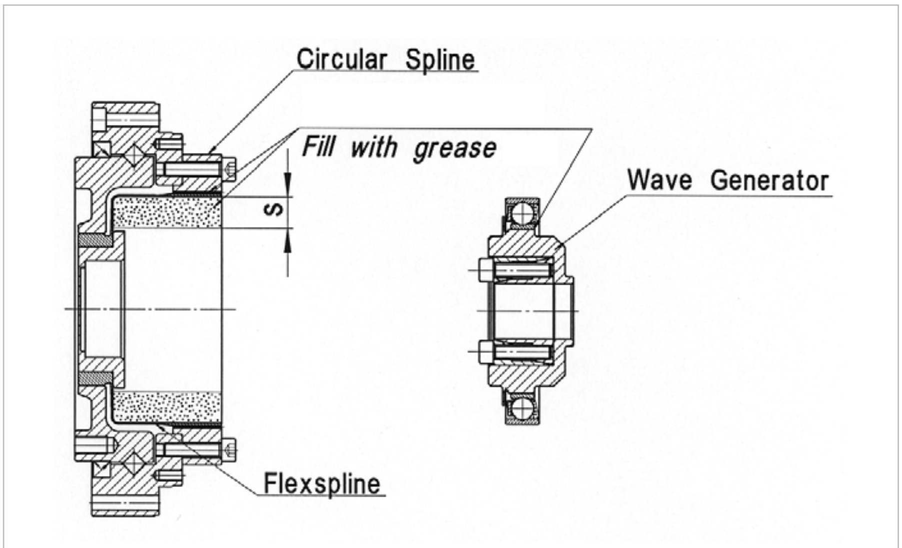


5.5.2 Amount of Grease CPU-M

Table 58.2 [mm]

Sizes	14	17	20	25	32	40	45	50	58
s	3	4	5	6	8	10	11	12	14

Illustration 58.3



5.5.3 Additional Grease Package

When the unit is mounted to the motor with the adaptor flange design recommended by Harmonic Drive AG, 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 the grease reservoir between Wave Generator and motor d-shield during assembly, see illustration 59.3. This additional grease amount is delivered in a separate package together with the unit.

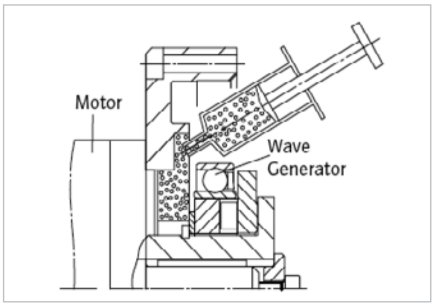
Table 59.1

Sizes		14	17	20	25	32	40	45	50	58
Standard grease quantity (contained in the gear of the unit at delivery)	ca. [g]	5.5	10	16	40	60	130	180	260	360
	ca. [cm^3]	6	11	18	44	66	143	198	286	396
Recommended additional grease quantity for grease reservoir (is delivered in a separate package. together with the unit)	ca. [g]	2	3	4	6	14	27	54	90	108
	ca. [cm^3]	2	3	4	7	16	30	60	100	120

Table 59.2

Ordering code for grease	Available packages [kg]
Special grease Flexolub®-A1	1,0; 25

Illustration 59.3

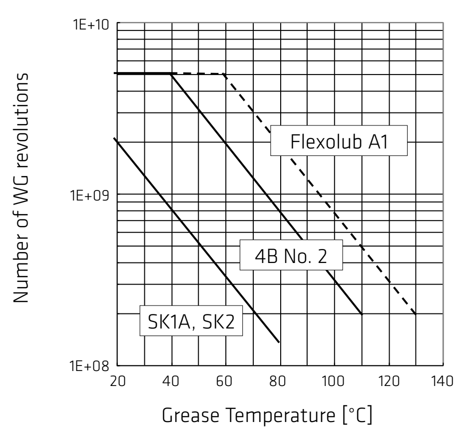


5.5.4 Grease Change

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

Illustration 59.4



Equation 59.5

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

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

L_{GTn} = see diagram

T_r = Rated torque

T_{av} = Average torque

5.5.5 Oil Lubrication

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

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

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

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

5.6 Assembly

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

General information
Clean, degrease and dry all mating surfaces to ensure an adequate coefficient of friction. The values given 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 Mounting

5.7.1 Motor Assembly CPU-M

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 CPU-M

The characteristics of the CPU-M require dimensions and tolerances in table 61.1 and illustration 62.1 for optimal performance.

Table 61.1

Sizes	14	17	20	25	32	40	45	50	58
ø D	16	26	30	37	37	45	45	45	56
ø F	36.5	47	53	66	86	106	120	131	154
ø $G_{-0.1}$	37.5	48	55.5	69	90.5	110	125	139	160
$H^{+0.1}$	6.5	7	8	10.5	14.5	18	20	23	26
$I^{+0.1}$	9.5	10	11	14.5	19.5	24	28	31	36
N	1	1.5	1.5	1.5	2	2	3	4	4
ø P H7	60	72	82	96	125	154	175	190	217
ø R	$50^{+0.027}$	$60^{+0.034}$	$70^{+0.036}$	$85^{+0.050}$	$110^{+0.055}$	$135^{+0.065}$	$155^{+0.070}$	$170^{+0.075}$	$195^{+0.091}$
S	2.5	3	3	5	6.5	11	12	16	19
$T^{+0.1}$	4.3	6.3	6.9	7.8	9.8	10.3	8.8	12.8	11.3
$U^{+0.1}$	10.5	13	14.6	18	24	28	28.5	35.5	37
$V^{+0.1}$	13.5	16	17.6	22	29	34	36.5	43.5	47
ø $W^{+0.1}$	50.4	60.4	70.4	85.4	110.4	135.4	155.4	170.4	195.4
ø b	68	78	88	105	135	165	190	206	234
ø c	2.9	3.4	3.4	3.4	4.5	5.5	5.5	6.6	6.6
ø d	55	66	76	91	118	144	164.5	180	206
e	M2.5	M2.5	M2.5	M3	M4	M5	M6	M6	M8
$f_{-0.1}$	1	1.3	1.3	1.3	1.3	2	2	2	2
$g_{-0.1}$	0.7	1	1	1	1	1.7	1.7	1.7	1.7
x	0.030	0.034	0.044	0.047	0.050	0.063	0.065	0.066	0.068
y	0.030	0.040	0.040	0.040	0.040	0.050	0.050	0.050	0.050
z	0.030 (0.016)	0.034 (0.018)	0.044 (0.019)	0.047 (0.022)	0.050 (0.022)	0.063 (0.024)	0.065 (0.027)	0.066 (0.030)	0.068 (0.033)

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

Illustration 62.1

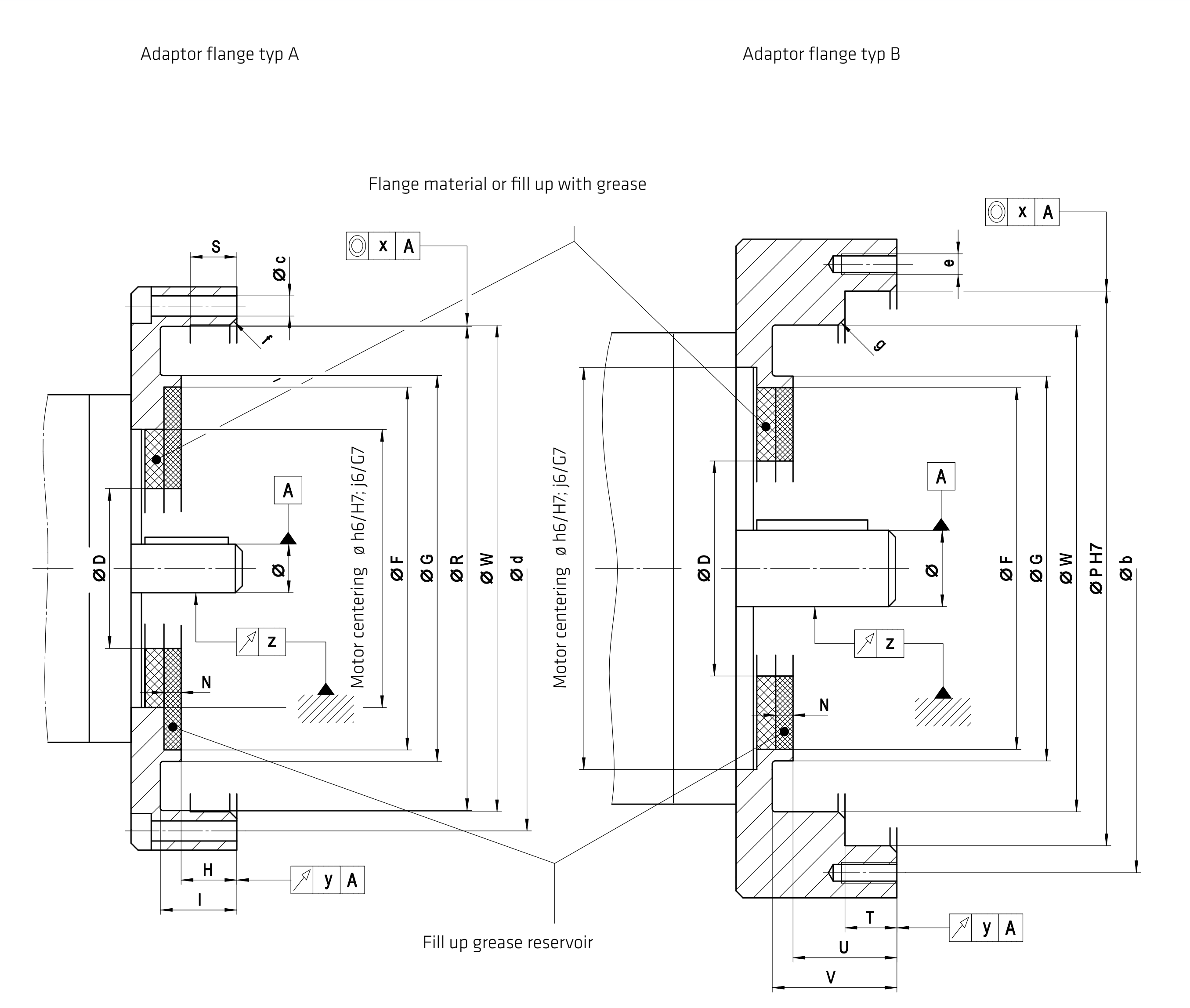
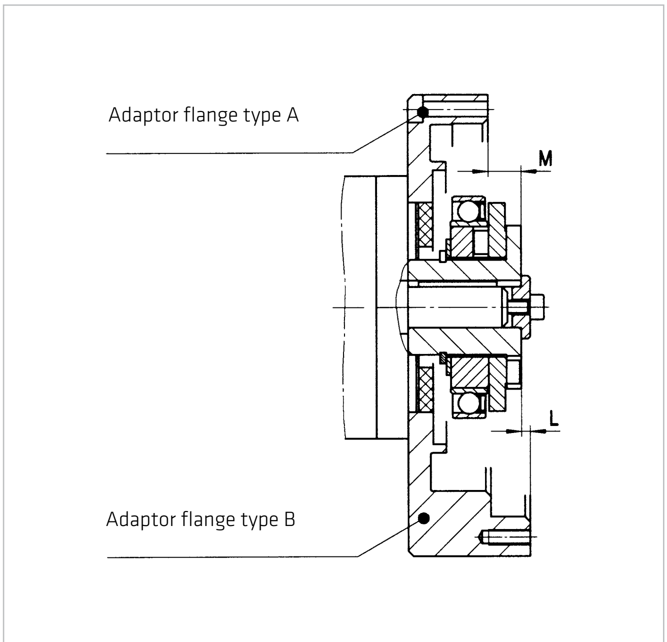


Illustration 62.2



The prescribed axial position for the standard Wave Generator is defined by the variables M (for adaptor flange type A) and L (for adaptor flange type B), see also illustration 58.1 and table 59.1. When using a solid Wave Generator (Option), the provided data on the specific confirmation drawings are valid.

Mounting Units CPU-M

When mounting the motor, two different approaches are possible, see illustration 63.3 and 63.4.

Illustration 63.1 **Adaptor flange typ A**

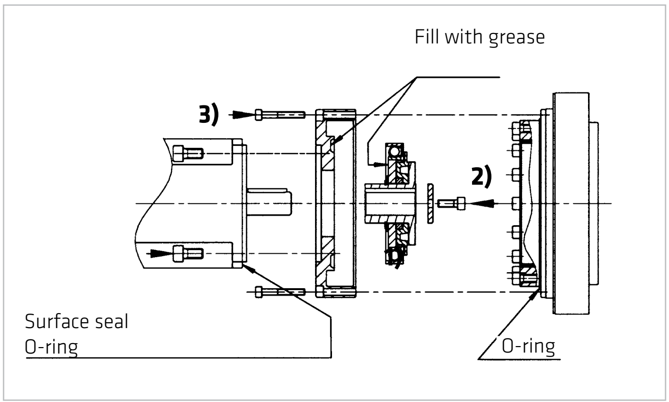


Illustration 63.2 **Adaptor flange typ B**

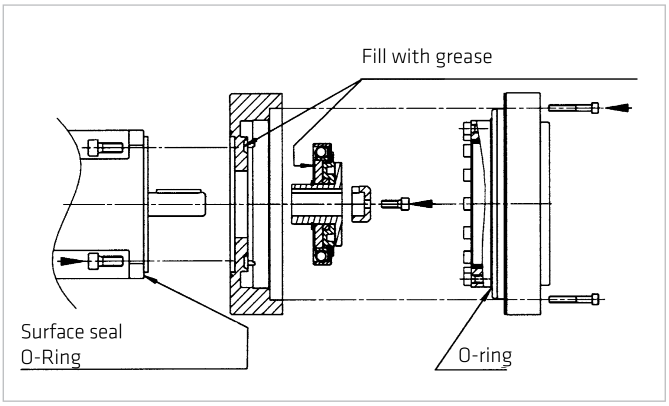
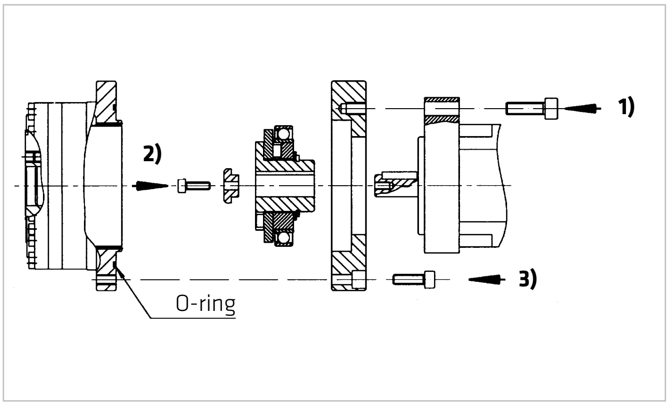


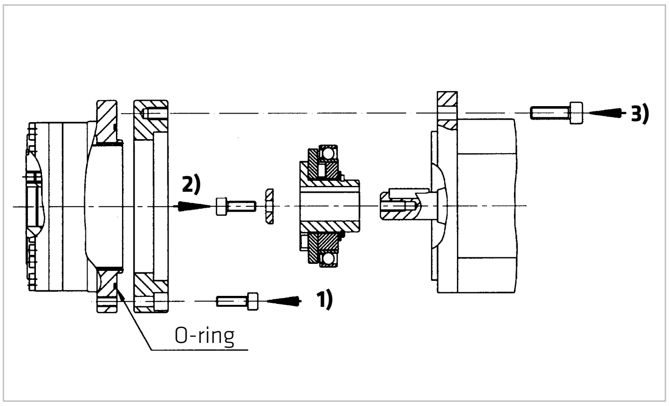
Illustration 63.3



Installation steps as shown in illustration 63.1:

1) Mount the flange assembly to the motor.
2) Mount the Wave Generator to the motor shaft.
3) Installation of the flange including motor onto the unit.

Illustration 63.4



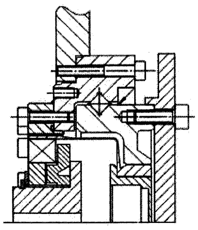
Installation steps according to illustration 63.2:

1) Mount the flange to the Unit.
2) Mount the wave generator to the motor shaft.
3) Mount the motor onto the flange.

Adaption Examples Units CPU-M

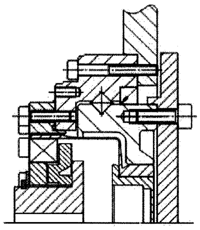
Housing

Illustration 64.1



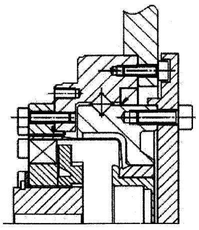
Use of through holes

Illustration 64.2



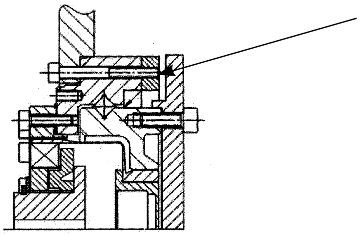
Use of through holes

Illustration 64.3



Use of tapped blind hole threads

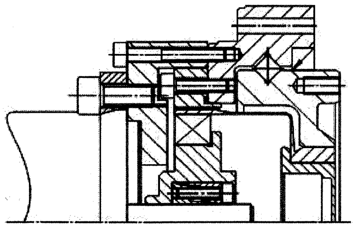
Illustration 64.4



Use of through holes with separate thread ring
(thread ring on request)

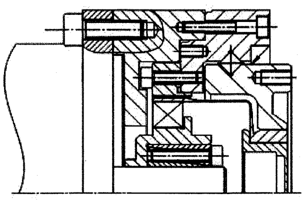
Motor

Illustration 64.5



Small motor, flange type A

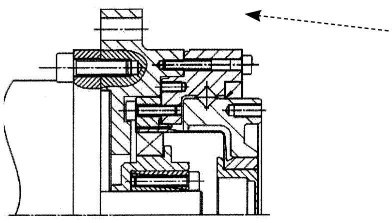
Illustration 64.6



Big motor, flange type B

Individual Adaptation for Housing and Motor

Illustration 64.7



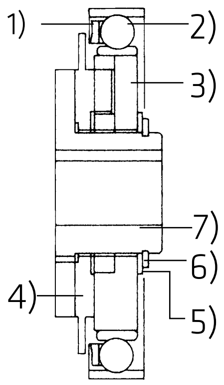
In this case the through holes must be used, as shown in the picture. The counter sunk drillings must not be used!

Any motor, any flange type

5.7.2 Wave Generator Components CPU-M

Illustration 65.1 shows a standard Wave Generator with Oldham Coupling.

Illustration 65.1



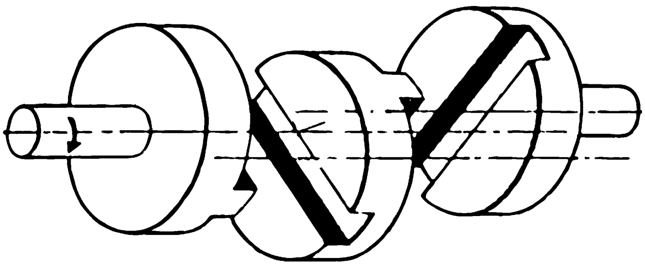
1) Ball Separator
2) Wave Generator bearing
3) Wave Generator plug
4) Insert
5) Thrust washers
6) Snap ring
7) Wave Generator hub

Wave Generator Modifications

CPU-M units are provided with an Oldham coupling to compensate for eccentricity of the input shaft (see illustration 65.2).

Principle of an Oldham coupling

Illustration 65.2



Maximum Bore Diameter for CPU-M

If a large-bore Wave Generator or an input coupling completely free of backlash is required, the Oldham coupling may be removed and the input shaft can be attached directly to the Wave Generator plug. This is the so called “Solid Wave Generator” configuration. The Wave Generator bore may be enlarged or splined to accept a hollow shaft or a splined shaft. The maximum allowable bore diameter, with or without keyway or splines, is given in table 66.2.
Use of a solid Wave Generator demands tighter tolerances for the motor shaft and housing, as described in the section “Assembly Tolerances” for the selected product.

Illustration 66.1

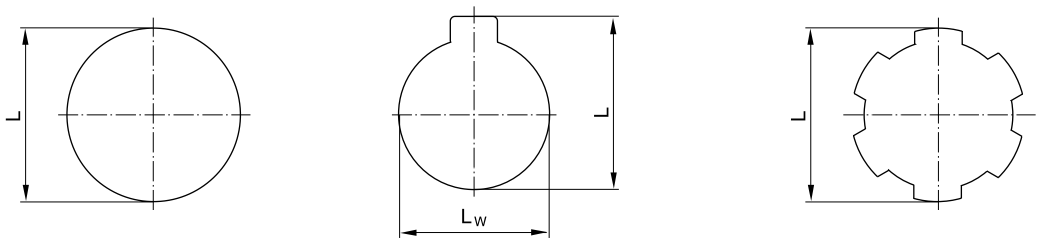


Table 66.2 [mm]

Sizes	**14**	**17**	**20**	**25**	**32**	**40**	**45**	**50**	**58**
L_W for keys to DIN 6885 T1	12	13	17	22	28	34	39	44	50
L	17	20	23	28	36	42	47	52	60

5.7.3 Mounting the Wave Generator (WG) to the Motor Shaft CPU-M

The CPU-M units are delivered with the Wave Generator adapted for the motor shaft. The hub of the Oldham coupling is secured on the motor shaft by means of a key or clamping element. Please observe the recommendations for the correct axial position of the Wave Generator inside the gearbox, see illustration 67.1 and 67.2.

The axial attachment of the hub must withstand the axial forces acting on the Wave Generator. When mounted correctly, the motor shaft should extend at least 2/3 of the entire hub length, thereby ensuring reliable transmission of the motor torque.

Illustration 67.1

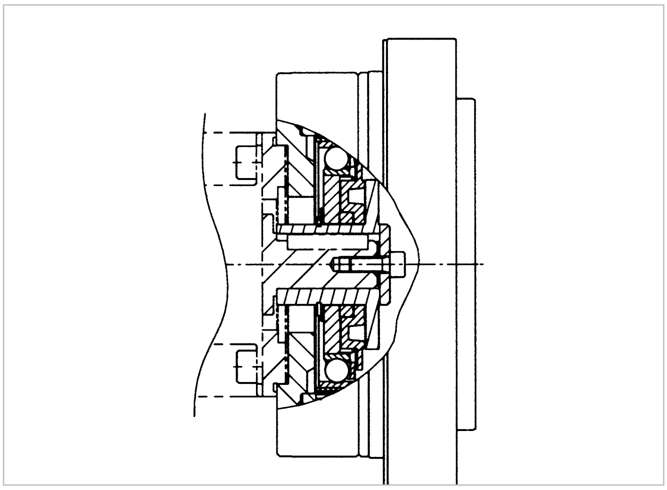
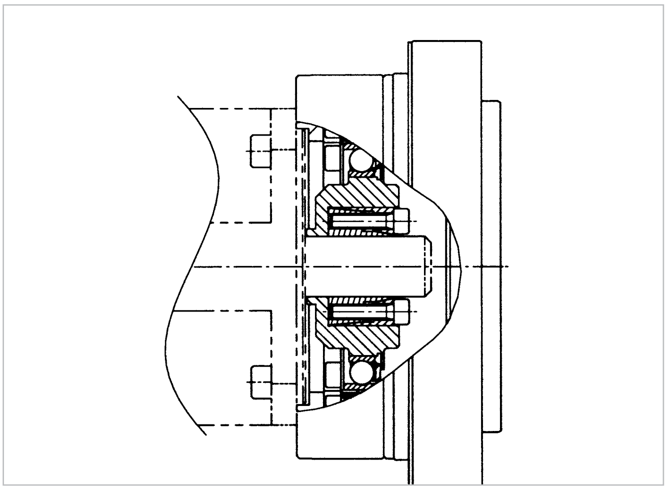


Illustration 67.2



For stepping motor operation and for large motor shaft diameters the use of a solid Wave Generator is recommended. Illustration 67.1 shows the standard version with Oldham coupling and keyway. Illustration 67.2 shows a solid Wave Generator without Oldham coupling. The Wave Generator is attached directly to the motor shaft by means of a clamping element.

- Push the greased Wave Generator onto the motor shaft according to the assembly dimension in the confirmation drawing.
- Insert the plug into the bore of the Wave Generator hub and tighten with the screw. When a clamping element is used, tighten its screws crosswise in five steps to the torque given in the confirmation drawing.

5.7.4 Check before assembly of the Wave Generator (WG)

- Final check of position of the Wave Generator. For some clamping elements an axial movement may occur during tightening. Please take account of this effect when positioning the Wave Generator on the shaft.
- Check whether the WG is lubricated in accordance with illustration 59.3. When the gear is oil lubricated, fill in the prescribed oil quantity.

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

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

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

Assembly of the Motor/Adaptor Flange Sub-Assembly to the Unit

Mount the O-ring. Apply some assembly paste or grease (chapter 4.2.3), if necessary. Connect the preassembled sub-assembly consisting of motor, Wave Generator and adaptor flange to the Unit. It is essential that the components are carefully aligned during the assembly. The teeth of the Flexspline and Circular Spline must mesh symmetrically for proper function.

Alternatively, the motor assembly can be carried out while the motor shaft is rotating slowly (n <10 rpm). This procedure simplifies the assembly. The assembly must be performed gently without using undue force.

5.7.6 Assembly Control CPU-M

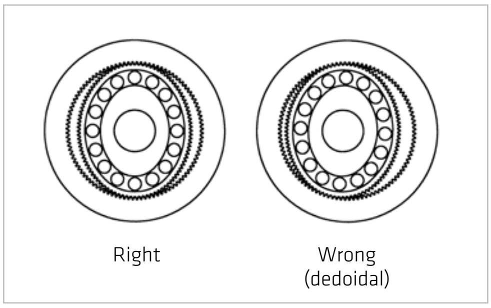
Very rarely, an eccentric tooth mesh, called dedoidal, may occur.
The correct assembly can be checked as follow:

- 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 68.1



5.7.7 Assembly of the Output Flange

Table 69.1

Sizes		14	17	20	25	32	40	45	50	58
Number of Bolts		12	12	12	12	12	12	12	12	12
Bolt Size		M3	M4	M4	M5	M6	M8	M10	M10	M10
Bolt pitch diameter	[mm]	43	52	62	76	96	118	135	152	175
Tightening Torque	[Nm]	2.3	5.1	5.1	10	17.4	42.2	83	83	83
Torque transmitting capacity [1]	[Nm]	85	188	228	463	847	1964	3621	4086	4688

5.7.8 Assembly of the Housing

Table 69.2

Sizes		14	17	20	25	32	40	45	50	58
Number of Bolts		8	12	12	12	12	12	12	12	12
Bolt Size		M3	M3	M3	M4	M5	M6	M8	M8	M10
Bolt pitch diameter	[mm]	68	80	89	105	135	168	190	206	236
Tightening Torque	[Nm]	2.3	2.3	2.3	5.1	10	17.4	42.2	42.2	83
Torque transmitting capacity [1]	[Nm]	89	158	177	378	805	1482	3158	3419	6317

[1] The tables are valid for completely degreased pads (friction coefficient µk = 0.15) and metric socket head cap screws according to EN ISO 4762 in 12.9 quality, untreated, oiled, with μ_{total} = 0.12.

Housing and output flange to be assembled as per table 69.1 and 69.2

5.7.9 Installation of the Input Shaft CPU-H

Table 69.3

Sizes		14	17	20	25	32	40	45	50	58
Number of screws		3	3	6	6	6	6	6	6	8
Size of the screws		M3	M3	M3	M3	M3	M4	M4	M4	M4
Tightening torque of screw	[Nm]	3	3	3	3	3	5.1	5.1	5.1	5.1

6. Glossary

6.1 Technical Data

AC Voltage constant k_{EM} [V_{rms} / 1000 rpm]

Effective value of the induced motor voltage measured at the motor terminals at a speed of 1000 rpm and an operating temperature of 20° C.

Ambient operating temperature [°C]

The intended operating temperature for the operation of the drive.

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

Maximum permissible average gear input speed for grease lubrication.

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

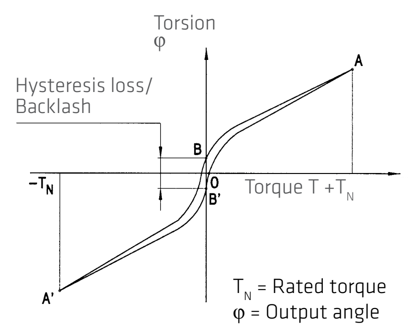
Maximum permissible average gear input speed for oil lubrication.

Average torque T_A [Nm]

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

Backlash (Harmonic Planetary gears) [arcmin]

When subjected to the rated torque, Harmonic Planetary gears display characteristics shown in the hysteresis curve. When a torque is applied to the output shaft of the gear with the input shaft locked, the torque-torsion relationship can be measured at the output. Starting from point 0 the graph follows successive points A-B-A-B-A 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 tom 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.

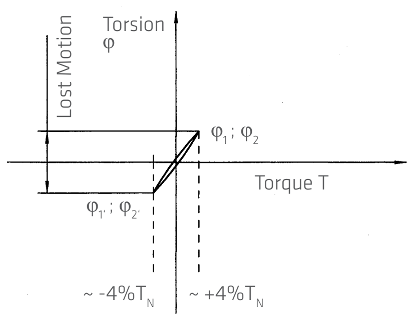
Inductance (L-L) L_{L-L} [mH]

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 ± 4% of the rated torque.



Maximum current I_{max} [A]
The maximum current is the maximum current that can be applied for a short period.

Maximum DC bus voltage $U_{DC\ (max)}$ [VDC]
The maximum DC bus power supply for the correct operation of the actuator. This value may only be exceeded for a short period during the braking or deceleration phase.

Maximum hollow shaft diameter $d_{H\ (max)}$ [mm]
For gears with a hollow shaft, this value is the maximum diameter of the axial hollow shaft.

Maximum input speed (grease lubrication) $n_{in\ (max)}$ [rpm]
Maximum allowed input speed for gearing with grease lubrication.

Maximum input speed (oil lubrication) $n_{in\ (max)}$ [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 [kgm^2]
Mass moment of inertia at motor side.

Moment of inertia J_{in} [kgm^2]
Mass moment of inertia of the gearing with respect to the input.

Moment of inertia J_{out} [kgm^2]
Mass moment of inertia with respect to the output.

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

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

Number of pole pairs p

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

Offset R [mm]

Distance between output bearing and contact point of load.

Pitch circle diameter d_p [mm]

Pitch circle diameter of the output bearing.

Protetcion 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.

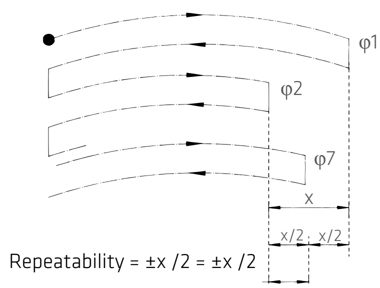
Ratio i [ ]

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 ± 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 be not be exceeded.

Resistance (L-L, 20° C) R_{L-L} [Ω]

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

Size

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

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

2) CHM Servo motor series

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

3) Direct drives from the TorkDrive® series

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

Static load rating C_0 [N]

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

Static tilting moment M_0 [Nm]

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

Tilting moment stiffness K_B [Nm/arcmin]

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.

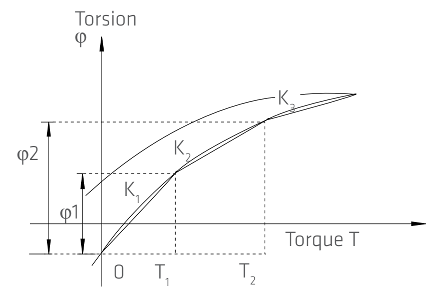
Torque constant (output) k_{Tout} [Nm/A_{rms}]

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.

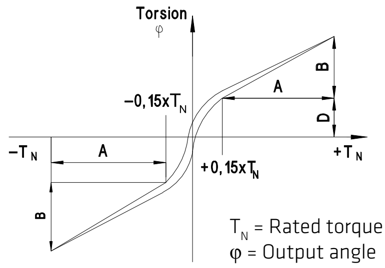
The value given for the torsional stiffness K_3 is an average that has been determined during numerous tests. The limit torques T_1 and T_2 and calculation example for the total torsional angle Gesamtverdrehwinkels can be found in the secondary technical documentation.



K_1, K_2, K_3 = Torsional stiffness, w = Output angle
φ1 = Torsion angle, with output torque T_1
φ2 = Torsion angle, with output torque T_2

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

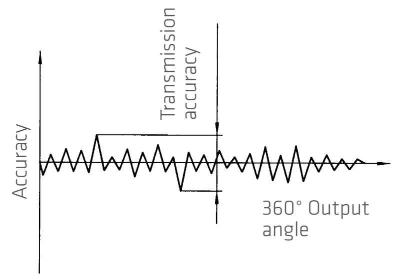
The amount of elastic rotation at the output for a given torque and blocked input shaft. The torsional rigidity of the Harmonic Planetary gear describes the rotation of the gear above a reference torque of 15% of the rated torque. In this area the torsional stiffness is almost linear.



T_N = Rated torque
φ = Output angle

Transmission accuracy [arcmin]

The transmission accuracy of the gear represents 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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