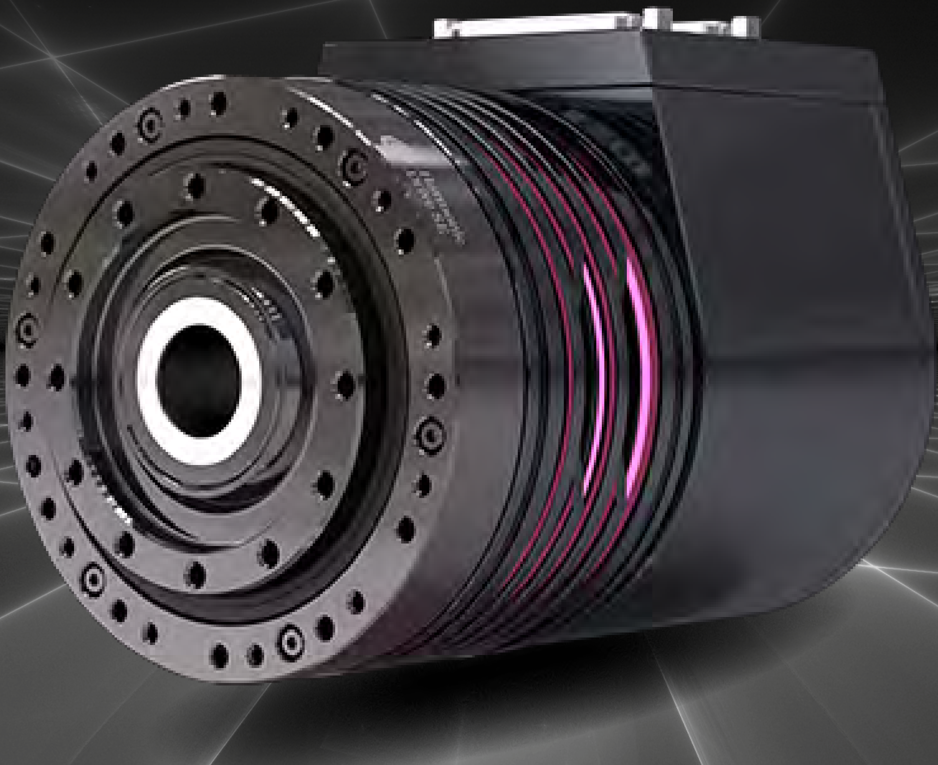
Engineering data
IHD Servo Actuators

Harmonic Drive SE



1. General

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

Instructions of 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
When configuring drive systems using Harmonic Drive SE products, additional documents may be required. Documentation is provided for all products offered by Harmonic Drive SE 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 these manufacturers.

Before commissioning servo actuators and servo motors from Harmonic Drive SE with servo drives, we advise you to obtain the relevant documents for each device.

Your feedback
Your feedback is important to us. Please send suggestions and comments about our products and documentation to:

Harmonic Drive SE
Marketing and Communications
Hoenbergstraße 14
65555 Limburg / Lahn
E-Mail: info@harmonicdrive.de

1.1 Description of Safety Alert Symbols

Table 5.1

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.
INFO	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.
	Warning of hot surfaces.
	Warning of suspended loads.
	Precautions when handling electrostatic sensitive components.
	Warning of electromagnetic environmental compatibility.

1.2 Disclaimer and Copyright

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

2. Safety Instructions

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

2.1 Hazards

DANGER

Electric servo actuators and motors have dangerous live and rotating parts. All work during connection, operation, repair and disposal must be carried out by qualified personnel as described in the standards EN 50110-1 and IEC 60364! Before starting any work, and especially before opening covers, the actuator must be properly isolated. In addition to the main circuits, the user also has to pay attention to any auxilliary circuits.

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

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

ATTENTION

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

ADVICE

Cables must not come into direct contact with hot surfaces.

DANGER

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

DANGER

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

DANGER

Risk of injury due to improper handling of batteries.

Observing the battery safety rules:
- do not insert batteries in reverse. Observe the + and - marks on the battery and on the electrical device
- do not short circuit
- do not recharge
- do not force open or damage
- do not expose to fire, water or high temperature
- remove and discard exhausted batteries from the electrical device immediately
- keep batteries out of reach of children. If swallowed, seek medical assistance immediately

WARNING

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

Injury caused by moving or ejected parts:
Contact with moving parts or output elements and the ejection of loose parts (e.g. feather keys) out of the motor enclosure can result in severe injury or death.
- Remove or carefully secure any loose parts
- Do not touch any moving parts
- Protect against all moving parts using the appropriate safety guards

Unexpected movement of machines caused by inactive safety instructions:
Inactive or non adapted safety functions can trigger unexpected machine movements that may result in serious injury or death.
- Observe the information in the appropriate product documentation before commissioning
- Carry out a safety inspection for functions relevant to safety on the entire system, including all safety related components

Make sure the safety functions relevant to your product are applied
- Perform regular function tests
- Only use the system productively after having correctly executed the safety relevant functions

ATTENTION

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

INFO

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

2.2 Intended Purpose

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

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

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

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

2.3 Improper Use

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

2.4 Use in Special Application Areas

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

- Aerospace
- Areas at risk of explosion
- Machines specially constructed or used for a nuclear purpose whose breakdown might lead to the emission of radio activity
- Vacuum
- Household devices
- Medical equipment
- Devices which interact directly with the human body
- Machines or equipment for transporting or lifting people
- Special devices for use in fairgrounds or amusement parks

2.5 Declaration of Conformity

2.5.1 Gears

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

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

2.5.2 Servo Actuators and Motors

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

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

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

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

2.5.3 Integrated Systems

Harmonic Drive® Integrated Systems described in the engineering data comply with the EMC Directive. Commissioning is prohibited until the final product conforms to the Machinery Directive.

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

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

3. Product Description

Smart, compact & highly integrated

Plug and Play via software: The new Smart System IHD from Harmonic Drive® brings together 50 years of experience with precision gears and state-of-the-art motor and drive technology. Experien ce innovation with our highly integrated drive solution, all without a control cabinet.

Integration made easy

Highly compact and highly integrated: The IHD system comprises a backlash-free gearbox, a sophisticated servo motor, a dual motor feedback system for position measurement and a powerful motion controller in a ready-to-use drive solution. Easy integration into your application is supported not only by the drive's central hollow shaft, which is predestined to carry a wide variety of media, but also by our specially developed, user-friendly software solution for simple commissioning – plug and play.

Compatible and predictive

Thanks to thermal optimization of its design, the IHD meets all requirements for high-performance applica tions in the field of stationary and mobile drive technology. Advanced simulation tools for thermal evalua tion of the system have been developed for this purpose. The IHD system has an application processor for future smart applications such as condition monitoring and can be used as a separate platform for custo mer-specific application programming. The system operates with DC voltages of 24V or 48V. Communica tion with the machine controller is possible via CANopen, Ethernet and EtherCAT.
The servo actuators in our IHD Series are the perfect combination of highly dynamic, compact synchronous servo motors and zero backlash gears with output bearings. Our servo actuators with hollow shaft are another outstanding choice thanks to their low weight, small volume, excellent torque density, long lifetime and high standards of reliability.

Table 10.1

Torque capacity	Accuracy	Dynamic	Tilt resistant	Low weight	Short design	Small outer diameter	Large hollow shaft	Temperature range
•••	•••	•	•••	•	•	•••	•••	••

••• perfect •• optimal • good

Technical Data

Actuator IHD-20 with 24 V DC bus voltage

Table 11.1

			Data Actuator			Data output bearing			Dimensions		
Size	Ratio i [ ]	Power supply V_{cc} [VDC]	Maximum torque T_{max} [Nm]	Maximum output speed n_{max} [rpm]	Continuous stall torque T_0 [Nm]	Dynamic radial load $F_{R\ dyn\ (max)}$ [N]	Dynamic axial load $F_{A\ dyn\ (max)}$ [N]	Dynamic tilting moment $M_{dyn\ (max)}$ [Nm]	Outer dimension A [mm]	Length L [mm]	Hollow shaft diameter d_H [mm]
20	50	24	73	68	44	8600	15800	172	106	127	18
	100		107	34	64						
	160		120	21	64						

Actuator IHD-20 with 48 V DC bus voltage

Table 11.2

			Data Actuator			Data output bearing			Dimensions		
Size	Ratio i [ ]	Power supply V_{cc} [VDC]	Maximum torque T_{max} [Nm]	Maximum output speed n_{max} [rpm]	Continuous stall torque T_0 [Nm]	Dynamic radial load $F_{R\ dyn\ (max)}$ [N]	Dynamic axial load $F_{A\ dyn\ (max)}$ [N]	Dynamic tilting moment $M_{dyn\ (max)}$ [Nm]	Outer dimension A [mm]	Length L [mm]	Hollow shaft diameter d_H [mm]
20	50	48	73	120	44	8600	15800	172	106	127	18
	100		107	60	64						
	160		120	38	64						

4. Ordering Code

4.1 Overview

Table 12.1

Series	Size Version	Ratio			Power supply	Controller	Protocol	Connector	Brake	Smart features	Technology options
IHD	20A	50	100	160	24 48	II1 Internal IE1 External[1]	N=Ethernet E=EtherCAT C=CANopen P=Profinet	RS AS	0 = Without B = Brake	Enhanced functions (see 4.1.2)	According to customer requirements (see 4.1.3)
Ordering code											
IHD	**-20A**	**-50**			**-24**	**-II1**	**-E**	**-RS**	**-0**	**-XX**	**-SP**

1) On request

4.1.1 Connector

Table 12.2

Ordering code	Description
RS	Radial D-Sub
AS	Axial D-Sub (on request)

4.1.2 Smart features

The integrated dual core micro controller provides additional computing power to introduce further functionalities which can be specified within customized solutions in co-operation with the customer.

4.1.3 Technology options

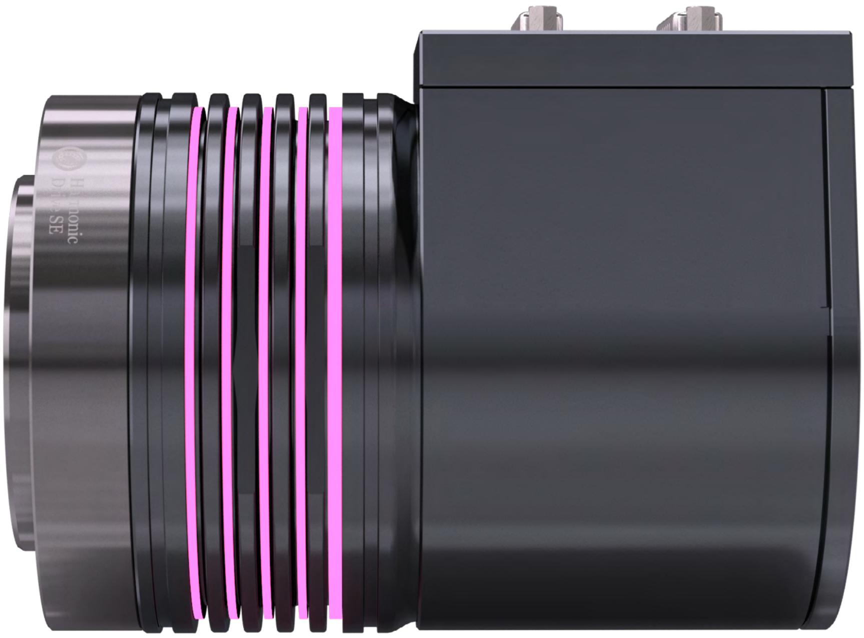
The integrated drive system consists of components which can be adopted to the customer needs. Modifications on the housing as well as on the electrical connection can be carried out in close co-operation with the customer.

4.2 Combinations

Table 13.1

Size Version		IHD-20A
Ratio	50	●
	100	●
	160	●
Communication Interface	EtherCAT	●
	CANopen	●
Brake	B	●

● available ○ on request - not available



5. Technical Data

5.1 General Technical Data

Table 14.1

	Symbol [Unit]	
Motor winding		
Insulation class (EN 60034-1)		F
Insulation resistance (500 VDC)	MΩ	100
Insulation voltage (10 s)	V_{eff}	700
Lubrication		4BNo2
Degree of protection (EN 60034-5)		IP68
Ambient operating temperature	°C	0 ... 40
Ambient storage temperature	°C	-20 ... 60
Altitude (a.s.l.)	m	< 1000
Relative humidity (without condensation)	%	20 ... 80
Vibration resistance (DIN IEC 60068 Part 2-6, 10 ... 500 Hz)	g	5
Shock resistance (DIN IEC 60068 Part 2-27, 11 ms)	g	30
Corrosion protection (DIN IEC 60068 Part 2-11 Salt spray test)	h	-
Temperature sensors		1 x PT1000[1)]
Gear Component Set		CSG
Controller data		
Controller		i201A-H1-1.1.0
Power Supply		
Recommended power supply	V_{DC}	24-48
Recommended STO input voltage	V_{DC}	5-30
Recommended logic power supply (optional)	V_{DC}	8-30
Standby power consumption	W	<= 5
Interfaces		
EtherNet EtherCAT CANopen		Cyclic Synchronous Position Cyclic Synchronous Velocity Cyclick Synchronous Current Profiled Position (trapezoidal and s-curves) Profile Velocity Interpolated Position (P, PT, PVT) Homing
Additional inputs and outputs		
Digital Input (single ended)	V_{DC}	3.3 & 5
Open collector output with maximum sink current	mA	100
Differential analog input	V_{DC}	+/- 10
Recommended braking resistor	Ω	10 (200 / max 5A)

1) Save separation according to EN 61800-5-1

The continuous operating characteristics given in the following apply to an ambient temperature of 40 °C and an aluminium cooling surface with the following dimensions:

Tabelle 14.2

Series	Size Version	Unit	Dimension
IHD	20A	[mm]	300 x 300 x15

5.2 Actuator Data

5.2.1 Actuator IHD-20 with 24 V DC bus voltage

Technical Data

Dimensions

Table 15.1

	Symbol [Unit]	IHD-20A		
Mechanical data				
Ratio	i [ ]	**50**	**100**	**160**
Maximum output torque	T_{max} [Nm]	73	107	120
Maximum output speed	n_{max} [rpm]	68	34	21
Continuous stall torque	T_0 [Nm]	44	64	64
Hollow shaft diameter	d_H [mm]	18.1		
Weight without brake	m [kg]	3.3		
Weight with brake	m [kg]	3.7		
Mechanical time constant (without brake)	T_m [ms]	5.7		
Electrical data				
Maximum current (for 2 s)	I_{max} [A_{eff}]	27.8	20.1	14.5
Maximum DC bus voltage	U_{DCmax} [V_{DC}]	60		
DC bus voltage	U_{DC} [V_{DC}]	24		
Electrical time constant (20 °C)	t_e [ms]	1.2		
Rated operation point				
Rated speed	n_N [rpm]	50	27	18
Rated torque	T_N [Nm]	32	64	64
Rated current	I_N [A_{DC}]	11.2	11.5	7.8
Rated voltage	U_N [V_{DC}]	24		
Electrical input power	P_{in} [W]	268	277	187
Mechanical output power	P_{out} [W]	168	181	121
Rated efficiency	η_N [%]	62.7	65.3	64.7
Rated torque gear component set for calculating the Wave Generator lifetime	T_N [Nm]	33	52	52
Rated input speed of gear component set for calculating the Wave Generator lifetime	n_N [rpm]	2000		
Thermal specification				
Ambient temperature	T_{amb} [°C]	40		
Maximum winding temperature	$T_{cu,max}$ [°C]	105	105	90
Maximum housing temperature	$T_{frame,max}$ [°C]	85	85	75
Thermal time constant of actuator	T_{th} [s]	2200		

Performance Characteristics

The performance curves shown below are valid for the specified ambient operating temperature and the indicated DC bus voltage.

Illustration 16.1 IHD-20A-50, 24 VDC

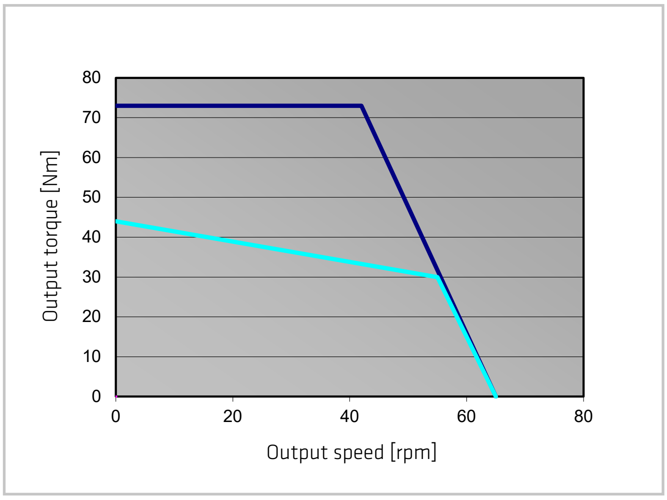


Illustration 16.2 IHD-20A-100, 24 VDC

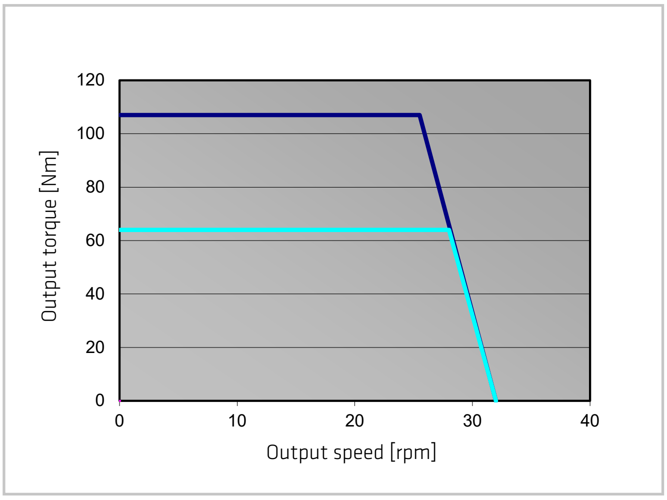
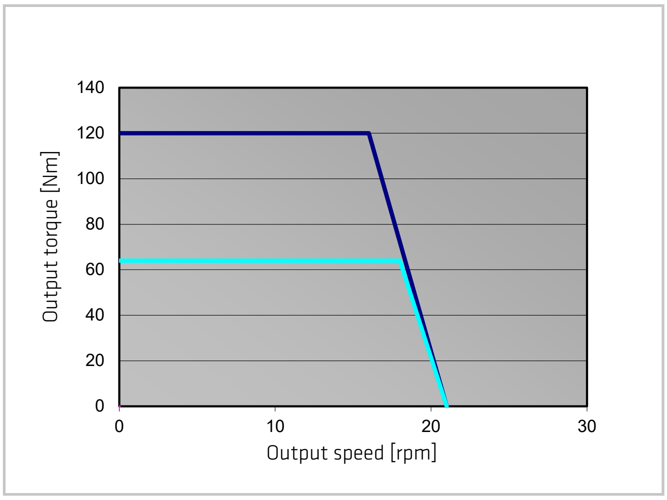


Illustration 16.3 IHD-20A-160, 24 VDC



5.2.2 Actuator IHD-20 with 48 V DC bus voltage

Technical Data

Dimensions

Table 17.1

	Symbol [Unit]	IHD-20A		
Mechanical data				
Ratio	i [ ]	**50**	**100**	**160**
Maximum output torque	T_{max} [Nm]	73	107	120
Maximum output speed	n_{max} [rpm]	120	60	38
Continuous stall torque	T_0 [Nm]	44	64	64
Hollow shaft diameter	d_H [mm]	18.1		
Weight without brake	m [kg]	3.3		
Weight with brake	m [kg]	3.7		
Mechanical time constant (without brake)	T_m [ms]	5.7		
Electrical data				
Maximum current (for 2 s)	I_{max} [A_{eff}]	27.3	20.6	14.7
Maximum DC bus voltage	U_{DCmax} [V_{DC}]	60		
DC bus voltage	U_{DC} [V_{DC}]	48		
Electrical time constant (20 °C)	t_e [ms]	1.2		
Rated operation point				
Rated speed	n_N [rpm]	70	35	21
Rated torque	T_N [Nm]	26	56	64
Rated current	I_N [A_{DC}]	6.2	6.5	4.5
Rated voltage	U_N [V_{DC}]	48		
Electrical input power	P_{in} [W]	297	311	218
Mechanical output power	P_{out} [W]	190	207	141
Rated efficiency	η_N [%]	63.9	66.6	64.6
Rated torque gear component set for calculating the Wave Generator lifetime	T_N [Nm]	33	52	52
Rated input speed of gear component set for calculating the Wave Generator lifetime	n_N [rpm]	2000		
Thermal specification				
Ambient temperature	T_{amb} [°C]	40		
Maximum winding temperature	$T_{cu,max}$ [°C]	105	105	90
Maximum housing temperature	$T_{frame,max}$ [°C]	85	85	75
Thermal time constant of actuator	T_{th} [s]	2200		

Performance Characteristics

The performance curves shown below are valid for the specified ambient operating temperature and the indicated DC bus voltage.

Illustration 18.1

IHD-20A-50, 48 VDC

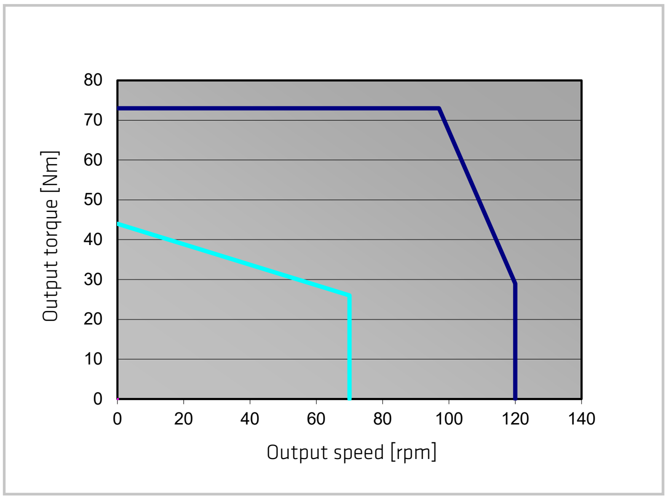


Illustration 18.2

IHD-20A-100, 48 VDC

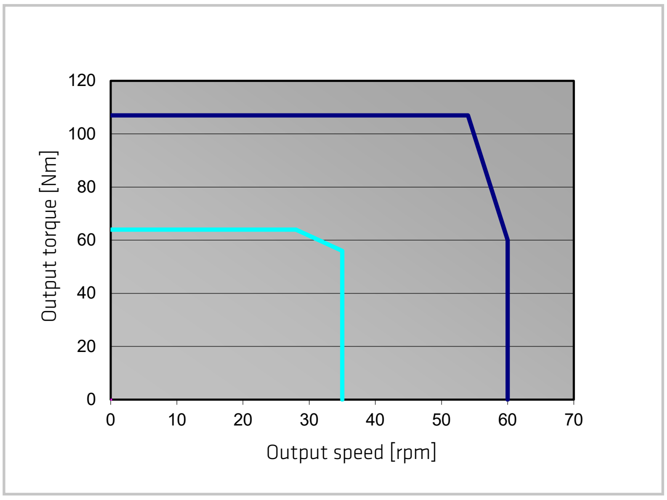
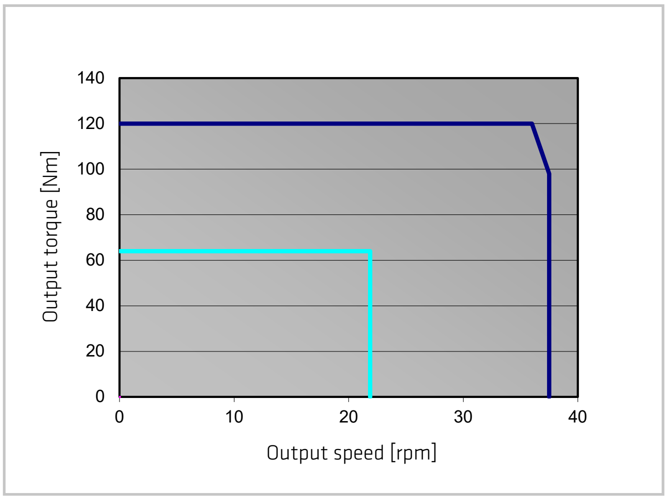


Illustration 18.3

IHD-20A-160, 48 VDC



Moment of Inertia

Table 19.1

	Symbol [Unit]	IHD-20A		
Ratio	i [ ]	**50**	**100**	**160**
Moment of Inertia output side				
Moment of inertia without brake	J_{out} [kgm^2]	0.33	1.34	3.43
Moment of inertia with brake	J_{out} [kgm^2]	0.38	1.5	3.84
Moment of Inertia at motor				
Moment of inertia at motor without brake	J [$x10^{-4}$ kgm^2]	1.34		
Moment of inertia at motor with brake	J [$x10^{-4}$ kgm^2]	1.5		

Technical Data Motor Brake

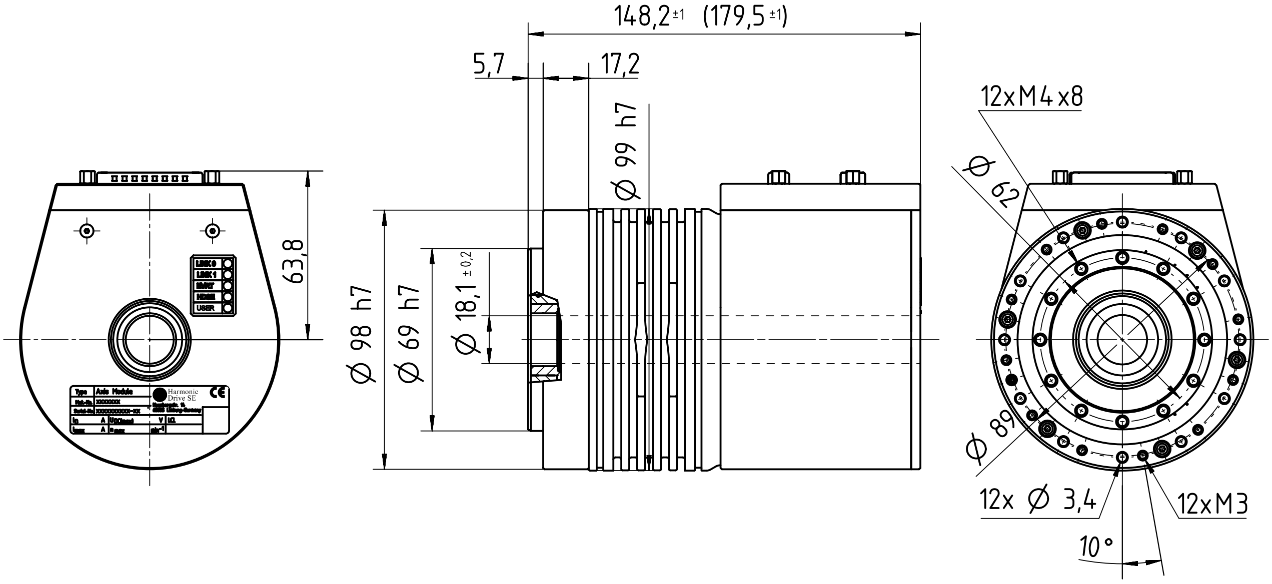
Table 19.2

	Symbol [Unit]	IHD-20A		
Ratio	i [ ]	**50**	**100**	**160**
Brake voltage	U_{Br} [V_{DC}]	24 ± 10 %		
Brake holding torque (at output)	T_{Br} [Nm]	36	72	115
Brake power consumption	P_{Br} [W]	9.5		
Brake current to open	I_{OBr} [A_{DC}]	0.4		
Number of brake cycles at n = 0 rpm		-		
Emergency brake cycles		-		
Opening time	t_O [ms]	-		
Closing time	t_C [ms]	-		

5.3 Dimensions

Illustration 20.1

[mm]



The appropriate CAD drawings as 2D or 3D files can be provided on request.

5.4 Accuracy

Table 20.2

	Symbol [Unit]	IHD-20A[1]
Ratio	i [ ]	**≥ 50**
Transmission accuracy	[arcmin]	< 1
Repeatability	[arcmin]	< ±0.1
Hysteresis loss	[arcmin]	< 1
Lost Motion	[arcmin]	< 1

1) Refering to gear accuracy, using motor side encoder

5.5 Torsional Stiffness

Table 20.3

	Symbol [Unit]	IHD-20A[1]	
Limit torque	T_1 [Nm]	7	
	T_2 [Nm]	25	
Ratio	i [ ]	**50**	**> 50**
Torsional stiffness	K_3 [$\cdot 10^3$ Nm/rad]	23	29
	K_2 [$\cdot 10^3$ Nm/rad]	18	25
	K_1 [$\cdot 10^3$ Nm/rad]	13	16

1) Torsional stiffness related to the gear

5.6 Bearings

5.6.1 Output bearing

Our servo actuators incorporate a high stiffness output bearing. This specially developed bearing can withstand high axial forces and radial forces as well as tilting moments. The reduction gear thus protected from external loads, so guaranteeing a long life and consistent performance. The integration of an output bearing also serves to reduce subsequent design and production cost, by removing the need for an additionally output bearing in many applications.

5.6.2 Technical Data

Table 21.1

	Symbol [Unit]	IHD-20A
Bearing type[1]		C
Pitch circle diameter	d_p [m]	0.07
Offset	R [m]	0.016
Dynamic load rating	C [N]	21000
Static load rating	C_0 [N]	27000
Dynamic tilting moment[2]	$M_{dyn\ (max)}$ [Nm]	172
Static tilting moment[3]	$M_{0\ (max)}$ [Nm]	603
Tilting moment stiffness[5]	K_B [Nm/arcmin]	70
Dynamic axial load[4]	$F_{A\ dyn\ (max)}$ [N]	15800
Dynamic radial load[4]	$F_{R\ dyn\ (max)}$ [N]	8600

1) C = Cross roller bearing, F = Four point contact bearing

2) These values are valid for moving gears. They are not based on the equation for lifetime 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.

3) These values are valid for gears at a standstill and for a static load safety factor f_s = 1.8

4) These data are valid for n =15 rpm and L_{10} = 15000 h.

3,4) These data are only valid if following conditions are fulfilled.
M_0: F_a = 0 N; F_r = 0 N
F_a: M_0 = 0 Nm; F_r = 0 N
F_r: M_0 = 0 Nm; F_a = 0 N

5) Average value

5.6.3 Tolerances

Illustration 21.2

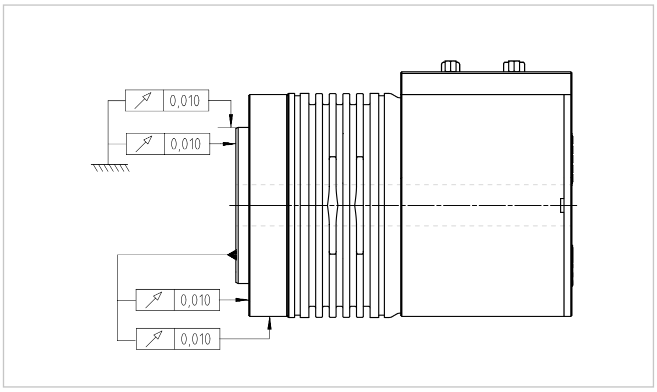


Table 21.3

	[Unit]	IHD-20A
a	[mm]	0.01
b	[mm]	0.01
c	[mm]	0.01
d	[mm]	0.01

5.7 Feedback systems

The IHD system is equipped with a so called Dual Feedback System.

Two singleturn absolute position sensors are available within the system. One sensor is connected to the motor shaft, the second is conntected to the gear output side, meaning gear hollow shaft. Major parameters are:

Table 22.1

Sensor type	Symbol [Unit]	
Function		Singleturn absolute
Code disk		Master-Nonius
Number of poles		64/63
Resolution	Bit	16
	Counts	65536
Position accuracy	p2p [°]	0.2

5.8 Temperature sensors

For motor protection at speeds greater than zero, temperature sensors are integrated in the motor windings. For applications with high load where the speed is zero, additional protection (e.g. I^2 t monitoring) is recommended.

Table 22.2

Sensor type	Quantity	Parameter	Symbol [Unit]	Limit	
				Warning	Switch-off
PT 1000	1	Temperature	T [°C]	110	120

5.9 Electrical connections

Table 23.1

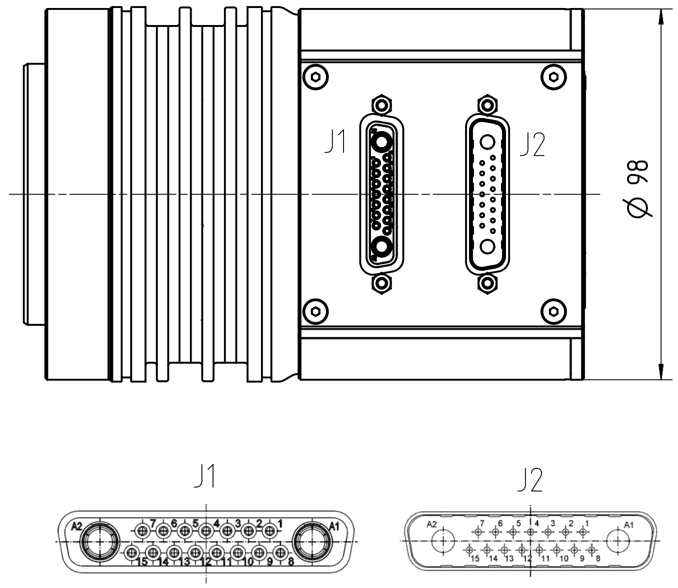


Table 23.2

Output Connector J1 (Female)		Input Connector J2 (Male)	
PIN	Description	PIN	Description
16 - A1	DC-BUS +	16 - A1	DC-BUS +
1	P1 - CH / TX+	1	P0 - CH / TX+
2	P1 - CL /TX-	2	P0 - CL /TX-
3	P1 - CG / RX+	3	P0 - CG / RX+
4	P1-CT / RX-	4	P0-CT / RX-
5	D-OUT	5	D-IN
6	D-GND / AN REF	6	D-GND / AN REF
7	nc	7	Bres
8	nc	8	Bres
9	AN+	9	AN+
10	AN-	10	AN-
11	LOGIC+	11	LOGIC+
12	LOGIC-	12	LOGIC-
13	STO - 1	13	STO - 1
14	STO - REF	14	STO - REF
15	STO - 2	15	STO - 2
17 - A2	DC-BUS-	17 - A2	DC-BUS-

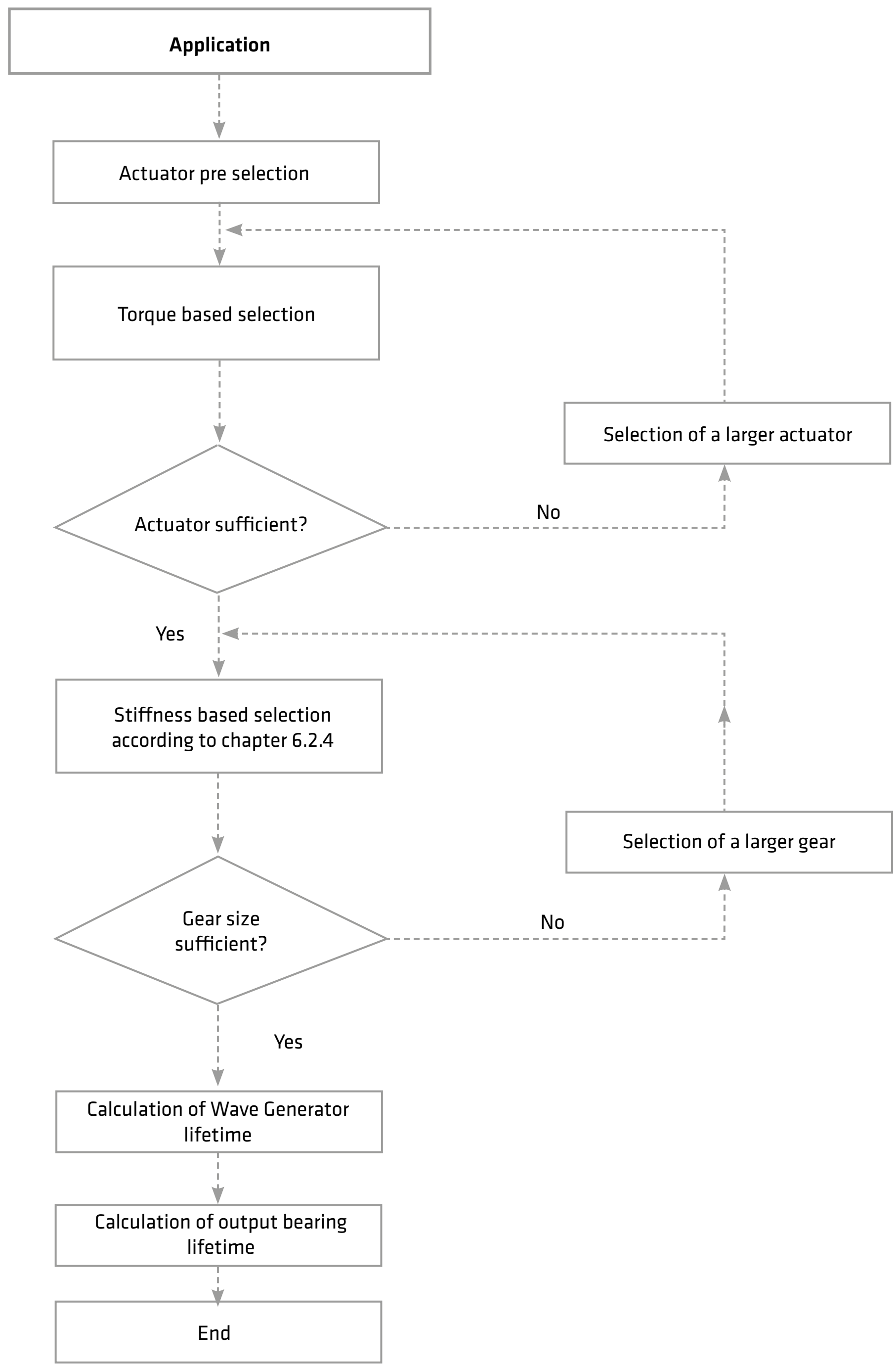
6. Selection Procedure

6.1 Selection Procedure Servo Actuators

In principle, both torque and stiffness requirements should be taken into account in the design. Whereas, for example, in robotics applications, the required torques are more decisive for the gear size, the torsional stiffness necessary for the process is often decisive in machine tool construction. In addition, both the service life and the static safety should be calculated for the output bearings. We therefore recommend that the design is carried out according to the following diagram.

ADVICE

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



6.2 Actuator dimensioning

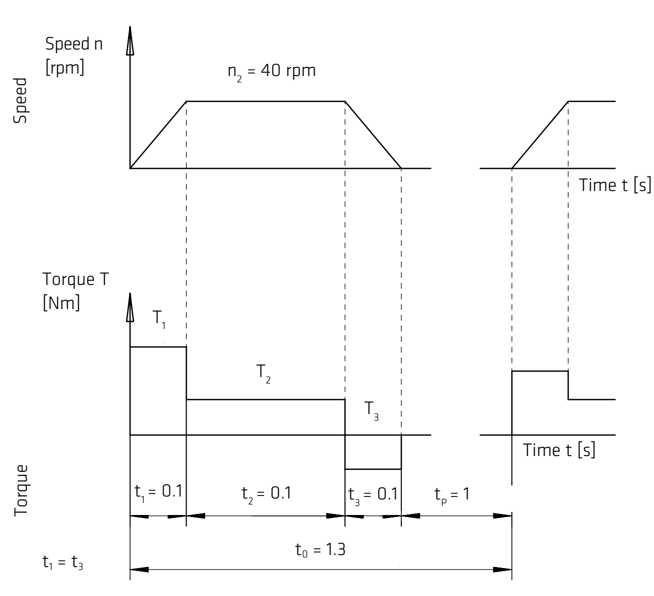
6.2.1 Torque based dimensioning

Checking the permissible loads

Application output data		
Torque (Stage 1 ... n)	$T_1 \dots T_n$	[Nm]
Load time (Stage 1 ... n)	$t_1 \dots t_n$	[s]
Operating cycle	t_o	[s]
Break time	t_p	[s]
Load torque (e. g. friction)	T_L	[Nm]
Load speed	n_2	[min^{-1}]
Load moment of inertia	J_L	[kgm^2]
Required lifetime Wave Generator bearing	$L_{10erf.}$	[h]

Permissible load of the gear		
Maximum torque	T_{max}	[Nm]
Maximum speed	n_{max}	[min^{-1}]
Moment of inertia	J_{out}	[kgm^2]

Illustration 25.1



Equation 25.2

Preselection of the servo actuator based on the load data

$n_2 \leq n_{max}$

$J_L \leq K \cdot J_{out}$

$K \leq 3$ for dynamic applications

$K > 3 \dots \leq 10$ for less dynamic applications

Equation 25.3

Validation of the speed cycle using the load curve and preselection of the servo actuator

Equation 25.4

Checking the permissible maximum torque

$T_1 \leq T_{max}$

Equation 25.5

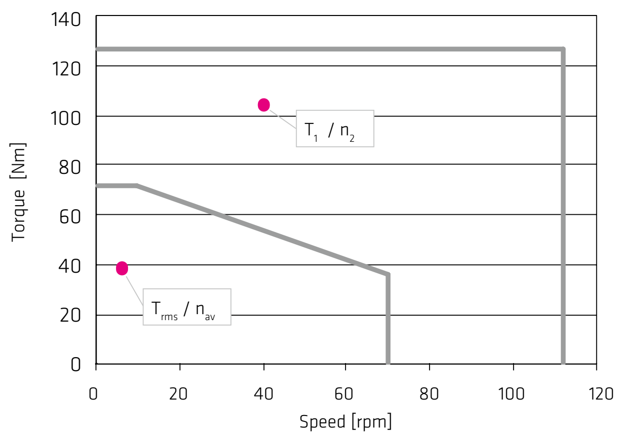
Calculation of the acceleration torque

$$T_1 = T_L + \frac{2\pi}{60} \cdot \frac{(J_{out}+J_L) \cdot n_2}{t_1}$$

Note: For servo actuators the input moment of inertia must also be taken into consideration!

Illustration 25.6

Review T_{rms} / n_{av} within the characteristic curve for continuous operation
Review T_1 / n_2 within the characteristic curve for intermittent operation



Equation 25.7

Calculation of the effective torque

$$T_{rms} = \sqrt[2]{\frac{T_1^2 \cdot t_1 + T_2^2 \cdot t_2 + .. T_n^2 \cdot t_n}{t_1 + t_2 + .. t_n + t_p}}$$

Equation 25.8

Calculation of the average speed

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

Equation 25.9

Calculation of the duty cycle

$$ED = \frac{t_1 + t_2 + \dots t_n}{t_1 + t_2 + \dots t_n + t_p} \cdot 100\ \%$$

Equation 25.10

Checking the lifetime of the Wave Generator ball bearing

Calculated lifetime L_{10} > required lifetime $L_{10erf.}$

Equation 25.11

Validation the lifetime of the Wave Generator ball bearing according to chapter 6.2.2

Calculation example

The torque based dimensioning should be based on a reference cycle which represents a typical load on the gear including acceleration and deceleration phases.

Application load data

J_L	=	1,3 kgm^2	t_0	=	1,3	s	n_p	=	0,2 s
t_1	=	0,1 s	$L_{10erf.}$	=	7000	s	K	≤	3
t_2	=	0,1 s	n_1	=	3	s	T_L	=	5 Nm
t_3	=	0,1 s	n_2	=	0,4	s			
t_p	=	1,0 s	n_3	=	0,15	s			

Permissible load of the actuator

Preselected actuator	CanisDrive-25A-50		
Maximum torque	T_{max}	=	127 Nm
Maximum speed	n_{max}	=	112 rpm
Moment of inertia	J_{out}	=	127 kgm^2

Preselection of the servo actuator based on the load data

n_2 = 40 rpm ≤ n_{max} = 112 rpm ✓

J_L = 1,3 kgm^2 ≤ 3 · J_{out} = 1.063 kgm^2 ✓

K ≤ 3 for dynamic applications

Validation of the speed cycle using the load curve

Checking the permissible maximum torque

T_1 = 103,8 Nm ≤ T_{max} = 127 Nm ✓

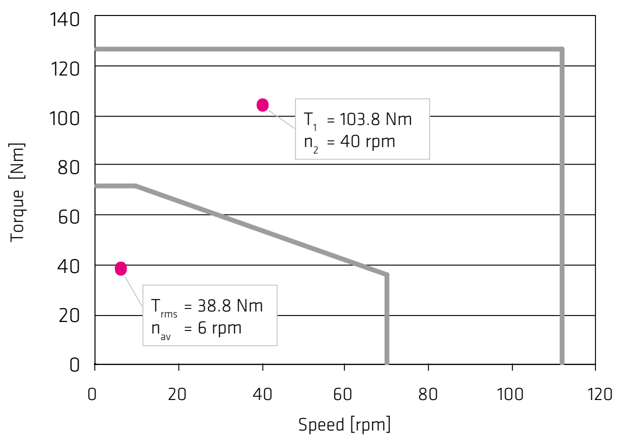
Calculation of the acceleration torque

$$T_1 = 5 + \frac{2\pi}{60} \cdot \frac{(1.3 + 1.06) \cdot 40}{0.1} = 103.8 \text{ Nm}$$

Note: For servo actuators the input moment of inertia must also be taken into consideration!

Review T_{rms} / n_{av} within the characteristic curve for continuous operation

Review T_1 / n_2 within the characteristic curve for inermittent operation ✓



Calculation of the effective torque

$T_2 = T_L = 5$ Nm

$T_3 = T_L - (T_1 - T_L) = -93.8$ Nm

$$T_{rms} = \sqrt[2]{\frac{103.8^2 \cdot 0.1 + 5^2 \cdot 0.1 + (-93.8)^2 \cdot 0.1}{1.3}} = 38.8 \text{ Nm}$$

Calculation of the average speed

$$n_{av} = \frac{|20| \cdot 0.1 + |40| \cdot 0.1 + |20| \cdot 0.1}{1.3} = 6 \text{ rpm}$$

Calculation of the duty cycle

$$ED = \frac{0.1 + 0.1 + 0.1}{1.3} \cdot 100\,\% = 23\,\%$$

Checking the lifetime of the Wave Generator ball bearing

L_{10} = 18211 h > $L_{erf.}$ = 7000 h ✓

Validation the lifetime of the Wave Generator ball bearing

$$L_{10} = \frac{1}{5} \cdot \frac{2000}{300} \cdot \left(\frac{51}{78.6}\right) = 18211 \text{ h}$$

6.2.2 Lifetime of the Wave Generator ball bearing

The lifetime calculation of gears and servo actuators based on the strain wave gear principle refers to the lifetime of the Wave Generator ball bearing. The nominal torques at nominal speed given in the performance data tables are based on the nominal life L_n of the Wave Generator ball bearing.

The expected life can be determined at a given average input speed $n_{in\ av}$ and given average output torque T_{av} using equation 27.1. The lifetime L_{50} indicates the calculated lifetime at 50% failure probability, L_{10} at 10% failure probability.

Equation 27.1

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

Equation 27.2

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

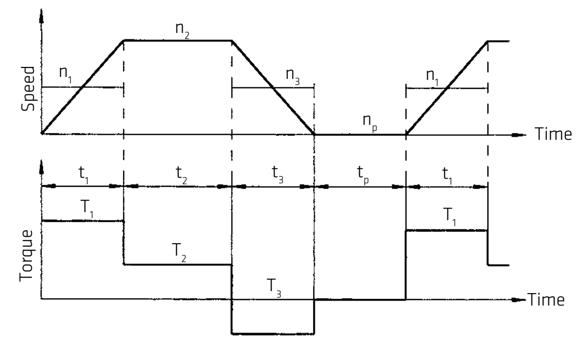
Table 27.3

Harmonic Drive® Series	Nominal lifetime L_n [h]	Rated speed n_N [rpm]
CobaltLine, CSG, SHG, CanisDrive®, BH, IHD	50000	2000
HFUC, HFUS, CPL, CSD, CPU, CSF-Mini, SHD, CHA, CHA-C, FHA-C, FHA-C Mini, LynxDrive, BDA-HFUC, RSF-Mini	35000	2000
PMG-5, PMA-5	15000	4500
PMG-8 ... 14, PMA-8 ... 14	15000	3500

The average output speed can be calculated with equation 27.5 and the average input speed can be calculated with Equation 27.6.

Application output data		
Torque (Stage 1 ... n)	$T_1 \ldots T_n$	[Nm]
Load time (Stage 1 ... n)	$t_1 \ldots t_n$	[s]
Break time	t_p	[s]
Output speed (Stage 1 ... n)	$n_1 \ldots n_n$	[rpm]
Maximum torque	T_{max}	[Nm]
Average torque	T_{av}	[Nm]
Maximum output speed	$n_{out\ max}$	[rpm]
Maximum input speed	$n_{in\ max}$	[rpm]
Gear data		
Rated torque	T_n	[rpm]
Rated speed	n_n	[Nm]
Nominal lifetime of Wave Generator ball bearing	T_n	[rpm]

Illustration 27.4



Equation 27.5

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

Equation 27.6

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

Equation 27.7

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

6.2.3 Calculation of the torsion angle

The torsion angle of the gear or servo actuator under load can be calculated as follows:

Equation 28.1

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

φ = Angle [rad]
T = Torque [Nm]
T_1 = Limit torque 1, from chapter „Torsional Stiffness“ [Nm]
T_2 = Limit torque 2, from chapter „Torsional Stiffness“ [Nm]
K_1 = Torsional stiffness until limit torque T_1, from chapter "Torsional Stiffness“ [Nm/rad]
K_2 = Torsional stiffness until limit torque T_2, from chapter "Torsional Stiffness“ [Nm/rad]
K_3 = Torsional stiffness above limit torque T_2, from chapter "Torsional Stiffness“ [Nm/rad]

Equation 28.2

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

Equation 28.3

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

Example: Component Set CSG-32-100-2A-GR

Application data:
T = 60 Nm

Gear parameters:
$K_1 = 67 \cdot 10^3$ Nm/rad $T_1 = 29$ Nm
$K_2 = 110 \cdot 10^3$ Nm/rad $T_2 = 108$ Nm
$K_3 = 120 \cdot 10^3$ Nm/rad

$$\varphi = \frac{29\text{ Nm}}{67 \cdot 10^3\text{ Nm/rad}} + \frac{60\text{ Nm} - 29\text{ Nm}}{110 \cdot 10^3\text{ Nm/rad}}$$

$\varphi = 2{,}5$ arcmin
$\varphi = 7{,}15 \cdot 10^{-4}$ rad

Equation 28.4

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

6.2.4 Stiffness based dimensioning

Recommended minimum resonance frequencies

In addition to the selection scheme "Torque based dimensioning" we recommend to perform a stiffness based dimensioning. For this purpose, the characteristic values given in table 29.1 should be considered for the minimum resonance frequencies recommended for the specific application. Basically, the higher the requirement for a low vibration movement and the higher the movement dynamics, the higher the recommended minimum resonance frequencies.

Table 29.1

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

* Depending on the application, a secondary gear stage can be useful. We recommend consultation with Harmonic Drive SE.

Calculation of the resonance characteristics

Resonance frequency (Gear output)

Equation 30.1 can be used to calculate the output side resonance frequency for a given torsional stiffness K_1 of the Harmonic Drive® Gear and the moment of inertia of the load.

Equation 30.1

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

f_n = Resonance frequency [Hz]
K_1 = Torsional stiffness gear K_1 [Nm/rad]
J = Moment of inertia of the load [kgm^2]

The calculated frequency should be higher than the value given in equation 30.1. As the moment of inertia of the load increases, the influence of the application on the design result also increases. If the moment of inertia = 0, the selected application has no calculated influence on the design result.

Resonance speed (Gear input)

The resonance speed n_n at input side (motor side) can be calculated with equation 30.2.

Equation 30.2

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

We recommend to pass the resonance speed during operation quickly. This can be achieved by selecting a suitable gear reduction. Another possibility is to select a suitable gear stiffness so that the resonance speed is outside the required speed range.

Calculation example

CSG-40-120-2A-GR preselected according to „Selection Procedure: Torque based dimensioning“.

Planned application: Milling head woodworking
Moment of inertia output side: 7 kgm^2
Recommended minimum resonance frequency„Table .1“: ≥ 30 Hz
Calculated resonance frequency of the preselected gear
CSG-40-120-2A-GR: $f_n = \frac{1}{2\pi} \cdot \sqrt{\frac{1.3 \cdot 10^5}{7}} = 22 \text{ Hz}$

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

With the larger gear CSG-50-120-2A-GR the following calculated resonance frequency results:

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

Due to the rigidity based selection, the CSG-50-120-2A-GR gear is recommended.

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

This speed should be passed through rapidly during acceleration and braking or should be set outside the used speed range.

6.3 Dimensioning output bearing

6.3.1 Life for continuous operation

The operating life of the output bearing can be calculated using equation 31.1.

Equation 31.1

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

L_{10} [h]	=	Lifetime (10 % probability of failure)
n_{av} [rpm]	=	Average output speed, see following pages
C [N]	=	Dynamic load rating
P_c [N]	=	Dynamic equivalent load (chapter 6.3.3)
f_w	=	Operating factor (table 33.2)
B	=	Bearing type exponent (table 51.3)

6.3.2 Life for oscillating motion

The operating life at oscillating motion can be calculated using equation 31.2.

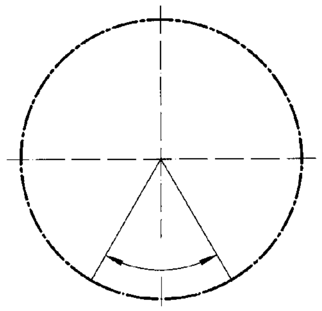
Equation 31.2

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

L_{OC} [h]	=	Operating life for oscillating motion (10 % probability of failure)
n_1 [cpm]	=	Number of oscillations/minute (one oscillation corresponds to 2φ)
C [N]	=	Dynamic load rating
P_C [N]	=	Dynamic equivalent load (chapter 6.3.3)
φ [°]	=	Oscillating angles
f_W	=	Operating factor (Table 33.2)
B	=	Bearing type exponent (table 51.3)

At oscillating angles < 5° fretting corrosion may occur due to insufficient lubrication. in this case please contact our sales engineer for countermeasures. Bearing type of the selected product see "technical data of the output bearing".

Illustration 31.3 Oscillating Angle



6.3.3 Dynamic equivalent load

With a dynamic bearing load, the load cycle of the output bearing must be converted into the dynamic equivalent load and the average output speed to calculate the service life.

Illustration 32.1

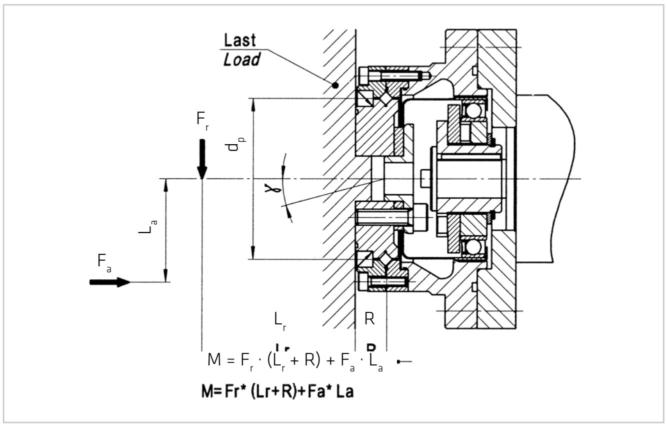
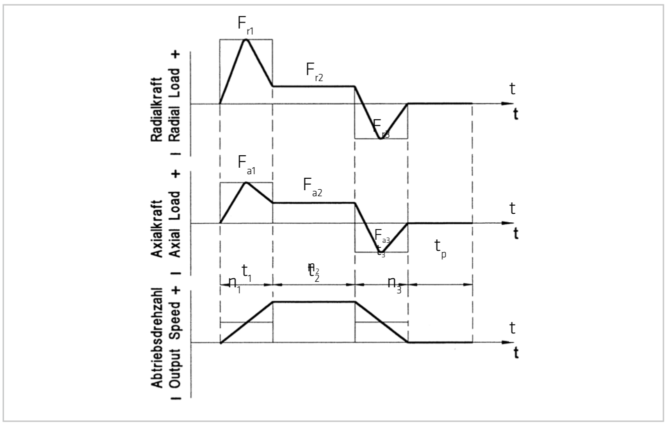


Illustration 32.2



Dynamic equivalent load

Equation 32.3

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

Equation 32.4

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

Equation 32.5

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

P_C [N]	=	Dynamic equivalent load
F_{rav} [N]	=	Average radial load
F_{aav} [N]	=	Average axial load
F_{rn} [N]	=	Radial force of stage n
F_{an} [N]	=	Axial force of stage n
n_n [rpm]	=	Speed of stage n
t_n [s]	=	Time of stage n
d_p [m]	=	Pitch circle diameter of the roller track of the output bearing, see technical data of output bearing
x [ ]	=	Radial load factor (table 32.6)
y [ ]	=	Axial load factor (table 32.6)
M [Nm]	=	Average tilting moment
B [ ]	=	Bearing type exponent

Tabelle 32.6

Condition	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

Average output speed

Equation 33.1

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

Operating factor

Tabelle 33.2

Load conditions	Operating factor f_w
No vibrations and impacts	1 … 1.2
Normal load	1.2 … 1.5
Impacts and/or vibrations	1.5 … 3

Bearing type exponent

Table 33.3

Bearing type	Bearing type exponent
Cross roller bearing	10/3
Four point bearing	3

6.3.4 Permissible static bearing load

In case of a static load on the output bearing, the static safety factor is calculated using the following equation. The chapter "Output Bearings, Technical Data" contains data for the permissible static tilting moment with a purely static tilting moment (without additional axial and radial force).

Equation 34.1

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

f_s	=	Static load safety factor
C_0	=	Static load rating
x_0	=	1, Static radial force factor
y_0	=	0.44, Static axial force factor
P_0	=	Static equivalent load
d_p	=	Pitch circle diameter of the output bearing roller track
M	=	Static tilting moment

Table 34.2

Operating conditions of the bearing	Recommendation of the static load safety factor f_s
Normal	~ 1.5
Vibrations / Impacts	~ 2
High transmission accuracy	~ 3

6.3.5 Angle of tilt

The angle of tilt of the output flange as a function of the tilting moment acting on the output bearing, can be calculated by means of equation 34.4:

Equation 34.4

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

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

7. Design Guidelines

7.1 Notes on design integration

We recommend the following fit selection for structural design:

Table 35.1

	Unit	IHD-20A
Load side		
Fit of bearing inner ring	[mm]	69 h7
Recommended tolerance area	[mm]	H7
Housing side		
Fit of bearing outer ring	[mm]	98 h7
Recommended tolerance area	[mm]	H7

7.2 Protection against corrosion and penetration of liquids and debris

The product achieves the degree of protection according to the table „Technical Data“ when the connectors are suitable for the mentioned degree of protection and the ambient conditions (condensation, liquids and gases) do not cause corrosion on the running surfaces of the radial shaft seals. Special versions can deviate from the above protection class.

Sharp edged or abrasive parts (cutting chips, splinters, dust from metal, minerals, etc.) must not come into contact with radial shaft seals.
A liquid film permanently standing on the radial shaft seal must be prevented. As a result of changing operating temperatures, pressure differences occur in the actuator, which lead to suction of the liquid standing on the shaft seal.

An additional customer side shaft seal or a sealing air connection must be provided if a liquid film permanently standing on the shaft seal cannot be prevented. An enclosure or a sealing air connection must be provided if oil mist, for example, is to be expected constantly in the vicinity of the actuator.

Sealing air specification: constant overpressure in the actuator; the supplied air must be dried and filtered, overpressure max. 10^4 Pa.

8. Installation and Operation

8.1 Transport and Storage

The transportation of the servo actuators and motors should always be in the original packaging.

If the servo actuators and motors are not put into operation immediately after delivery, they should be stored in a dry, dust and vibration free environment. Storage should be for no longer than 2 years at room temperatures (between +5 °C ... +40 °C) so that the grease life is preserved.

INFO

Tensile forces in the connecting cable must be avoided.

ADVICE

Lithium metal batteries are dangerous goods according to UN 3090. Therefore they are generally subject to transport regulations, depending on the transport mode.
The batteries installed in the motor feedback systems do not contain more than 1 g of lithium or lithium alloy and are exempt from dangerous goods regulations.

8.2 Installation

Check the performance and protection and check the suitability of the conditions at the installation site. Take suitable constructive measures to ensure that no liquid (water, drilling emulsion, coolant) can penetrate the output bearing or encoder housing.

ADVICE

The installation must be protected against impact and pressure on the gear.

The mounting must be such that heat loss can be adequately dissipated.

No radial forces and axial forces may act to the protection sleeve of the hollow shaft actuator.

During installation, the actuator must be fitted ensuring the machine housing can be rotated without terminals. Already low terminals may affect the accuracy of the gear and, should this be the case, the installation of the machine housing should be checked.

8.3 Mechanical Installation

The data necessary for mounting the actuator and for connecting to the load are given in the following table.

Table 38.1

	Unit	IHD-20A
Load assembly		
Number of screws		12
Screw size		M4
Screw quality		12.9
Pitch circle diameter	[mm]	62
Screw tightening torque	[Nm]	5.1
Transmittable torque	[Nm]	228
Housing assembly		
Number of screws		12
Screw size		M3
Screw quality		12.9
Pitch circle diameter	[mm]	89
Screw tightening torque	[Nm]	2.3
Transmittable torque	[Nm]	177

Data valid for completely degreased connecting interfaces (friction coefficient μ = 0.15).
The screws must be secured against loosening.
The threads of the load attachment must be sealed.
It is recommended to use LOCTITE 243 to secure the screws.

8.4 Electrical Installation

All work should be carried out with power off.

DANGER

Electric servo actuators and motors have dangerous live and rotating parts. All work during connection, operation, repair and disposal must be carried out only by qualified personnel as described in the standards EN 50110-1 and IEC 60364!
Before starting any work, and especially before opening covers, the actuator must be properly isolated. In addition to the main circuits,
the user also has to pay attention to any auxilliary circuits.

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

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

DANGER

Due to the fact that the motor contains permanent magnets, a voltage is generated at the motor terminals when the rotor is turned.

ADVICE

- The connecting cables must be adapted to the ambient conditions, current intensities, the occurring voltages and mechanical requirements.
- The protective earth must be connected to the terminal marked PE.
- All cables used should be provided with a shield and in addition, the encoder cable should feature twisted pair leads.
- The power supply is switched off before connecting and disconnecting the power connection and signal connections.
- Observe EMC-compliant cable routing. Signal lines and power lines must be routed separately.
- Note equipotential bonding.
- When mounting the drives on moving parts, an additional equipotential bonding conductor (≥ 10 mm^2) as close as possible to the servo actuator is recommended.

ADVICE

Encoders and sensors contain electrostatically sensitive components, observe the ESD measures!

8.5 Commissioning

ADVICE

Commissioning must be executed in accordance with the documentation of Harmonic Drive SE.

Before commissioning, please check that:
- The actuator is properly mounted
- All electrical connections and mechanical connections are designed according to requirements
- The protective earth is properly connected
- All attachments (brakes, etc.) are operational
- Appropriate measures have been taken to prevent contact with moving and live parts
- The maximum speed n_{max} is specified and cannot be exceeded
- The set up of the drive parameters has been executed
- The commutation is adjusted correctly

⚠ ATTENTION

Check the direction of rotation of the load uncoupled. Any existing loose parts must be removed or secured.

In the event of changes in the normal operating behaviour, such as increased temperature, noise or vibration, switch the actuator off. Determine the cause of the problem and contact the manufacturer if necessary. Even if the actuator is only on test, do not put safety equipment out of operation.

This list may not be complete. Other checks may also be necessary.

ADVICE

Due to heat generation from the actuator itself, tests outside the final mounting position should be limited to 5 minutes of continuous running at a motor speed of less than 1000 rpm. These values should not be exceeded in order to avoid thermal damage to the actuator.

For actuators with 4BNo2 lubricant, a running-in process is recommended under the following conditions:
Load: without load
Gear input speed: 1000 rpm
Time: 15 - 20 min
During the running-in process, the drive temperature must be monitored to prevent damage from overheating.

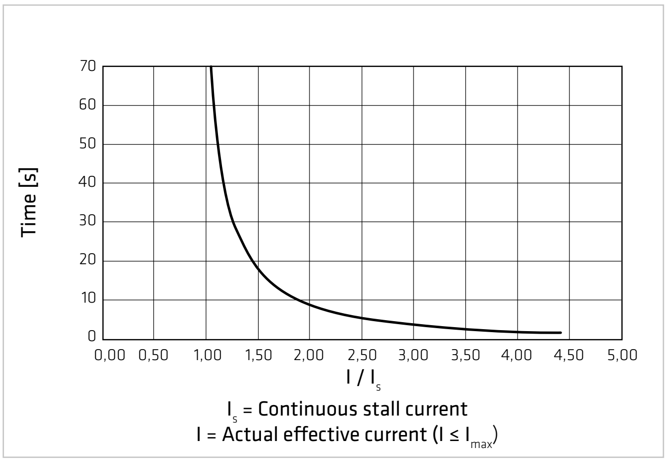
8.6 Overload Protection

To protect the servo actuators and motors from temperature overload sensors are integrated into the motor windings.

The temperature sensors alone do not guarantee motor protection. Protection against overload of the motor winding is only possible with an input speed > 0. For special applications (eg. load at standstill or very low speed) is an additional overload protection by limiting the overload period.

The built specification of the integrated temperature sensors can be found in the technical data.

Illustration 40.1 Overload characteristics



In addition, it is recommended to protect the motor winding against overload by the use of I^2t monitoring integrated in the controller. The graph shows an example of the overload characteristic for the I^2t monitoring. The overload factor is the ratio between the actual RMS current and continuous stall current.

8.7 Shutdown and Maintenance

In case of malfunctions or maintenance measures, or to shutdown the motors, proceed as follows:

1. Follow the instructions in the machine documentation.
2. Bring the actuator on the machine to a controlled standstill.
3. Turn off the power and the control voltage on the controller.
4. For motors with a fan unit; turn off the motor protection switch for the fan unit.
5. Turn off the mains switch of the machine.
6. Secure the machine against accidental movement and against unauthorised operation.
7. Wait for the discharge of electrical systems then disconnect all the electrical connections.
8. Secure the motor, and possibly the fan unit, before disassembly against falling or movement then pay attention to the mechanical connections.

⚠ DANGER

Risk of death by electric voltages.
Work in the area of live parts is extremely dangerous.

- Work on the electrical system may only be performed by qualified electricians. The use of a power tool is absolutely necessary.

- Observing the five safety rules:
    1. Unlock
    2. secure against being switched on again
    3. determine freedom from voltage
    4. ground and short-circuit
    5. cover or cordon off adjacent live parts

- Before starting work check with a suitable measuring instrument if there are any parts under residual voltage. (e.g. capacitors, etc.). Wait until the residual voltage is within a save range.

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

⚠ ATTENTION

Burns from hot surfaces with temperatures of over 100 °C

Let the motors cool down before starting work. Cooling times of up to 140 minutes may be necessary.

Wear protective gloves.

Do not work on hot surfaces!

WARNING

Persons and property during maintenance and operation

Never perform maintenance work on running machinery. Secure the system during maintenance against re-starting and unauthorised operation.

8.7.1 Cleaning

Excessive dirt, dust or chips may adversely affect the operation of the actuator and can, in extreme cases, lead to failure. At regular intervals (latest after one year) you should therefore, clean the actuator to ensure a sufficient dissipation of the surface heat.

Insufficient heat radiation can have undesirable consequences.

- The bearing life is reduced by operation at inadmissibly high temperatures (bearing grease decomposes).
- Overtemperature shutdown despite operation after selection data, because the corresponding cooling is missing.

8.7.2 Check the electrical connections

DANGER

Lethal electric shock by touching live parts!

In any case of defects of the cable sheath the system must be shut down immediately and the damaged cable should be replaced. Do not make any temporary repairs on the connection cables.

- Connection cord should be periodically checked for damage and replaced if necessary.
- Check optionally installed power chains for defects.
- Protective conductor connections should be in a good condition and tightness checked at regular intervals. Replace if necessary.

8.7.3 Check the mechanical fastenings

The fastening screws and the load of the housing must be checked regularly.

8.7.4 Maintenance intervals for battery buffered motor feedback systems

ADVICE

Please note the information on battery life time in the chapter „Motor Feedback Systems“!

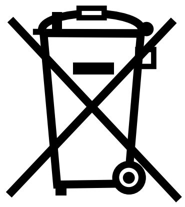
9. Decommissioning and Disposal

Harmonic Drive® Products contain lubricants for bearings and gears as well as electronic components and printed circuit boards. Depending on the used motor feedback system the actuator can also include a lithium thionyl chloride battery. It is required to dispose the product correctly in accordance to the national and local regulations.

Lubricants and batteries must be handled in accordance with national health and safety regulations. If required, please request the valid safety data sheet for the lubricant from us.

ADVICE

- Batteries do not contain hazardous materials according to EC directives 91/157/EEC, 93/86/EEC, and 2011/65/EU (RoHS directive)
- EC battery directive 2006/66/EC has been implemented by most EC member states,
- According to the EU Battery Directive, Lithium batteries are marked with the symbol of the crossedout wheeled bin (see figure). The symbol reminds the end user that batteries are not permitted to be disposed of with household waste, but must be collected separately.
- A disposal service is offered upon request by Harmonic Drive SE.



10. Glossary

10.1 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]

Specifies the temperature range permitted for normal operation.

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

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

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

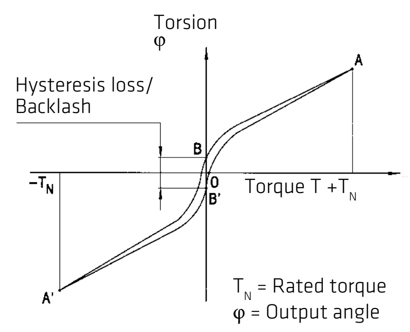
Maximum permissible average gear input speed for oil lubrication. The applications average input speed must be lower than the permitted average input speed of the gear.

Average torque T_A [Nm]

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

Backlash (Harmonic Planetary Gears) [arcmin]

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



Brake closing time t_C [ms]

Delay time to close the brake.

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

Current for applying the brake.

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

Current required to open the brake.

Brake holding torque T_{BR} [Nm]

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

Brake opening time t_O [ms]

Delay time for opening the brake.

Brake voltage U_{Br} [VDC]

Supply voltage of the holding brake.

Continuous stall current I_0 [A_{rms}]

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

Continuous stall torque T_0 [Nm]

Allowable actuator stall torque.

Demagnetisation current I_E [A_{rms}]

Current at which rotor magnets start to demagnetise.

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

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

Dynamic load rating C [N]

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

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

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

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

With the bearing rotating, this is the maximum allowable tilting moment with no additional axial forces or radial forces applied. This value is not based on the equation for lifetime calculation of the output bearing but on the maximum allowable deflection of the Harmonic Drive® Component Set. This value must not be exceeded even if the lifetime calculation of the bearing permits higher values.

Electrical time constant τ_e [s]

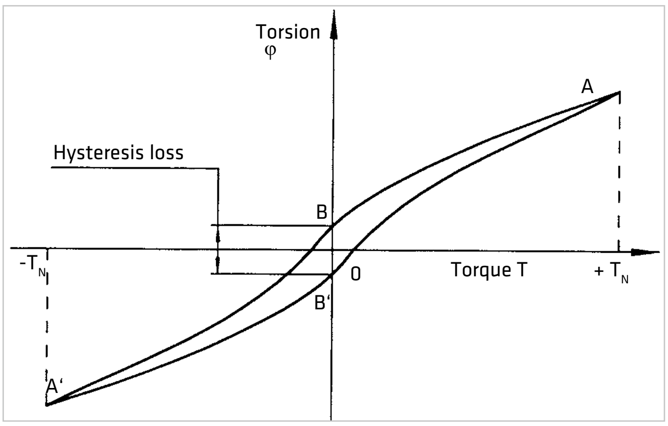
The electrical time constant is the time required for the current to reach 63 % of its final value.

Hollow shaft diameter d_H [mm]

Free inner diameter of the axial hollow shaft.

Hysteresis loss (Harmonic Drive® Gears)

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



T_N = Rated output torque
φ = Output rotation angle

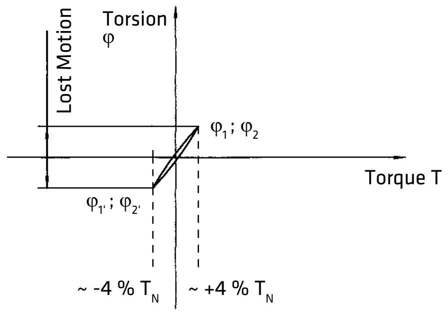
Inductance (L-L) L_{L-L} [mH]

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

Lost Motion (Harmonic Drive® Gears) [arcmin]

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

The illustration shows the angle of rotation φ measured against the applied output torque as a hysteresis curve with the Wave Generator locked. The lost motion measurement of the gear is taken with an output torque of about ±4 % of the rated torque.



Maximum current I_{max} [A]

The maximum current is the maximum current that can be applied for a short period.

Maximum DC bus voltage $U_{DC\,(max)}$ [VDC]

The maximum DC bus power supply for the correct operation of the actuator. This value may only be exceeded for a short period during the braking or deceleration phase.

Maximum hollow shaft diameter $d_{H\,(max)}$ [mm]

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

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

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

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

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

Maximum motor speed n_{max} [rpm]

The maximum allowable motor speed.

Maximum output speed n_{max} [rpm]

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

Maximum output torque T_{max} [Nm]

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

Maximum power P_{max} [W]

Maximum power output.

Mechanical time constant τ_m [s]

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

Momentary peak torque T_M [Nm]

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

Moment of inertia J [kgm^2]

Mass moment of inertia at motor side.

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

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

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

Mass moment of inertia with respect to the output.

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

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

Nominal Service Life L_n [h]

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

Number of pole pairs p

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

Offset R [m or mm]

Distance between output bearing centre and point of application of load.

Pitch circle diameter d_p [m] or [mm]

Pitch circle diameter of the output bearing rolling element raceway.

Protection class IP

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

Rated current I_N [A]

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

Rated motor speed n_N [rpm]

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

Rated power P_N [W]

Output power at rated speed and rated torque.

Rated speed n_N [rpm]

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

Rated speed n_N [rpm], Mechanical

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

Product series	n_N
CobaltLine, HFUC, HFUS, CSF, CSG, CSD, SHG, SHD, CPL	2000 rpm
PMG size 5	4500 rpm
PMG size 8 to 14	3500 rpm
HPG, HPGP, HPN	3000 rpm

Rated torque T_N [Nm]

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

Rated torque T_N [Nm], Mechanical

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

Rated voltage U_N [V_{rms}]

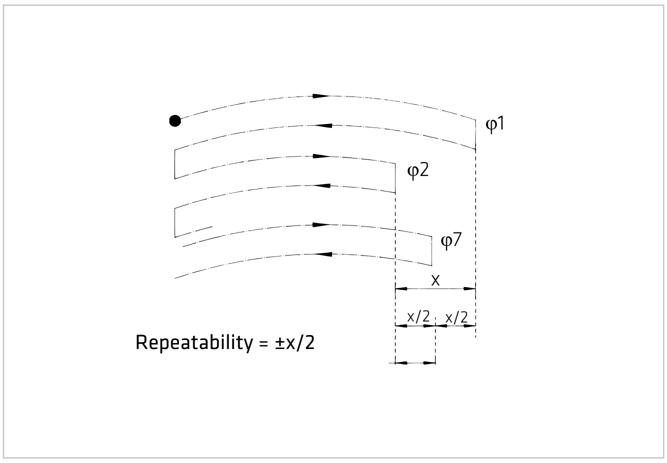
Supply voltage for operation with rated torque and rated speed. Indicated is the effective value of the Line Voltage.

Ratio i [ ]

The ratio is the reduction of input speed to the output speed.
Note for Harmonic Drive® Gears: In the standard drive arrangement, the Wave Generator is the drive element while the Flexspline is the driven element and the Circular Spline is fixed to the housing. Since the direction of rotation of the input (Wave Generator) is opposite to the output (Flexspline), a negative ratio must be considered.

Repeatability [arcmin]

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



Repeated peak torque T_R [Nm]

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

Resistance (L-L, 20 °C) R_{L-L} [Ω]

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

Size

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

Static load rating C_0 [N]

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

Static tilting moment M_0 [Nm]

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

Synchronous inductance L_d [mH]

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

Tilting moment stiffness K_B [Nm/arcmin]

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

Torque constant (motor) k_{TM} [Nm/A_{rms}]

Quotient of stall torque and stall current.

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

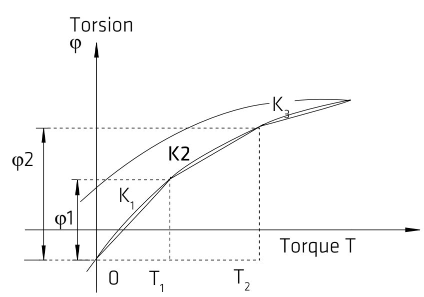
Quotient of stall torque and stall current, taking into account the transmission losses.

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

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

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

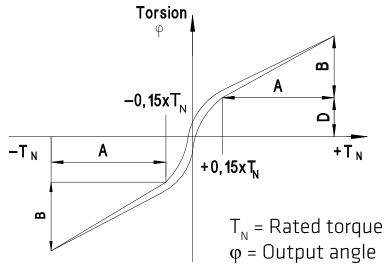
The values given for the torsional stiffness K_1, K_2 and K_3 are average values that have been determined during numerous tests. The limit torques T_1 and T_2 and an calculation example for the torsional angle can be found in chapter "torsional stiffness" and "calculation of the torsion angle" of this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



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

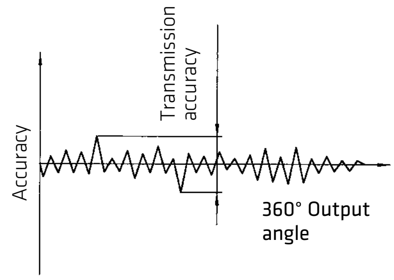
Torsional stiffness (Harmonic Planetary Gears) K3 [Nm/rad]

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



Transmission accuracy [arcmin]

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



Weight m [kg]

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

10.2 Labelling, Guidelines and Regulations

CE-Marking

With the CE marking, the manufacturer or EU importer declares in accordance with EU regulation, that the product meets the applicable requirements of the EU harmonization legislation.

REACH Regulation

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

RoHS EU Directive

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

PASSION GENERATES THE HIGHEST QUALITY.

Harmonic Drive SE
Hoenbergstraße 14
65555 Limburg/Lahn
Germany

T +49 6431 5008-0
info@harmonicdrive.co.uk
www.harmonicdrive.co.uk

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