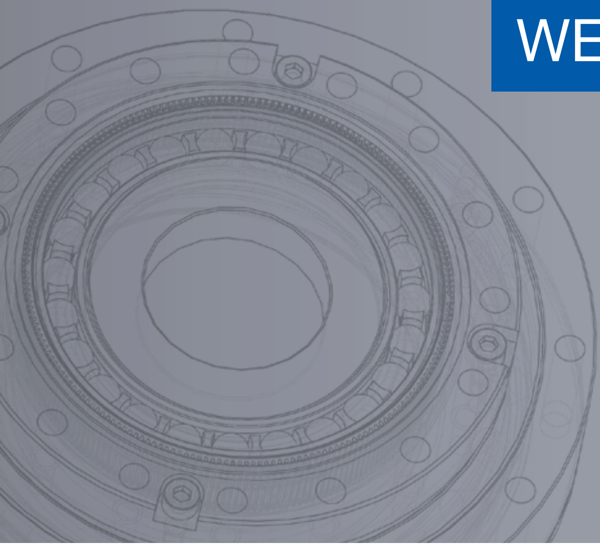
DRIVE TECHNOLOGY ENGINEERED FOR ROBOTICS

WE DRIVE YOUR COBOT



INNOWELLE

CONTENTS

1. COMPANY

INNOWELLE GmbH is focused on the development, research, design, testing and the manufacturing process of precise strain wave gears as well as complete mechatronic systems such as our Intelligent COBOT Module ICM.

We are your competent premium partner in the development and production of gear technologies and drive technologies for the robotics industry and specialise in the production of small and medium production volumes at the highest quality level.

INNOWELLE IS THE SPECIALIST IN DRIVE TECHNOLOGY FOR ALL ROBOT MANUFACTURERS:

- **Strain Wave Gear**
  We focus on five sizes of precise strain wave gear types with a torque range between 18Nm and 372Nm. The gears are available as a component kit, gearbox type or simplicity gearbox type. The gears are also available with or without hollow shaft.

- **Intelligent COBOT Module**
  Our Intelligent COBOT Module ICM is available in five sizes. It is equipped with a precise strain wave gear, a tilting resistant cross roller bearing, an effective synchronous motor, a fail-safe brake, two position sensors and a controller with EtherCAT protocol or CANopen protocol.

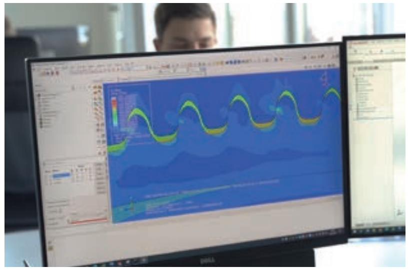
STRENGTHS OF INNOWELLE GMBH AS YOUR PARTNER

- **Extraordinary knowledge of strain wave gear technology**
- **Engineering for Robotic Drive Technology**
  Mechanics, Mechatronic, Robot Joint Design, Strain wave gear integration, Motor, Brake, Sensors, Drivers ...
- **Flexibility in creation of customised solutions for robotics**
- **Main focus on robotic application**
- **Excellent market knowledge**
- **Extensive network in robotics**

INNOWELLE OFFERS ALL THE ESSENTIAL TECHNOLOGIES FOR MECHANICAL OR ELECTROMECHANICAL DRIVE SYSTEMS. OUR SERVICES COVER ALL AREAS OF MODERN DEVELOPMENT.

Research & development

- New technologies for mechanical and mechatronic drive technology
- Optimisation of existing technologies and expertise
- Basic research and improvement



Engineering & design

- Customer- and market-specific products
- Modular systems and individually configurable products
- Fast pace of innovation
- New product and business areas
- Savings potential, reusable solutions

Prototype manufacturing

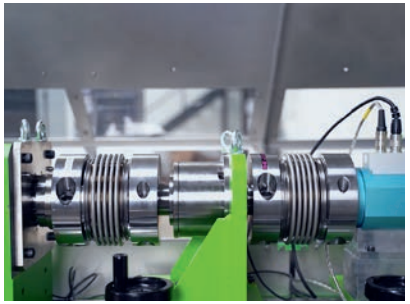
- Manufacture and assembly of fully functional drive systems
- Models for planned series products
- Optimisation for series production
- Validation and verification of requirements regarding technology and the final products
- Rapid results concerning theoretically developed solutions

Transfer of expertise to series production

- Design and optimisation of the series production and assembly process
- Material flow and value flow analyses
- Machine and process capabilities
- Support in quality assurance and development of Kaizen Continuous Improvement Process, and the achievement of quality management objectives

Planning, project management and pre-development

- Scheduling and resource planning
- Process orientation and structuring
- Periodic controlling and support until the successful completion of the project



Service life and durability tests

- Testing materials, components and systems
- Inspections to prevent component failure
- Static and dynamic strength hypotheses
- Failure criteria, damage assessments and lifetime estimates
- Increasing the operational and design strength of the components

2. PRODUCT OVERVIEW

We offer you a wide range of products with strain wave technology designed in Germany. Through collaboration with our partners for components, manufacturing parts and assembly in the European Union, in the USA and in Asia we are able to provide fully integrated products and total drive solutions.

The product range of INNOWELLE GmbH is the ideal choice for solving any motion task.

The main features of all our products are:

- Excellent positioning accuracy
- Zero backlash
- High torque capacity
- Lifelong precision
- High single stage gear ratio
- Compact and lightweight

WE DRIVE

YOUR COBOT

2.1 SIMPLICITY BOX

The Simplicity Box combines a precise strain wave gear and a tilt resistant output bearing for a flat and lightweight gearbox.
It is available in the following two versions with hollow shaft or for motor mounting and meets a wide range of robotics requirements.

DESIGNED TO MEET THE REQUIREMENTS OF ROBOTICS

SB-HO	The compact gearbox with hollow shaft for robotics and handling	**Features**	Large hollow shaft to pass shafts and cables	Easy integration into the application	Short length	Integrated output bearing	Low weight
		Benefits	Simplifies the integration into the design	Lowest effort for design and assembly	Using of dual sensors possible	Cost-effective solution	Lightweight design
SB-MO	The compact gearbox with tilting resistant output bearing	**Features**	Direct motor assembly	Integrated clamping element	Short length	Integrated output bearing	Low weight
		Benefits	Easy to assemble to the motor	Backlash-free motor assembly without keyway	Compact design	Cost-effective solution	Lightweight design

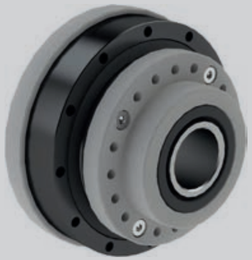
APPLICATION:

- Collaborative robots (COBOTS)
- Industrial robots
- Exoskeletons
- Humanoid robots

2.2 GEARBOX

The Gearbox combines a precise strain wave gear, a tilt resistant output bearing and a housing for a complete gearbox.
It is available in the following two versions with hollow shaft or for motor mounting and meets a wide range of requirements for automation, handling and machine tools.

THE COMPLETE GEARBOX



B-HO	The fully sealed gearbox with hollow shaft	**Features**	Complete gearbox with housing	Parallel motor attachment	Large hollow shaft	Integrated output bearing	Ready for installation
		Benefits	Minimises installation errors for better product quality	Easy integration into the application	Enables unique solutions in development and construction	Cost-effective solution	Lowest effort for design and assembly
B-MC	The gearbox for direct motor assembly	**Features**	Complete gearbox with housing	Direct motor assembly	Compact design	Integrated output bearing	Integrated clamping element
		Benefits	Minimises installation errors for better product quality	Easy to assemble to the motor	Easy integration into the application	Cost-effective solution	Backlash-free motor assembly without keyway

APPLICATION:

- Automation and handling
- Precise machine tools

2.3 COMPONENT KIT

The Component Kit is the basic component of all our products. It consists of the essential three components of a strain wave gear and combines all its outstanding features.

COMPONENTS:
- Wave Generator
- Flex Spline
- Circular Spline

THE FLEXIBLE COMPONENT KIT

C-MC	The basic strain wave gear component	**Features**	Lifelong precision and zero backlash	Compact and lightweight	Integrated clamping element	Without housing, input and output bearing	With or without hollow shaft
		Benefits	Best motion control and position accuracy	High single stage gear ratio	Backlash-free motor assembly without keyway	Enables a specific design	Maximum degrees of free-dom for the development of unique drive solutions

APPLICATION:
- Robotics
- Automation and handling
- Precise machine tools

2.4 INTELLIGENT COBOT MODULE

The Intelligent COBOT Module ICM is a fully integrated servo drive with excellent precision and the highest torque density. It consists of a precise strain wave gear, an efficient synchronous motor, several position sensors, a controller with EtherCAT protocol or CANopen protocol, a safety brake or an electromechanical locking system. It provides maximum flexibility when building every possible COBOT or robot arm for different payloads and/or different operational radii.

THE INTELLIGENT COBOT MODULE

ICM	The intelligent module	**Features**	Precise strain wave gear	Compact and lightweight design	Integrated controller with EtherCAT or CANopen protocol	Integrated STO function and fail-safe brake or mechanical locking system	Two integrated and indepen-dent position sensors	Power efficient synchronous motor
		Benefits	Reduces the investment into development and design	Enables unique solutions in development and construction	Simplifies supplier chain management and quality control management	Best protection for operator and co-worker	Excellent speed and positioning properties	For lowest energy consumption

APPLICATION:
- Collaborative robot (COBOT)
- Robotic, automation and handling
- Humanoid robot

3. ORDERING CODE

3.1 STRAIN WAVE GEARS

Design Type	Transmission Type	Size	Ratio	Version
SB	HO	20	100	A1

Configuration

Configuration	Description
A1	Generation

Ordering Code

SB	–	HO	–	20	–	100	–	A1

Design Type	
SB	Simplicity Box
B	Box
C	Component Kit

Transmission Type	
HO	Hollow shaft open flex spline
HC	Hollow shaft closed flex spline
MC	Motor shaft closed flex spline

Available sizes and ratios

Size \ Ratio	50	80	100	120	160
14 (35)	X	X	X		
17 (42)	X	X	X	X	
20 (50)	X	X	X	X	X
25 (63)	X	X	X	X	X
32 (80)	X	X	X	X	X

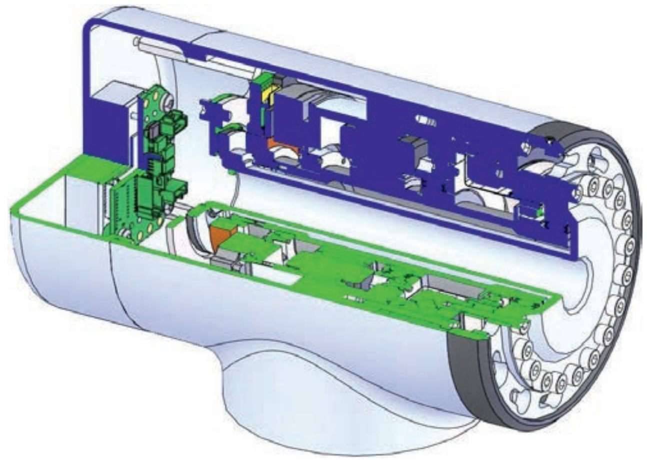
Size indicates the diameter of the gear in [inch/10].
The values in () indicate the diameter of the gear in [mm].

Combinations

Design Type	Transmission Type		
	HO	MO	MC
SB	X	X	
B	X		X
C			X

3.2 ORDERING CODE INTELLIGENT COBOT MODULE

Design Type	Size	Ratio	Configuration
ICM	14	51	A



Ordering Code

ICM	–	14	–	51	–	A

Design Type	
ICM	Intelligent COBOT Module

Available sizes and ratios

Size \ Ratio	51	81	101	121	161
14 (35)	X	X	X		
17 (42)	X	X	X	X	
20 (50)	X	X	X	X	X
25 (63)	X	X	X	X	X
32 (80)	X	X	X	X	X

Size indicates the diameter of the gear in [inch/10].
The values in () indicate the diameter of the gear in [mm].

Configuration

Configuration	Description
A	- multi-turn absolute encoder at the gear output - incremental encoder and Hall sensor at the motor side
	- fail-safe brake for ICM-17 … 32 - magnetic locking system for ICM-14

4. TECHNICAL DATA

4.1 GENERAL TECHNICAL DATA

Size	Ratio	Maximum Output Torque	Average Output Torque	Rated Output Torque	Emergency Stop Torque	Maximum Input Speed	Average Input Speed
	i [ ]	T_R [Nm]	T_A [Nm]	T_N [Nm]	T_M [Nm]	$n_{in(max)}$ [rpm]	$n_{av(max)}$ [rpm]
14 (35)	50	18	6.9	5.4	35	6000	3500
	80	23	11	7.8	47		
	100	28	11	7.8	54		
17 (42)	50	34	26	16	70	6000	
	80	43	27	22	87		
	100	54	39	24	110		
	120	54	39	24	86		
20 (50)	50	56	34	25	98	6000	
	80	74	47	34	127		
	100	82	49	40	147		
	120	87	49	40	147		
	160	92	49	40	147		
25 (63)	50	98	55	39	186	5600	
	80	137	87	63	255		
	100	157	108	67	284		
	120	167	108	67	304		
	160	176	108	67	314		
32 (80)	50	216	108	76	382	4800	
	80	304	167	118	568		
	100	333	216	137	647		
	120	353	216	137	686		
	160	372	216	137	686		

Size indicates the diameter of the gear in [inch/10]. The values in () indicate the diameter of the gear in [mm].

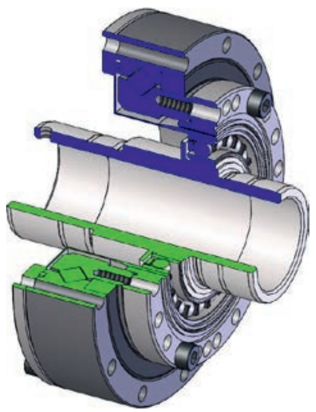
Weight [kg]					
Size	14	17	20	25	32
C-MC	0.10	0.14	0.23	0.38	0.87
SB-MO	0.37	0.52	0.72	1.20	2.53
SB-HO	0.41	0.59	0.83	1.39	2.87
B-MC	0.49	0.62	0.89	1.40	3.02
B-HO	0.67	0.92	1.35	2.05	4.14

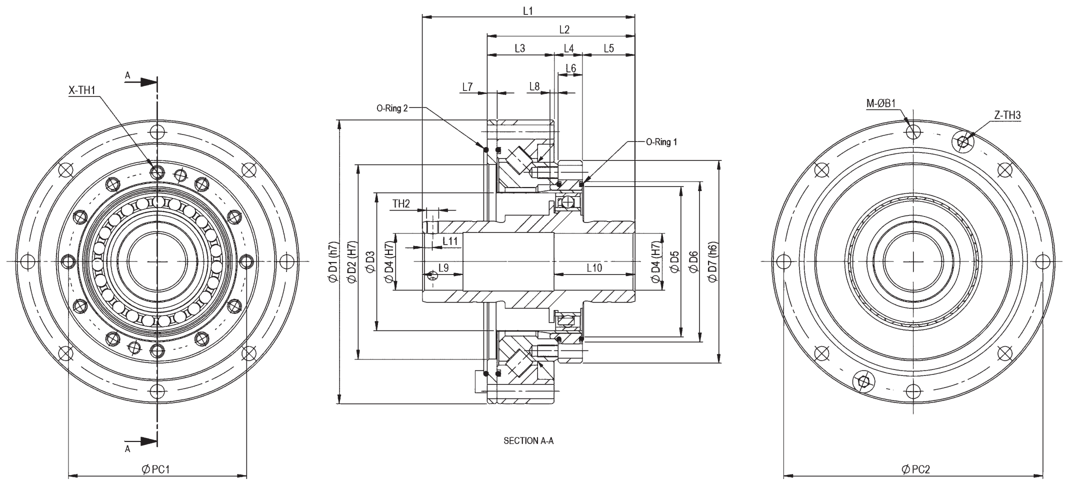
Moment of Inertia [kgm^2]					
Size	14	17	20	25	32
C-MC	$0.27\cdot10^{-5}$	$0.66\cdot10^{-5}$	$0.16\cdot10^{-4}$	$0.36\cdot10^{-4}$	$1.35\cdot10^{-4}$
SB-MO	$0.27\cdot10^{-5}$	$0.66\cdot10^{-5}$	$0.16\cdot10^{-4}$	$0.36\cdot10^{-4}$	$1.35\cdot10^{-4}$
SB-HO	$0.18\cdot10^{-4}$	$0.34\cdot10^{-4}$	$0.58\cdot10^{-4}$	$1.23\cdot10^{-4}$	$3.66\cdot10^{-4}$
B-MC	$0.27\cdot10^{-5}$	$0.66\cdot10^{-5}$	$0.16\cdot10^{-4}$	$0.36\cdot10^{-4}$	$1.35\cdot10^{-4}$
B-HO	$0.18\cdot10^{-4}$	$0.34\cdot10^{-4}$	$0.58\cdot10^{-4}$	$1.23\cdot10^{-4}$	$3.66\cdot10^{-4}$

4.2 DIMENSIONS

4.2.1 SIMPLICITY BOX, HOLLOW SHAFT OPEN FLEX SPLINE (14 / 17)

SB-HO





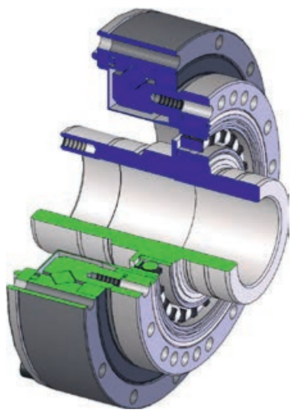
Size	ØPC1	X	TH1	ØPC2	Z	TH3	M	ØB1	ØD1	ØD2	ØD3	ØD4	ØD5	ØD6	ØD7	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11
14 (35)	Ø44	12	M3	Ø64	2	M3	8	Ø3.5	Ø70	Ø48	Ø33.9	Ø14	Ø37	Ø39.5	Ø50	52.5	36.5	16.5	7	13	6	2.4	2	10	20	2.5
17 (42)	Ø54	20	M3	Ø74	4	M3	12	Ø3.5	Ø80	Ø60	Ø41.7	Ø19	Ø46	Ø48.8	Ø60	56.5	40.5	19	7.5	14	6.5	3	2.5	10	22	2.5

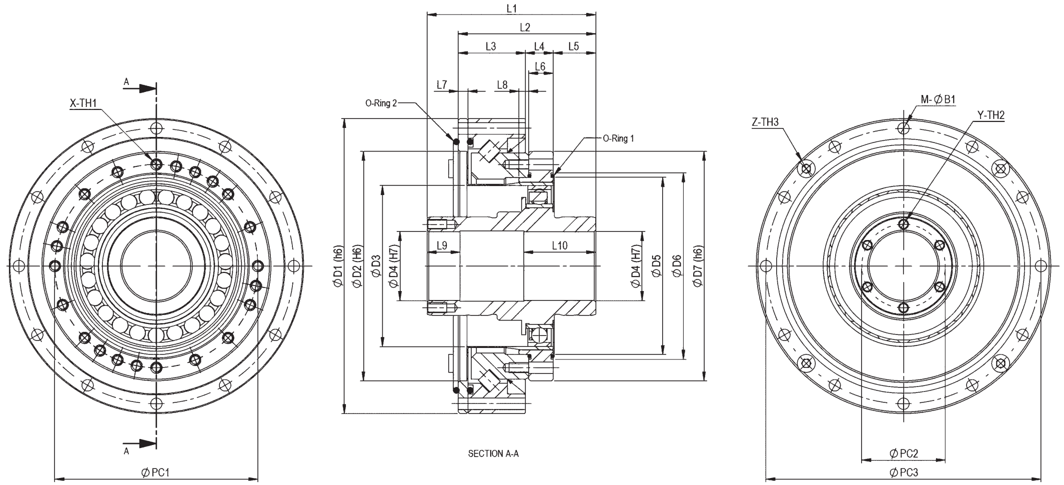
Dimensions in [mm]

4.2 DIMENSIONS

4.2.2 SIMPLICITY BOX, HOLLOW SHAFT OPEN FLEX SPLINE (20 / 25 / 32)

SB-HO





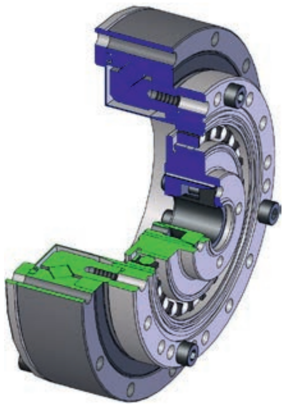
Size	ØPC1	X	TH1	ØPC2	Y	TH2	ØPC3	Z	TH3	M	ØB1	ØD1	ØD2	ØD3	ØD4	ØD5	ØD6	ØD7	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
20 (50)	Ø62	16	M3	Ø25.5	6	M3	Ø84	4	M3	12	Ø3.5	Ø90	Ø70	Ø49.1	Ø21	Ø54	Ø56.8	Ø70	51.5	42	20.5	8.5	13	7.5	3	3	10	22
25 (63)	Ø77	16	M4	Ø33.5	6	M3	Ø102	4	M3	12	Ø4.5	Ø110	Ø88	Ø61.3	Ø29	Ø67	Ø69.8	Ø85	55.5	45.5	22	12	11.5	10	3.3	3	10	23
32 (80)	Ø100	16	M5	Ø40.5	6	M3	Ø132	4	M4	12	Ø5.5	Ø142	Ø114	Ø79.7	Ø36	Ø88	Ø91.6	Ø110	65.5	56	27	15	14	14	3.6	3	10	25

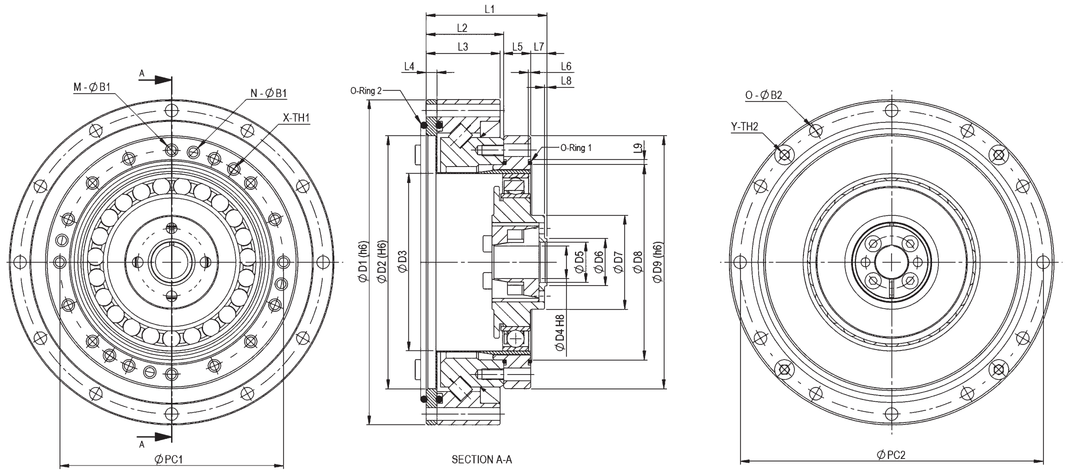
Dimensions in [mm]

4.2 DIMENSIONS

4.2.3 SIMPLICITY BOX, MOTOR SHAFT OPEN FLEX SPLINE

SB-MO





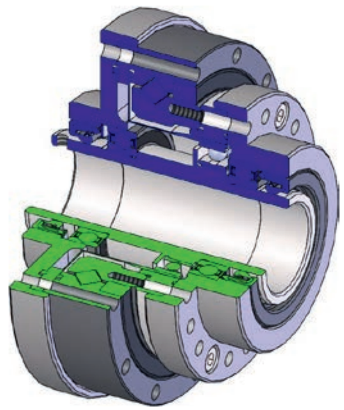
Size	ØPC1	M	N	ØB1	X	TH1	ØPC2	O	ØB2	Y	TH2	ØD1	ØD2	ØD3	ØD4	ØD5	ØD6	ØD7	ØD8	ØD9	L1	L2	L3	L4	L5	L6	L7	L8	L9
14 (35)	Ø44	12	-	Ø3.5	12	M3	Ø64	8	Ø3.5	2	M3	Ø70	Ø48	Ø33.9	Ø6	Ø6.4	Ø8	Ø20	Ø37	Ø50	28.5	17.5	16.5	2.4	6	0.7	5	1.1	1.25
17 (42)	Ø54	20	-	Ø3.5	20	M3	Ø74	12	Ø3.5	4	M3	Ø80	Ø60	Ø41.7	Ø8	Ø9.1	Ø10	Ø24	Ø46	Ø60	33	20	19	3	6.5	0.7	6.5	2.6	1.4
20 (50)	Ø62	16	4	Ø3.5	16	M3	Ø84	12	Ø3.5	4	M3	Ø90	Ø70	Ø49.1	Ø9	Ø11.2	Ø13	Ø26	Ø54	Ø70	33.5	21.5	20.5	3	7.5	0.7	4.5	0.7	1.4
25 (63)	Ø77	16	-	Ø4.5	16	M4	Ø102	12	Ø4.5	4	M3	Ø110	Ø88	Ø61.3	Ø11	Ø12.2	Ø14	Ø28	Ø67	Ø85	37	24	22	3.3	10	0.7	3	0.8	1.4
32 (80)	Ø100	16	-	Ø5.5	16	M5	Ø132	12	Ø5.5	4	M4	Ø142	Ø114	Ø79.7	Ø14	Ø15.2	Ø17	Ø35	Ø88	Ø110	44	28	27	3.6	14	1.3	2	0.5	1.8

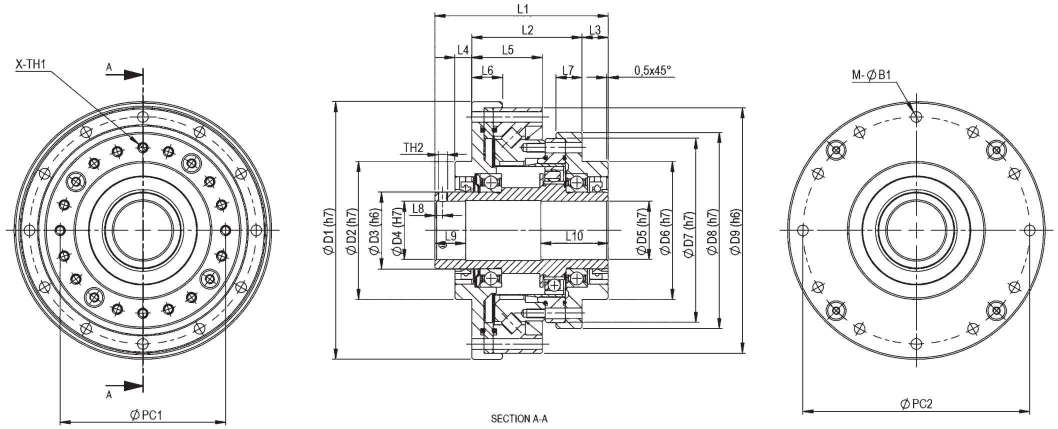
Dimensions in [mm]

4.2 DIMENSIONS

4.2.4 BOX, HOLLOW SHAFT OPEN FLEX SPLINE (14 / 17)

B-HO





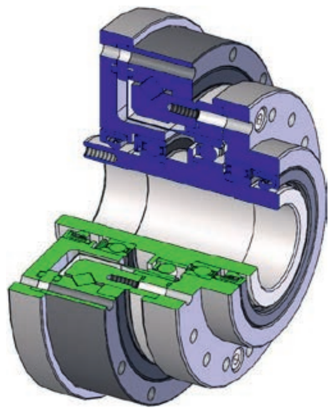
Size	ØPC1	X	TH1	ØPC2	TH2	M	ØB1	ØD1	ØD2	ØD3	ØD4	ØD5	ØD6	ØD7	ØD8	ØD9	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
14 (35)	Ø44	12	M3	Ø64	M3	8	Ø3.5	Ø74	Ø36	Ø20	Ø14	Ø14	Ø36	Ø50	Ø54	Ø70	52.5	33	7.5	5.5	20.5	9	8	2.5	10	20
17 (42)	Ø54	20	M3	Ø74	M3	12	Ø3.5	Ø84	Ø45	Ø25	Ø19	Ø19	Ø45	Ø60	Ø64	Ø80	56.5	36	8.5	5.5	23	10	8.5	2.5	10	22

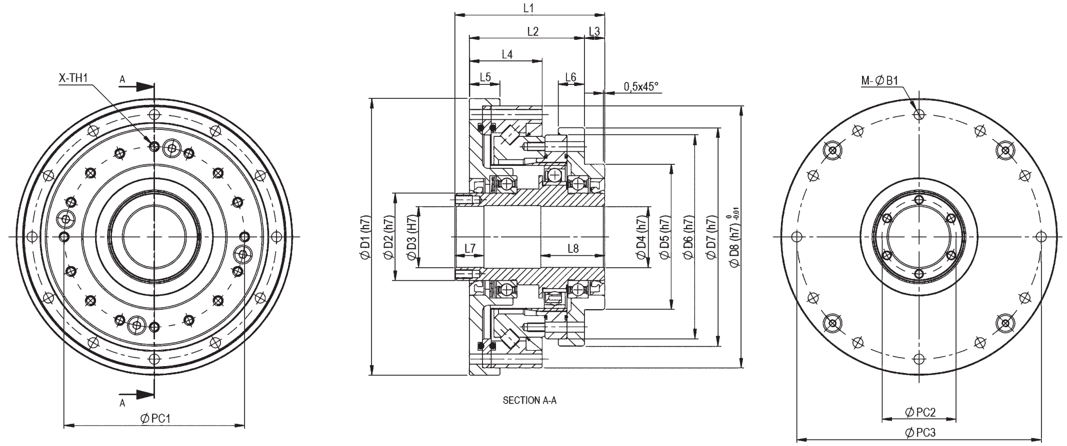
Dimensions in [mm]

4.2 DIMENSIONS

4.2.5 BOX, HOLLOW SHAFT OPEN FLEX SPLINE (20 / 25 / 32)

B-HO





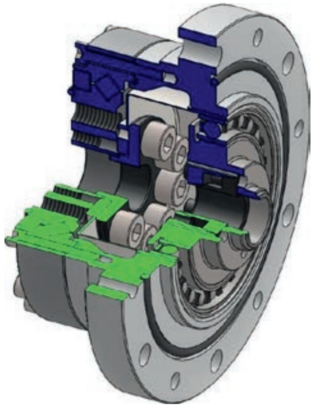
Size	ØPC1	X	TH1	ØPC2	N	TH2	ØPC3	M	ØB1	ØD1	ØD2	ØD3	ØD4	ØD5	ØD6	ØD7	ØD8	L1	L2	L3	L4	L5	L6	L7	L8
20 (50)	Ø62	16	M3	Ø25.5	6	M3	Ø84	12	Ø3.5	Ø95	Ø30	Ø21	Ø21	Ø50	Ø70	Ø75	Ø90	51.5	39.5	7	25	10.5	9	10	22
25 (63)	Ø77	16	M4	Ø33.5	6	M3	Ø102	12	Ø4.5	Ø115	Ø38	Ø29	Ø29	Ø60	Ø85	Ø90	Ø110	55.5	43.5	6	26	10.5	8.5	10	23
32 (80)	Ø100	16	M5	Ø40.5	6	M3	Ø132	12	Ø5.5	Ø147	Ø45	Ø36	Ø36	Ø85	Ø110	Ø115	Ø142	65.5	53.5	5	32	12	9.5	10	25

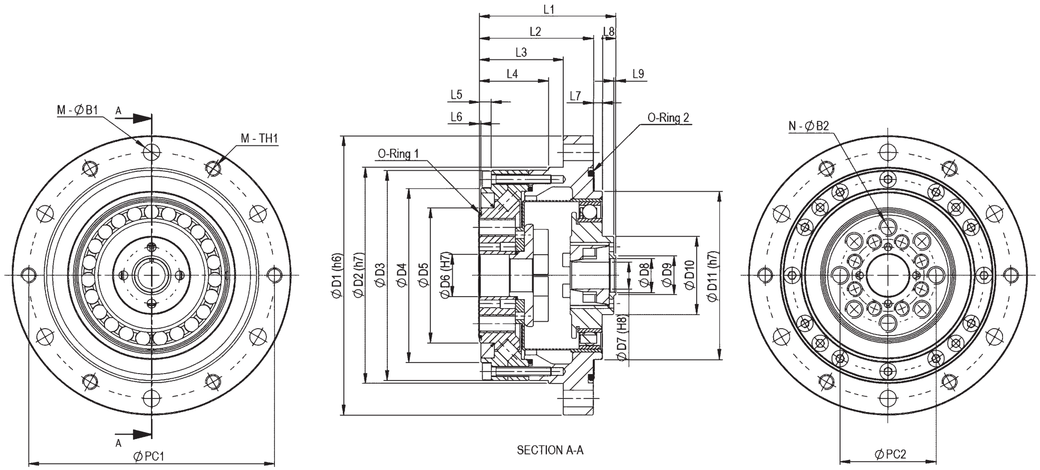
Dimensions in [mm]

4.2 DIMENSIONS

4.2.6 BOX, MOTOR SHAFT CLOSED FLEX SPLINE

B-MC





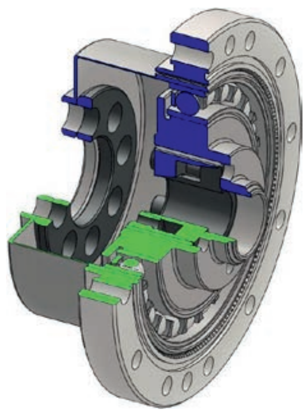
Size	ØPC1	M	ØB1	TH1	ØPC2	N	ØB2	ØD1	ØD2	ØD3	ØD4	ØD5	ØD6	ØD7	ØD8	ØD9	ØD10	ØD11	L1	L2	L3	L4	L5	L6	L7	L8	L9	O-Ring 1	O-Ring 2
14 (35)	Ø65	6	Ø4.5	M4	Ø23	6	M4	Ø73	Ø56	Ø55	Ø42.5	Ø31	Ø11	Ø6	Ø6.4	Ø8	Ø20	Ø38	41	34	27	23.5	4.5	0.5	2	7	1.1	28x0.6	50x2
17 (42)	Ø71	6	Ø4.5	M4	Ø27	6	M5	Ø79	Ø63	Ø62	Ø49.5	Ø38	Ø10	Ø8	Ø9.1	Ø10	Ø24	Ø48	45	37	29	25	4.5	0.5	1.5	8	2.6	34x1	55x2
20 (50)	Ø82	6	Ø5.5	M5	Ø32	8	M6	Ø93	Ø72	Ø70	Ø58	Ø45	Ø14	Ø9	Ø11.2	Ø13	Ø26	Ø56	45.5	38	28	23	4	0.5	3	7.5	0.7	40x1	66x2
25 (63)	Ø96	8	Ø5.5	M5	Ø42	8	M8	Ø107	Ø86	Ø85	Ø73	Ø58	Ø20	Ø11	Ø12.2	Ø14	Ø28	Ø67	52	46	36	31	4.5	-	3	6	0.8	53x1	80x2
32 (80)	Ø125	12	Ø6.5	M6	Ø55	8	M10	Ø138	Ø113	Ø112	Ø96	Ø78	Ø26	Ø14	Ø15.2	Ø17	Ø35	Ø90	62	57	45	40	5.5	1	3	5	0.5	68x1.8	105x2

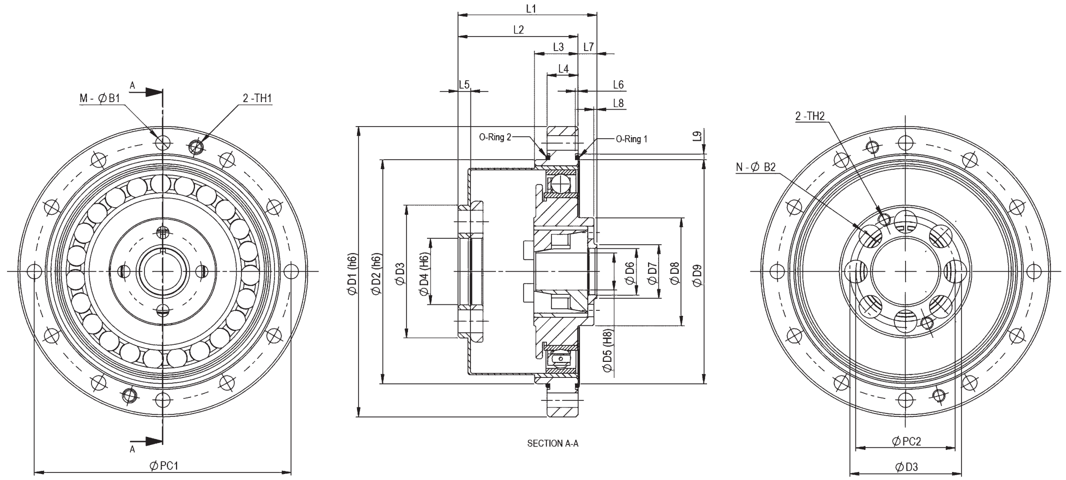
Dimensions in [mm]

4.2 DIMENSIONS

4.2.7 COMPONENT KIT, MOTOR SHAFT CLOSED FLEX SPLINE

C-MC





Size	ØPC1	M	ØB1	TH1	ØPC2	N	ØB2	ØPC3	TH2	ØD1	ØD2	ØD3	ØD4	ØD5	ØD6	ØD7	ØD8	ØD9	L1	L2	L3	L4	L5	L6	L7	L8	L9
14 (35)	Ø44	6	Ø3.5	M3	Ø17	6	Ø4.5	Ø18.5	M3	Ø50	Ø38	Ø23	Ø11	Ø6	Ø6.4	Ø8	Ø20	Ø37	28.5	23.5	17.5	6	2.4	2	0.7	1.1	1.25
17 (42)	Ø54	12	Ø3.5	M3	Ø19	6	Ø5.5	Ø21.5	M3	Ø60	Ø48	Ø27.2	Ø10	Ø8	Ø9.1	Ø10	Ø24	Ø46	33	26.5	20	6.5	3	2.5	0.7	2.6	1.4
20 (50)	Ø62	12	Ø3.5	M3	Ø24	8	Ø5.5	Ø27	M3	Ø70	Ø54	Ø32	Ø16	Ø9	Ø11.2	Ø13	Ø26	Ø54	33.5	29	21.5	7.5	3	3	0.7	0.7	1.4
25 (63)	Ø77	16	Ø4.5	M4	Ø30	8	Ø6.6	Ø34	M4	Ø85	Ø67	Ø40	Ø20	Ø11	Ø12.2	Ø14	Ø28	Ø67	37	34	24	10	3	3	0.7	0.8	1.4
32 (80)	Ø100	12	Ø5.5	M5	Ø40	8	Ø8.5	Ø45	M5	Ø110	Ø90	Ø52	Ø26	Ø14	Ø15.2	Ø17	Ø35	Ø90	44	42	28	14	3.2	3	0.7	0.5	1.4

Dimensions in [mm]

4.3 ACCURACY

Accuracy [arcmin]			
Size	14	17	≥ 20
Transmission accuracy	< 1.5	< 1.5	< 1
Repeatability	< ±0.1		
Hysteresis loss	< 2 (i = 50)		< 1 (i ≥ 80)
Lost motion	< 1		

4.4 TORSIONAL STIFFNESS

Torsional stiffness [Nm/rad]						
Size		14	17	20	25	32
T_1 in Nm		2	3.9	7	14	29
T_2 in Nm		6.9	12	25	48	108
i = 50	K_3	$6.7 \cdot 10^3$	$15.3 \cdot 10^3$	$27.0 \cdot 10^3$	$51.6 \cdot 10^3$	$115.0 \cdot 10^3$
	K_2	$5.6 \cdot 10^3$	$13.0 \cdot 10^3$	$21.3 \cdot 10^3$	$40.3 \cdot 10^3$	$92.4 \cdot 10^3$
	K_1	$4.1 \cdot 10^3$	$9.9 \cdot 10^3$	$15.9 \cdot 10^3$	$30.5 \cdot 10^3$	$65.8 \cdot 10^3$
i > 50	K_3	$8.3 \cdot 10^3$	$18.8 \cdot 10^3$	$34.0 \cdot 10^3$	$66.9 \cdot 10^3$	$141.0 \cdot 10^3$
	K_2	$7.2 \cdot 10^3$	$16.6 \cdot 10^3$	$29.6 \cdot 10^3$	$59.2 \cdot 10^3$	$130.0 \cdot 10^3$
	K_1	$5.7 \cdot 10^3$	$12.2 \cdot 10^3$	$19.5 \cdot 10^3$	$37.8 \cdot 10^3$	$81.7 \cdot 10^3$

4.5 TECHNICAL DATA OF THE OUTPUT BEARING

The gearbox types B and SB incorporate a high stiffness cross roller bearing. The cross roller bearing can withstand both axial and radial forces as well as tilting moments. This reduces the effort and costs for design, production and assembly for the user. The high stiffness cross roller bearing also keeps the gearbox free of external loads, ensuring a long service life and consistent accuracy of the gearbox.

Technical data – Cross roller bearing for gear type B-MC

Size	Pitch circle diameter	Offset	Dynamic load rating	Static load rating	Permissible dynamic tilting moment	Permissible static tilting moment 1)	Tilting moment stiffness 2)	Permissible axial load 3)	Permissible radial load 3)
	d_p [mm]	R [mm]	C [N]	C_0 [N]	M [Nm]	M_0 [Nm]	K_B [Nm/arcmin]	F_a [N]	F_r [N]
14	35	9.5	4700	6070	41	71	12.7	3213	2153
17	42.5	9.5	5290	7550	64	107	22.5	3616	2423
20	50	9.5	5780	9000	91	150	37.2	3951	2647
25	62	11.5	9600	15100	156	312	70.4	6563	4397
32	80	14	15000	25000	313	667	157	10255	6871

Technical data – Cross roller bearing for gear type B-HO, SB-HO, SB-MO

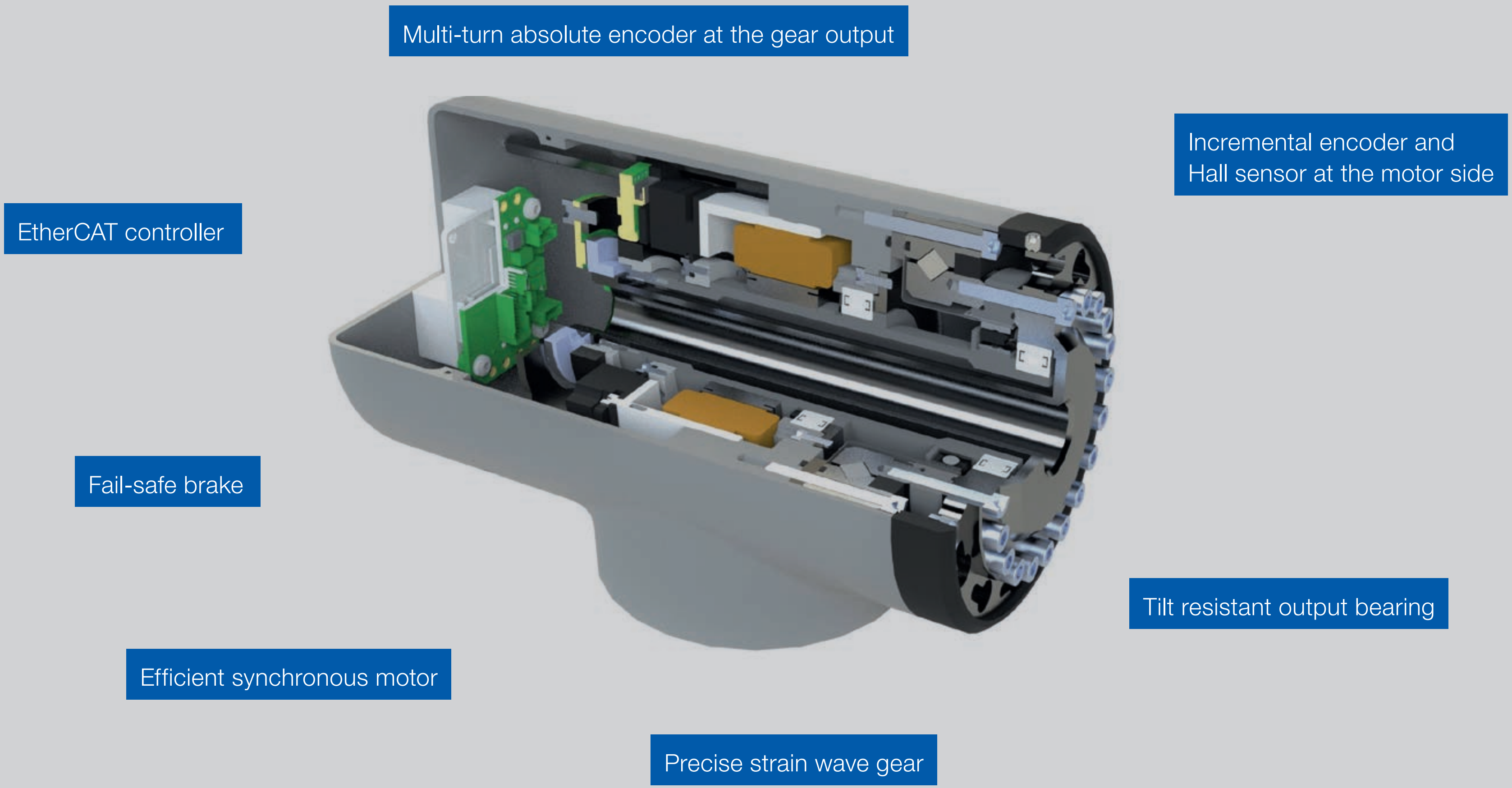
Size	Pitch circle diameter	Offset	Dynamic load rating	Static load rating	Permissible dynamic tilting moment	Permissible static tilting moment 1)	Tilting moment stiffness 2)	Permissible axial load 3)	Permissible radial load 3)
	d_p [mm]	R [mm]	C [N]	C_0 [N]	M [Nm]	M_0 [Nm]	K_B [Nm/arcmin]	F_a [N]	F_r [N]
14	50	21.6	5800	8600	74	143	24.7	3965	2657
17	60	22.3	10400	16300	124	326	44.8	7110	4764
20	70	26.6	14600	22000	187	513	73.3	9981	6687
25	85	29.7	21800	35800	258	1014	111	14903	9985
32	111	40.4	38200	65400	580	2420	291	26115	17497

1) The permissible static tilting moment M_0 is based on a static load safety factor of $f_s = 1.5$.
2) The tilting moment stiffness K_B is an average value.
3) The permissible axial load F_a and the permissible radial load F_r are estimated values based on $L_{10} = 15000$h, n = 15 rpm and $f_w = 1$.

Assumptions for the calculation:
M: $F_a = 0$; $F_r = 0$
F_a: $M = 0$; $F_r = 0$
F_r: $M = 0$; $F_a = 0$

5. TECHNICAL DATA ICM

5.1 STRUCTURE OF THE ICM



5.2 TECHNICAL DATA

General technical data	Unit	ICM
Supply voltage	[VDC]	48
Insulation resistant (500VDC)	[MΩ]	100
Degree of protection (EN 60034-5)		IP00 (valid for a single ICM) IP65 (valid in assembled condition)
Ambient operating temperature	[°C]	10 … 40
Altitude (a.s.l)	[m]	<1000
Relative humidity (without condensation)	[%]	20 … 80
Communication protocol		EtherCAT or CANopen
Resolution incremental encoder at motor side	[qc]	7680
Resolution multi-turn absolute encoder at output side		
– single turn	[bit]	19
– multi-turn (battery buffered)	[bit]	16

Intelligent COBOT Module	Unit	ICM 14 2)			ICM 17				ICM 20				
Ratio1)	[ ]	51	81	101	51	81	101	121	51	81	101	121	161
Maximum output torque	[Nm]	18	23	28	34	43	54	54	56	74	82	87	92
Maximum output speed	[rpm]	78	49	39	78	49	39	33	76	48	38	32	24
Maximum current	[Arms]	5.5	4.4	4.3	10.4	8.3	8.3	7.0	14.8	12.3	10.9	9.7	7.7
Maximum motor speed	[rpm]	4000			4000				3900				
Maximum output power	[W]	148	119	116	279	222	224	187	448	373	331	293	233
Moment of inertia without brake3)	[kgm²]	0.12	0.30	0.47	0.13	0.33	0.51	0.73	0.29	0.72	1.12	1.61	2.84
Moment of inertia with brake3)	[kgm²]	-	-	-	0.14	0.35	0.54	0.77	0.29	0.74	1.15	1.65	2.92
Weight	[kg]	1.3			1.9				2.7				
Hollow shaft diameter	[mm]	12			14				17				

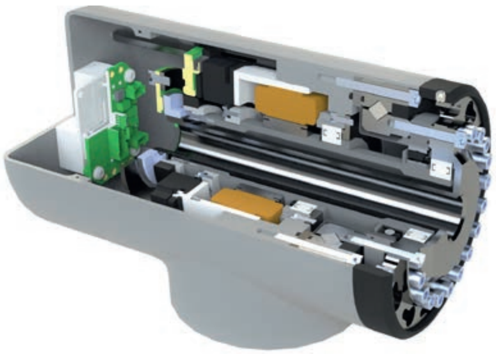
Intelligent COBOT Module	Unit	ICM 25					ICM 32				
Ratio1)	[ ]	51	81	101	121	161	51	81	101	121	161
Maximum output torque	[Nm]	98	137	157	167	176	216	304	333	353	372
Maximum output speed	[rpm]	76	48	38	32	24	49	30	24	20	15
Maximum current	[Arms]	25.8	22.7	20.9	18.6	14.7	36.2	32.1	28.2	24.9	19.7
Maximum motor speed	[rpm]	3900					2500				
Maximum output power	[W]	784	690	635	563	446	1108	982	863	763	605
Moment of inertia without brake3)	[kgm²]	1.30	3.27	5.08	7.29	12.9	1.92	4.85	7.53	10.8	19.1
Moment of inertia with brake3)	[kgm²]	1.32	3.33	5.18	7.44	13.2	1.95	4.91	7.64	11.0	19.4
Weight	[kg]	4.0					6.7				
Hollow shaft diameter	[mm]	22					26				

1) Output via circular spline

2) ICM-14 has a magnetic locking system that should only be used under standstill conditions. All other sizes have in its standard configuration a magnetic fail-safe brake.

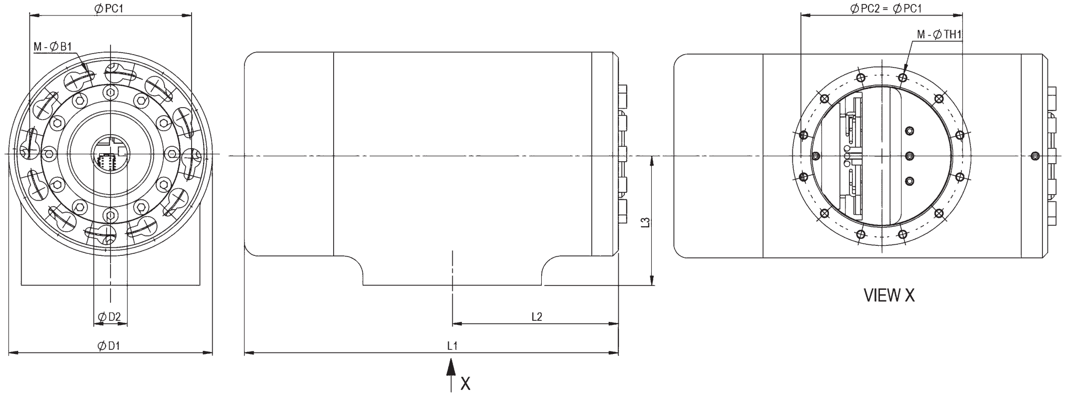
3) At output side. The standard configuration is with brake.

5.3 DIMENSIONS



Size	ØPC1	M	B1	ØTH1	D1	D2	L1	L2	L3
14 (35)	Ø58	12	Ø3.4	M3	Ø73	Ø12	128	57.5	47
17 (42)	Ø67	12	Ø3.4	M3	Ø82.5	Ø14	141.9	62.4	50
20 (50)	Ø77	12	Ø3.4	M3	Ø93	Ø17	160.5	72.5	62
25 (63)	Ø95	12	Ø4.5	M4	Ø114	Ø22	172.5	70	72
32 (80)	Ø124	12	Ø5.5	M5	Ø146	Ø26	186.5	87	84

Dimensions in [mm]



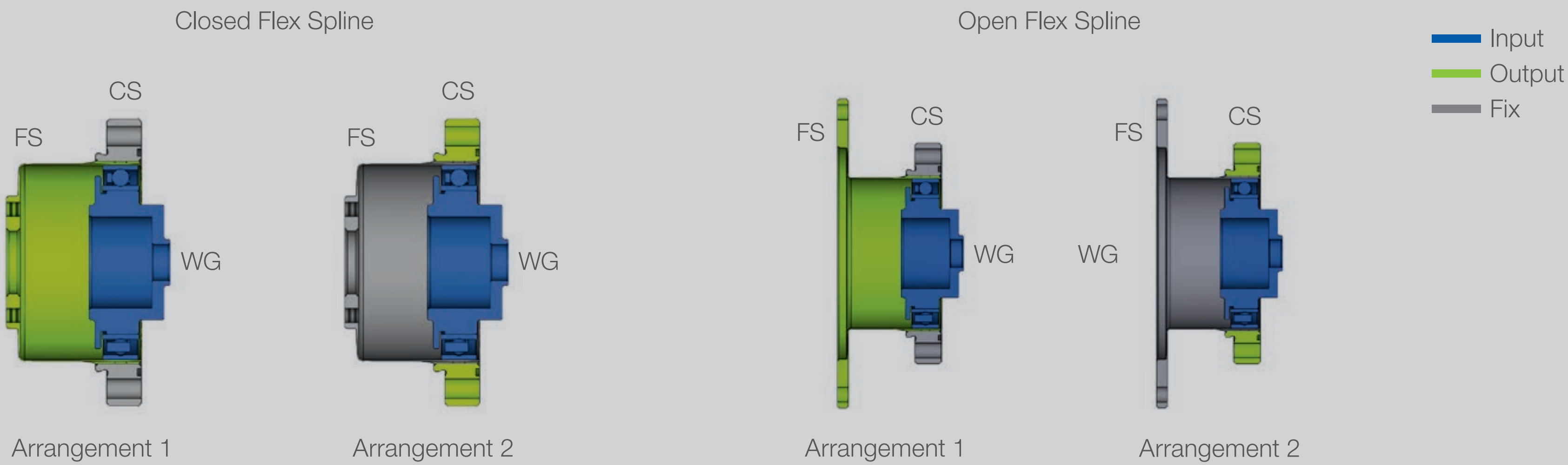
6. GEAR SELECTION PROCEDURE

A variety of different driving arrangements can be realised with strain wave gears.
The reduction ratio as well as the output rotation direction will also be affected by the selected drive arrangement.

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

The following figures show the essential components of a strain wave gear. FS = Flex Spline; CS = Circular Spline; WG = Wave Generator

THE VALUES FOR THE GEAR REDUCTION AND THE ROTATION DIRECTION ARE IN ACCORDANCE WITH THE DRIVE ARRANGEMENT:



	Drive arrangement 1	Drive arrangement 2
Ratio	$= -\frac{i}{1}$	$= \frac{i+1}{1}$
Wave Generator (WG)	Input	Input
Flex Spline (FS)	Output	Fix
Circular Spline (CS)	Fix	Output
Input vs. output direction	Opposite direction	Same direction

6.1 BASIC INTRODUCTION

Depending on the application, the required torque or stiffness can be the decisive criterion when selecting the gearbox. Nevertheless, it is essential that both torque and stiffness are taken into account when designing the gearbox. Please follow the procedure outlined below to get the exact gearbox you need for your application.

6.2 PRE-SELECTION

You should consider these questions when pre-selecting the gear:

Are the core elements of the gearbox enough for me or do I want to use the output bearing recommended by INNOWELLE? Ideally, directly with seals and housing covers, so that I can install the gear directly without any problems.

- C-Component kit (Core elements)
- SB-Simplicity box (Component kit + output bearing)
- B-Box (Simplicity box + shaft bearing + seals + housing cover)

Do I need a hollow shaft or a motor shaft at the drive side?

- H-Version (Hollow shaft)
- M-Version (Motor shaft)

What is the needed acceleration torque, deceleration torque and the needed continuous torque that occur in my application? The necessary torques of the application determine the gear size.

- 14 / 17 / 20 / 25 / 32

What are the maximum speed and average speed that occur in my application? The necessary speed of the application determines the gearbox reduction ratio.

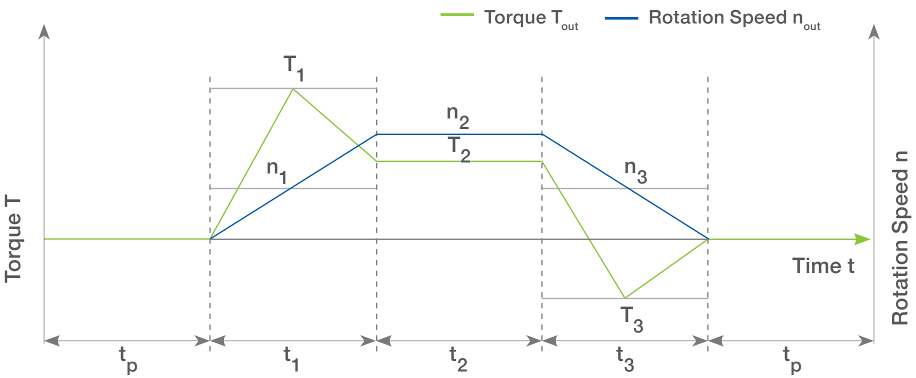
- 50 / 80 / 100 / 120 /160

6.3 LOAD CYCLE-BASED DIMENSIONING

The following procedure describes in detail the load cycle-based dimensioning of a strain wave gear. The limits shown in the procedure should not be exceeded. If the limits cannot be fulfilled with the selected gear size it is necessary to select a larger gear size.

Average output torque

The average output torque that affects the strain wave gear during the load cycle must be determined at first.



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

The calculated torque must be compared with the gear average torque from the technical data sheet.

$$T_{out,av} \leq T_A \ ?$$

Average output speed

In order to ensure the longest possible service life of the gear, the average input speed during a load cycle should not exceed the specification from the technical data sheet.

$$n_{out,av} = \frac{|n_1| * t_1 + |n_2| * t_2 + \cdots + |n_n| * t_n}{t_1 + t_2 + \cdots + t_n + t_p}$$

$$n_{in,av} = n_{out,av} * i$$

$$n_{in,av} \leq n_{av(max)} \ ?$$

Maximum output torque

Specifies the maximum acceleration and deceleration torque that can be applied for a short time in highly dynamic applications. This value should never exceed the repeated peak torque provided in the technical data sheet.

$$T_{out,max} \leq T_R \ ?$$

Emergency stop torque

In the event of an emergency stop or collision, the strain wave gear can be subjected to a brief emergency stop torque. However, damage to the gear and thus a reduced service life is not excluded. The magnitude and frequency of the overload output torque should be kept to a minimum value and it should be below the indication from the technical data sheet.

$$T_{out,K} \leq T_M \ ?$$

Maximum output speed

The maximum output speed must not be exceeded. It can be applied only for a short time in the load cycle due to heating issues.

$$n_{in,max} = n_{out,max} * i \qquad n_{in,max} \leq n_{max} \ ?$$

Service life of the wave generator bearing

The service life calculation of the wave generator bearing is carried out in accordance with DIN ISO 281. The reference values are the rated output torque from the technical data and a refence input speed n_N.

$$n_N = 2000 rpm. \qquad L_{10} = L_n * \frac{n_N}{n_{in,av}} * \left(\frac{T_N}{T_{out,av}}\right)^3$$

6.4 STIFFNESS-BASED DIMENSIONING

There may be applications where high stiffness is more important than the load cycle-based dimensioning of the strain wave gear. The stiffness-based dimensioning of the strain wave gear should always be made additionally to determine the resonance frequency of the application.

Description		
f_n	[Hz]	Resonance frequency
K_1	[Nm/rad]	Torsional stiffness
J	[kgm²]	Load moment of inertia

Application experience for f_n	
Joints in robotics	≥ 8
Standard applications in general mechanical engineering	≥ 15
Processing axis in machine tool	≥ 20

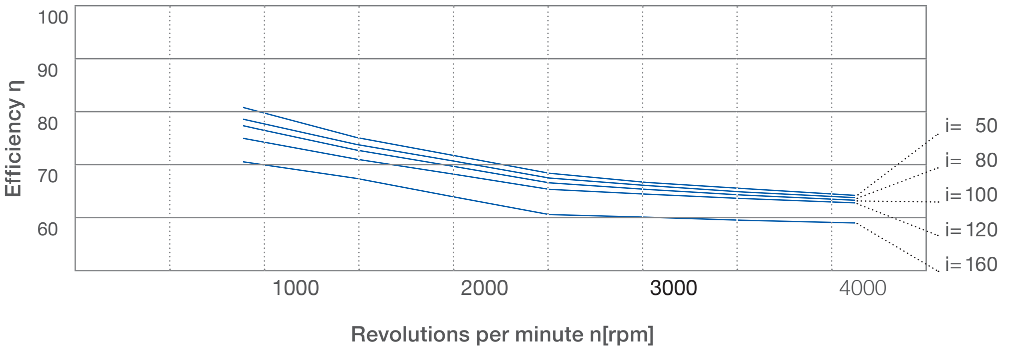
Resonance frequency

$$f_n = \frac{1}{2\pi} * \sqrt{\frac{K_1}{J}}$$

Resonance input speed

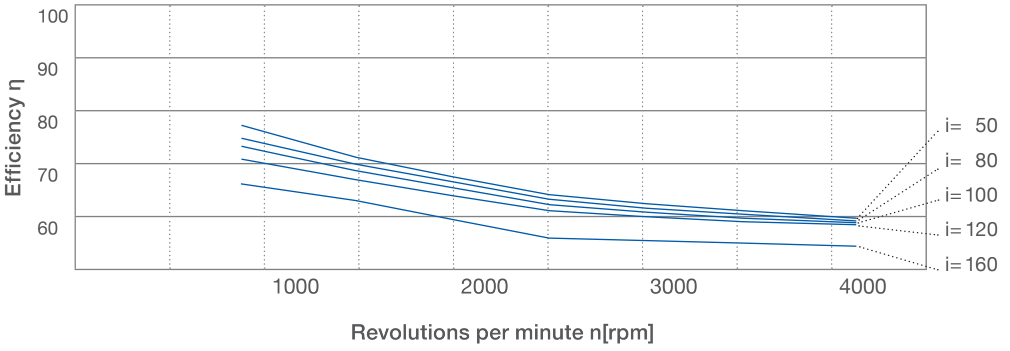
$$n_n = f_n * 30\, rpm$$

6.5 EFFICIENCY DESIGN TYPE C-MO, SB-MO, SB-HO AND B-MC



- Values apply for an ambient temperature of + 20°C.
- The efficiency increases with increasing temperature (approx. + 10% each 20K).
- The efficiency decreases with falling temperature (approx. − 20% each 20K).
- Values apply to standard INNOWELLE grease.

6.6 EFFICIENCY DESIGN TYPE B-HO



- The values are lower because of the sealing on the input shaft
- Values apply for an ambient temperature of + 20°C.
- The efficiency increases with increasing temperature (approx. + 10% each 20K).
- The efficiency decreases with falling temperature (approx. − 20% each 20K).
- Values apply to standard INNOWELLE grease.

6.7 SERVICE LIFE WAVE GENERATOR BEARING

The service life calculation of the wave generator bearing is carried out in accordance with DIN ISO 281. The reference values are the rated output torque from the technical data and a refence input speed of n_N= 2000 rpm.

$$L_{10} = L_n * \frac{n_N}{n_{in,av}} * \left(\frac{T_N}{T_{out,av}}\right)^3$$

Design Type	L_n [h]	n_N [min^{-1}]
SB, B, C	7000	2000

6.8 SERVICE LIFE OUTPUT BEARING

The service life of the output bearing can be determined depending on the application.

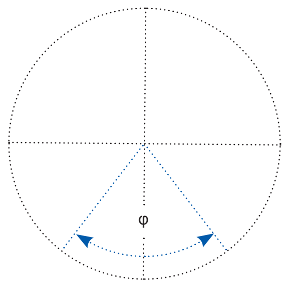
Continuous Operation

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

Oscillating Motion

$$L_{OC} = \frac{10^6}{60 * n_{OC}} * \frac{180}{\varphi} * \left(\frac{C}{f_w * P_c}\right)^B$$

Description		
L_{10}	[h]	Service life
L_{OC}	[N]	Service life at oscillating motion
C	[N]	Dynamic load rating
PC	[N]	Dynamic equivalent load
φ	[°]	Oscillating angle
f_w	[ ]	Operating factor
n_{av}	[min^{-1}]	Average output speed
n_{OC}	[1/min]	Number of oscillations per minute
$F_{r,av}$	[N]	Average radial load
$F_{a,av}$	[N]	Average axial load
M	[Nm]	Tilting moment
x	[ ]	Radial load factor
y	[ ]	Axial load factor
f_w		Operating factor



One oscillation = 2φ

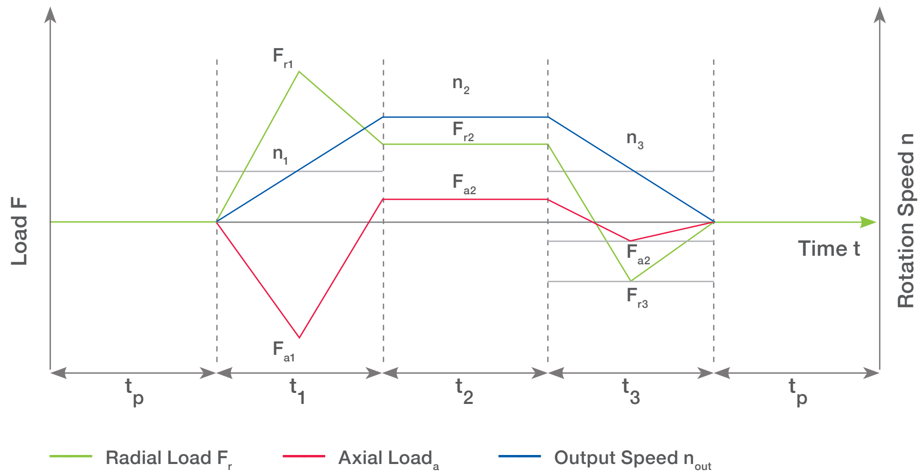
Bearing Type	B
Cross roller bearing	$\frac{10}{3}$

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

$$P_C = x * \left(F_{r,av} + \frac{2M}{d_p}\right) + y * F_{a,av}$$

$$F_{a,av} = \left(\frac{|n_1| * t_1 * (|F_{a1}|)^B + |n_2| * t_2 * (|F_{a2}|)^B + \cdots + |n_n| * t_n * (|F_{an}|)^B}{|n_1| * t_1 + |n_2| * t_2 + \cdots + |n_n| * t_n}\right)^{\frac{1}{B}}$$

$$F_{r,av} = \left(\frac{|n_1| * t_1 * (|F_{r1}|)^B + |n_2| * t_2 * (|F_{r2}|)^B + \cdots + |n_n| * t_n * (|F_{rn}|)^B}{|n_1| * t_1 + |n_2| * t_2 + \cdots + |n_n| * t_n}\right)^{\frac{1}{B}}$$



Load Factors	x	y
$\frac{F_{a,av}}{F_{r,av} + 2 * \frac{M}{d_p}} \leq 1{,}5$	1	0.45
$\frac{F_{a,av}}{F_{r,av} + 2 * \frac{M}{d_p}} > 1{,}5$	0.67	0.67

Load Conditions	f_w
No impact loads and/or vibrations	1 …1.2
Normal rotation, normal loads	1.2 … 1.5
Impact loads and/or vibrations	1.5 … 3

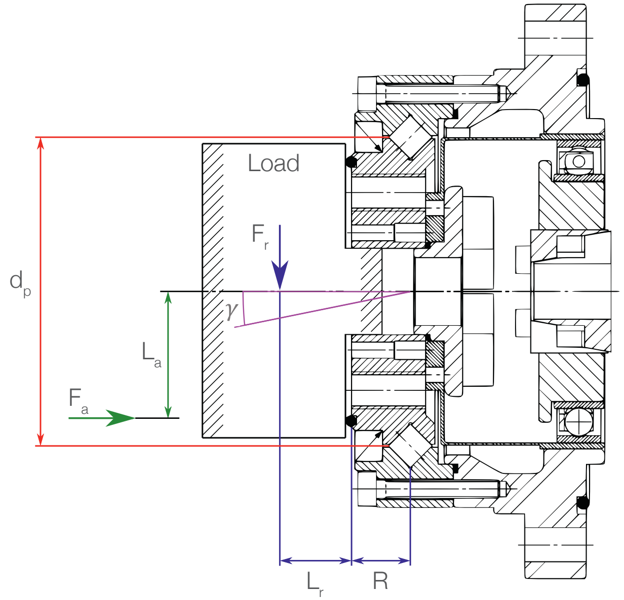
6.9 PERMISSIBLE STATIC TILTING MOMENT

In the evet of a static load, the bearing load capacity and the angle of inclination can be determined as follows:

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

$$M_0 = \frac{d_p * C_0}{2 * f_s} \qquad \gamma = \frac{M}{K_B}$$

Description		
f_s	[ ]	Static load safety factor
C_0	[N]	Static load rating
F_r	[N]	Radial load
F_a	[N]	Axial load
x_0	[ ]	1
y_0	[ ]	0.45
P_0	[1/min]	Static equivalent load
d_p	[mm]	Pitch circle diameter
γ	[arcmin]	Angle of inclination at the output bearing
M	[Nm]	Tilting moment at the output bearing
M0	[Nm]	Permissible static tilting moment itch
KB	[Nm/arcmin]	Radial load factor



$$M = F_r * (L_r + R) + F_a * L_a$$

Rotation Condition of Bearing	f_s
Normal	1 … 2
Impacts / Vibrations	2 … 3
High transmission accuracy	≥ 3

6.10 CALCULATION OF THE TORSIONAL ANGLE

The torsional angle under load conditions of the gear can be calculated as follows:

$T \leq T_1$

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

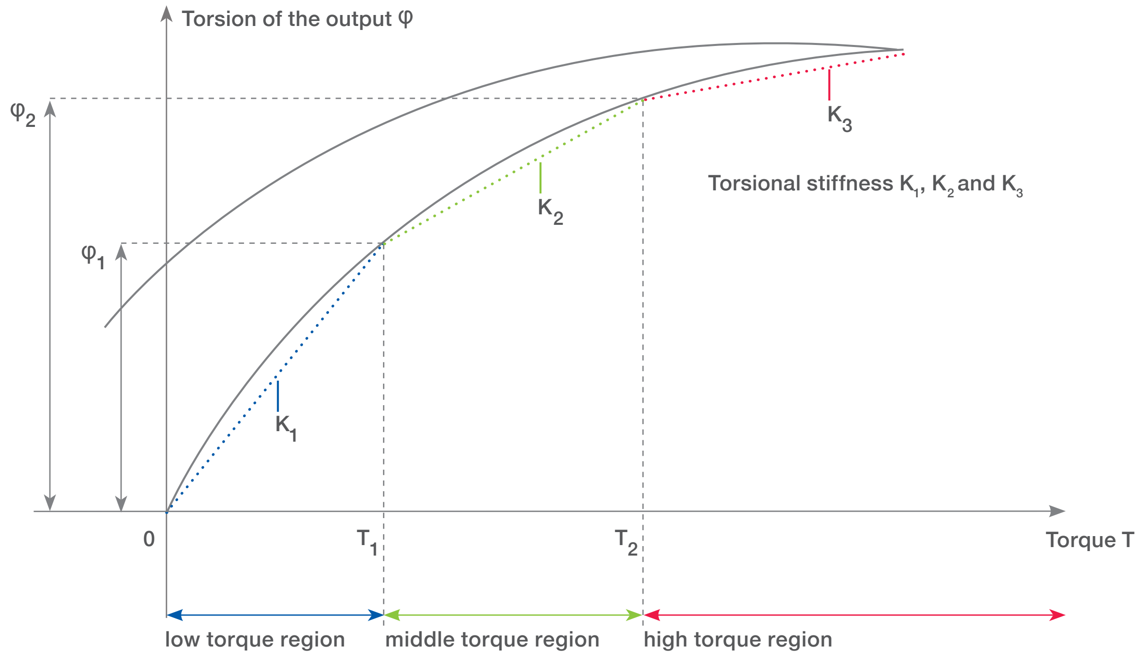
$T_1 < T \leq T_2$

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

$T > T_2$

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

Description		
φ	[rad]	Angle
T	[Nm]	Torque
T_1	[Nm]	Limit torque 1
T_2	[Nm]	Limit torque 2
K_1	[Nm/rad]	Torsional stiffness
K_2	[Nm/rad]	Torsional stiffness
K_3	[Nm/rad]	Torsional stiffness



6.11 NO LOAD STARTING TORQUE

The no load starting torque is the start-up torque that must be overcome in order to set the unloaded gearbox in motion.

C-MC, SB-MO, SB-HO, B-MC No load starting torque [mNm]					
Size	14	17	20	25	32
i = 50	33	51	66	120	260
i = 80	24	33	41	77	160
i = 100	21	29	37	69	150
i = 120	N/A	27	33	63	130
i = 160	N/A	N/A	29	55	120

B-HO No load starting torque [mNm]					
Size	14	17	20	25	32
i = 50	88	270	360	560	850
i = 80	75	250	330	500	740
i = 100	69	240	320	490	720
i = 120	N/A	240	310	480	680
i = 160	N/A	N/A	310	470	670

At a gear temperature of 20°C.

6.12 NO LOAD RUNNING TORQUE

The no load running torque is the torque needed to rotate the unloaded gearbox at a defined speed.

C-MC, SB-MO, SB-HO, B-MC No load running torque [mNm]					
Size	14	17	20	25	32
i = 50	36	53	107	199	407
i = 80	35	51	106	196	401
i = 100	35	51	105	195	400
i = 120	N/A	51	105	195	399
i = 160	N/A	N/A	104	194	398

B-HO No load running torque [mNm]					
Size	14	17	20	25	32
i = 50	101	262	373	604	1008
i = 80	100	260	371	601	1002
i = 100	100	260	370	600	1000
i = 120	N/A	260	370	599	999
i = 160	N/A	N/A	369	599	997

At a gear temperature of 20°C and an input speed of 2000 rpm.

6.13 NO LOAD BACK DRIVING TORQUE

The no load back driving torque describes the necessary torque to drive the unloaded gearbox backwards. The values were based on a calculation and represent only a guideline. In order to prevent the gearbox from turning backwards, a brake has to be used.

C-MC, SB-MO, SB-HO, B-MC No load back driving torque [Nm]					
Size	14	17	20	25	32
i = 50	1.74	2.68	3.47	6.32	13.68
i = 80	2.02	2.78	3.45	6.48	13.47
i = 100	2.21	3.05	3.89	7.26	15.79
i = 120	N/A	3.41	4.17	7.96	16.42
i = 160	N/A	N/A	4.88	9.26	20.21

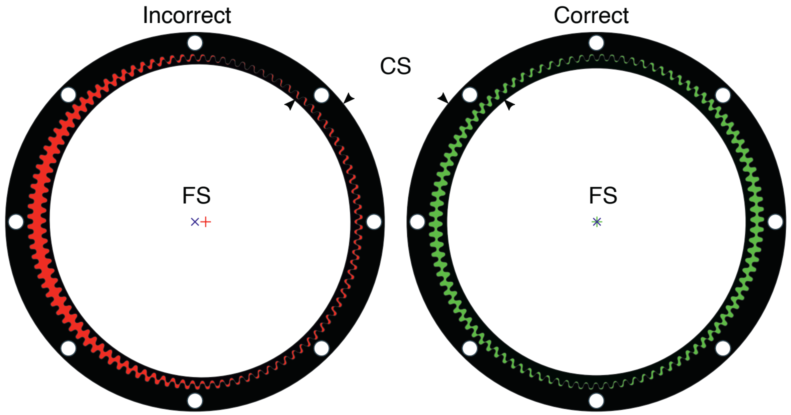
B-HO No load back driving torque [Nm]					
Size	14	17	20	25	32
i = 50	4.63	14.21	18.95	29.47	44.74
i = 80	6.32	21.05	27.79	42.11	62.32
i = 100	7.26	25.26	33.68	51.58	75.79
i = 120	N/A	30.32	39.16	60.63	85.89
i = 160	N/A	N/A	52.21	79.16	112.84

At a gear temperature of 20°C.

7. NOTES AND EXPLANATIONS

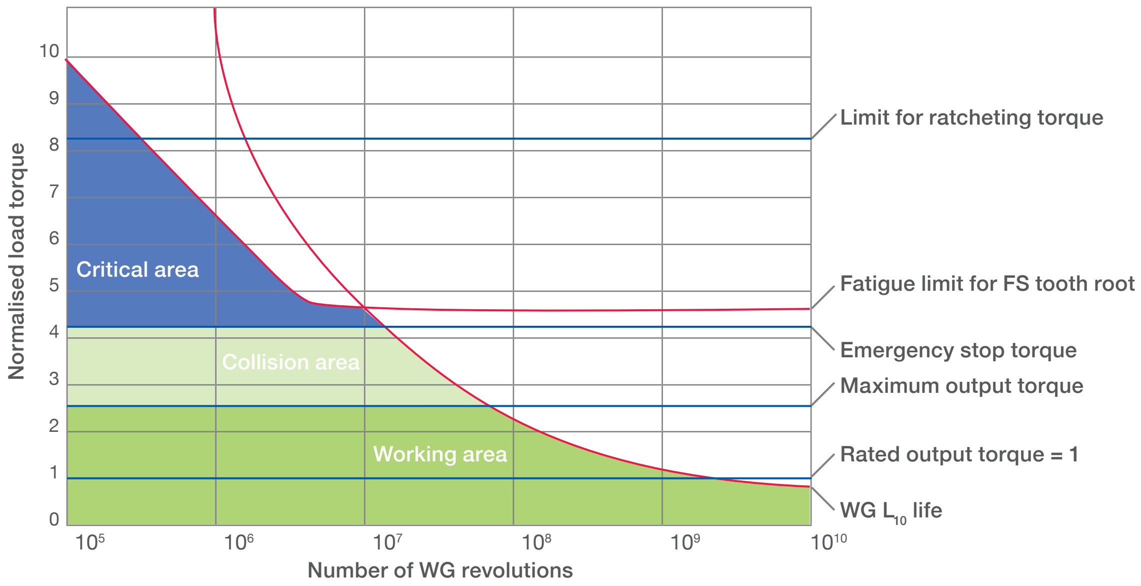
DEDOIDAL

When installing the strain wave gear, make sure that the flex spline is positioned in the centre of the circular spline. It can happen that the flex spline may skip a tooth on one side. This phenomenon is called dedoidal.



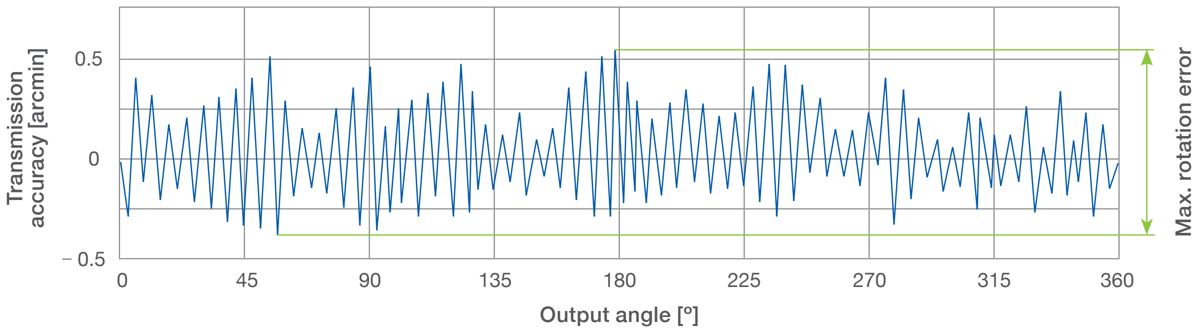
SERVICE LIFE

The relationship between load and service life differs for each component of the strain wave gear. Failures usually occur only at the flex spline or at the wave generator bearing. The flex spline can generally withstand higher loads than the wave generator. The wave generator limits in most load cases the service life. The service life of the WG bearing can be extended by cleaning and changing the grease.



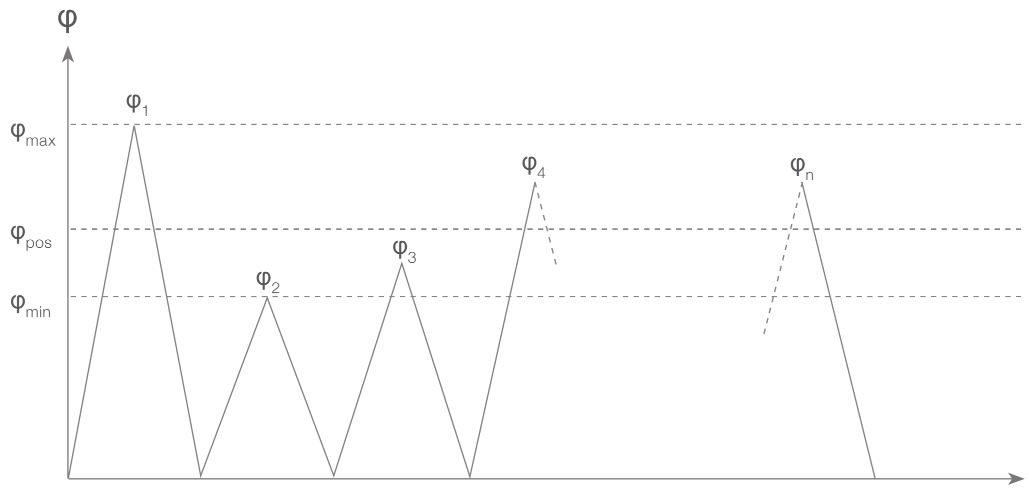
TRANSMISSION ACCURACY

The transmission accuracy describes the rotational translation error between measured input position and measured output position of the gear. It is measured for one rotational direction and one total gear output revolution. The result is the maximum difference between variances.



REPEATABILITY

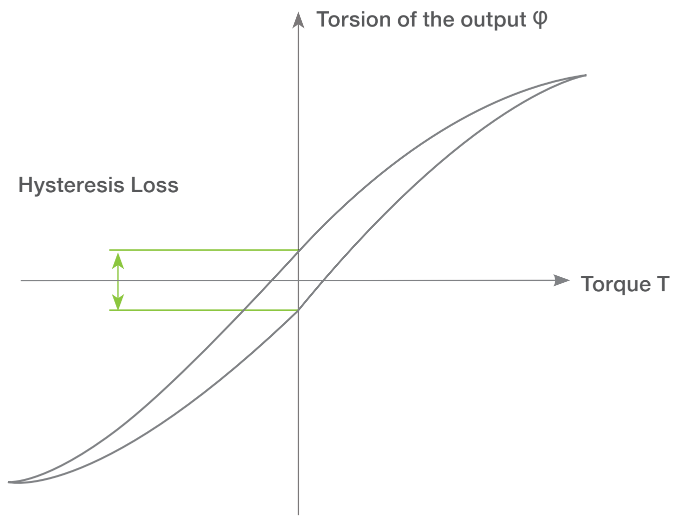
The repeatability is an important feature of strain wave gears. When determining the repeatability, a defined position φ_{pos} is repeatedly approached from the same direction. The deviation between the target value and reached actual position is measured.



$$Repeatability = \pm\frac{\varphi_{max} - \varphi_{min}}{2}$$

HYSTERESIS LOSS

The torsional torque diagram of a strain wave gear has the typical characteristic of a hysteresis curve. The hysteresis curve typically does not pass through the coordinate origin. The angle deviation at zero torque is called hysteresis loss.

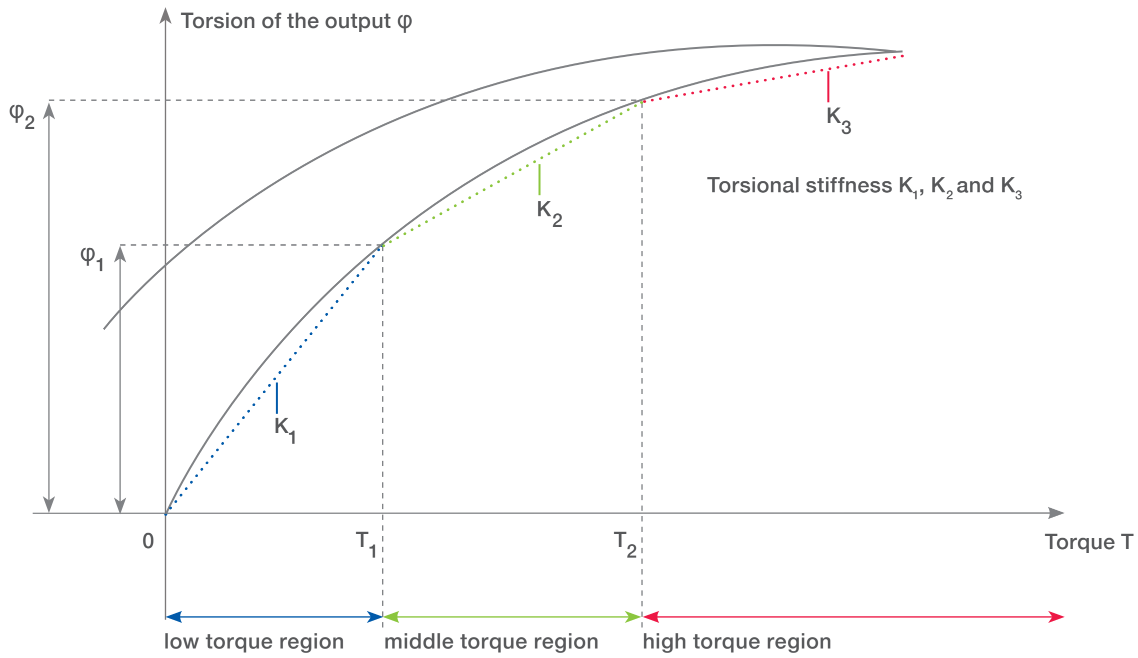


TORSIONAL STIFFNESS

The torsional stiffness describes the resistance of the gearbox to elastic deformation due to an applied torque.

The torsional angle at load condition at the gear output is measured while the input of the gear is blocked. The torsional stiffness is the quotient of applied torque and measured torsional angle. Since the torsional stiffness is not linear over the entire torque range, the transmission function $\varphi = f(T)$ is divided into three load ranges.

The values for the given torsional stiffness are average values that have been determined during numerous tests.



8. COPYRIGHT AND DISCLAIMER

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DISCLAIMER

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