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VOITH

High-performance universal joint shafts
Products, engineering, service

Universal joint shafts and hirth couplings

At Voith, we are the experts when it comes to Cardan drive elements and radial tooth couplings. Voith sets standards in the energy, oil & gas, paper, raw materials and transportation & automotive markets. Founded in 1867, Voith employs more than 19000 people, generates Euro 4.3 billion in sales, operates in about 50 countries around the world and is today one of the largest family-owned companies in Europe.

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1 Voith high-performance universal joint shafts
What makes them unique?

Features	Advantages
Closed bearing eye	Heavy-duty cross-sections without joints or bolts Minimal notch stresses Enclosed seal surfaces
Drop-forged journal crosses	Best possible torque capacity
FEM-optimized geometry	Optimal design for force flow Minimal notch stresses
High-strength tempered and case-hardened steels	Capability to withstand high static and dynamic loads
Load-optimized welded joints	Optimal design for force flow
Length compensation with SAE profile (straight flank profile) for larger series	Lower normal forces and thus lower displacement forces Low surface pressure High wear resistance
Patented balancing procedure	Dynamic balancing in two planes Balancing mass where unbalanced forces act
Engineering and product from a single source	One contact person when designing the driveline
Certification and classification for rail vehicles, ships, boats and for potentially explosive atmospheres (ATEX, etc.)	Officially approved product
Made in Germany	Seal of approval for quality, efficiency and precision
Voith Engineered Reliability	Competent and trustworthy partner

3

4

1 Assembly hall for Voith universal joint shafts

2 Welding robot

3 Balancing machine

4 Shipping

Benefits

+ Increased productivity
+ Long service life

+ Ease of movement
+ Long service life

+ Extremely smooth operation

+ Time and cost savings
+ Single-source responsibility

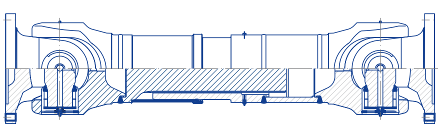
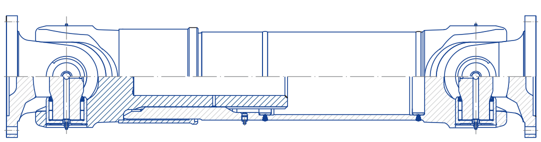
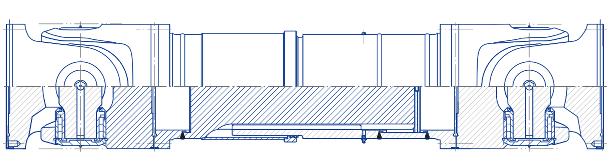
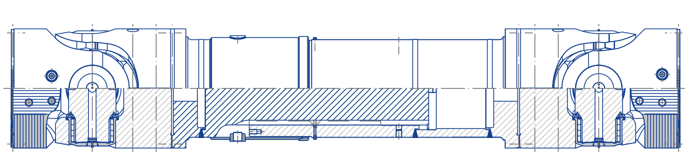
+ Time and cost savings

+ Reliability

+ Innovative product and system solutions

2 Range

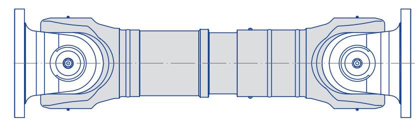
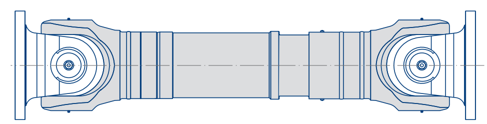
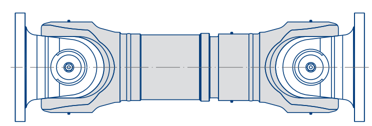
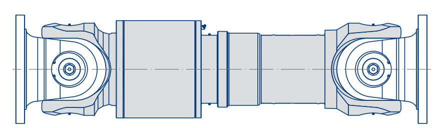
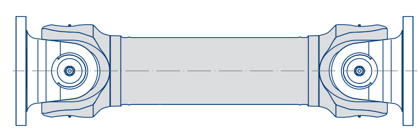
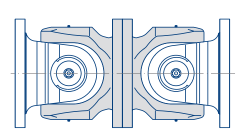
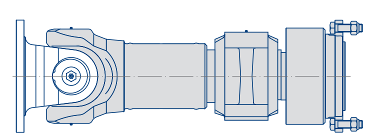
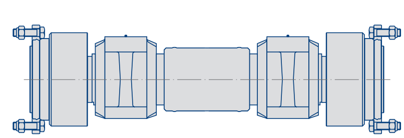
Voith high-performance universal joint shafts offer the ideal combination of torque capacity, torsion and bending rigidity. We supply everything from standard universal joint shafts to customer-specific adaptations and custom designs. And our wide range of services includes technical consultation, simulation of torsional vibrations and measurement of operating parameters.

Series		Torque range M_z [kNm]	Flange diameter a [mm]
S		0.25 to 35	58 to 225
R		32 to 1 000	225 to 550
CH		260 to 19 440	350 to 1 460
E		1 600 to 14 000	590 to 1 220

Features	Applications
• Basic version of Voith universal joint shafts • Non-split bearing eyes thanks to single-piece forged flange yoke • Length compensation with involute profile	• Paper machinery • Pumps • General mechanical engineering • Ships and boats • Rail vehicles • Test rigs • Construction machinery and cranes
• High torque capacity • Optimized bearing life • Flange in friction and positive locking design (see page 9) • Length compensation with involute profile up to size 315; SAE profile starting from size 350 (straight flank profile, see page 34); optional tripod (see page 36) • Optimized torsional rigidity and deflection resistance in a low-weight design • Particularly well-suited for use with high-speed drives • Optional: Low-maintenance length compensation using plastic-coated (Rilsan®) involute profile	• Rolling mill drives • Drives in general mechanical engineering tasks • Paper machinery • Pumps • Ships and boats • Rail vehicles
• Very high torque capacity • Optimized bearing life • One-piece flange yokes (integrated) • Flange yokes (neck / neckless) • Flange with Hirth coupling to transmit maximum torque • Length compensation with SAE profile (straight flank profile, see page 34)	• Rolling mill drives • Construction of heavy machinery • Paper machinery
• Maximum torque capacity • Optimized bearings for exceptionally demanding requirements • Patented 2-piece flange yoke (semi-integrated) • Flange yokes (neckless) • Flange with Hirth coupling to transmit maximum torque • Length compensation with SAE profile (straight flank profile, see page 34)	• Heavy-duty rolling mill drives

3 Designs

3.1 Center sections

Type	Description	
...T	Universal joint shaft with standard length compensation	
...TL	Universal joint shaft with extended length compensation	
...TK	Universal joint shaft with short length compensation	
...TR	Universal joint shaft with tripod length compensation	
...F	Universal joint shaft without length compensation (fixed-length shaft)	
...GK	Joint coupling: short, separable universal joint shaft without length compensation	
...FZ	Intermediate shaft with a single joint and bearing	
...Z	Intermediate shaft with double bearing	

3.2 Flanges

Type and description

Type S
Friction flange, torque transmission by a friction locking connection

Type k
Flange with split sleeves for torque transmission (DIN 15451)

Type Q
Flange with face key for torque transmission

Type H
Flange with Hirth coupling for torque transmission

3.3 Type designations

Example	R	T	250.8	S 285 / Q 250	R	2 560

Series
S, R, CH, E

Center-section design
T, TL, TK1, TK2, TK3, TK4, TR, F, GK, FZ, Z

Size

Flange design and size
input side / output side (see Section 7.1, page 32)
S …, K …, Q …, H …

Profile design
S: Steel on steel (standard)
R: Rilsan® coating on steel
P: PTFE coating on steel
–: for types TR, F, GK, FZ, Z

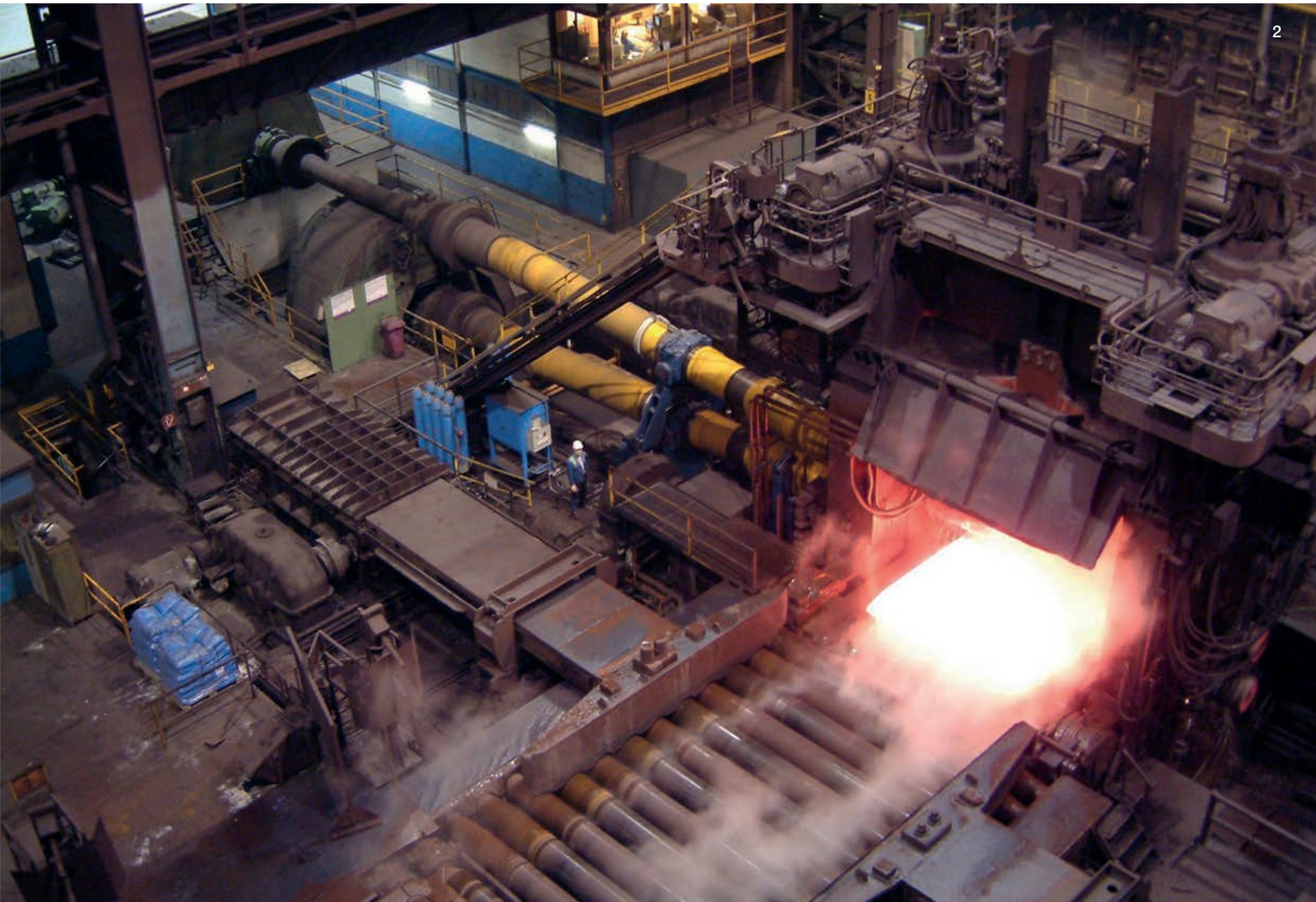
Length l, l_z or l_{fix} in mm

4 Applications

Rolling mills

1 Edging mill stand

2 Horizontal rolling stand

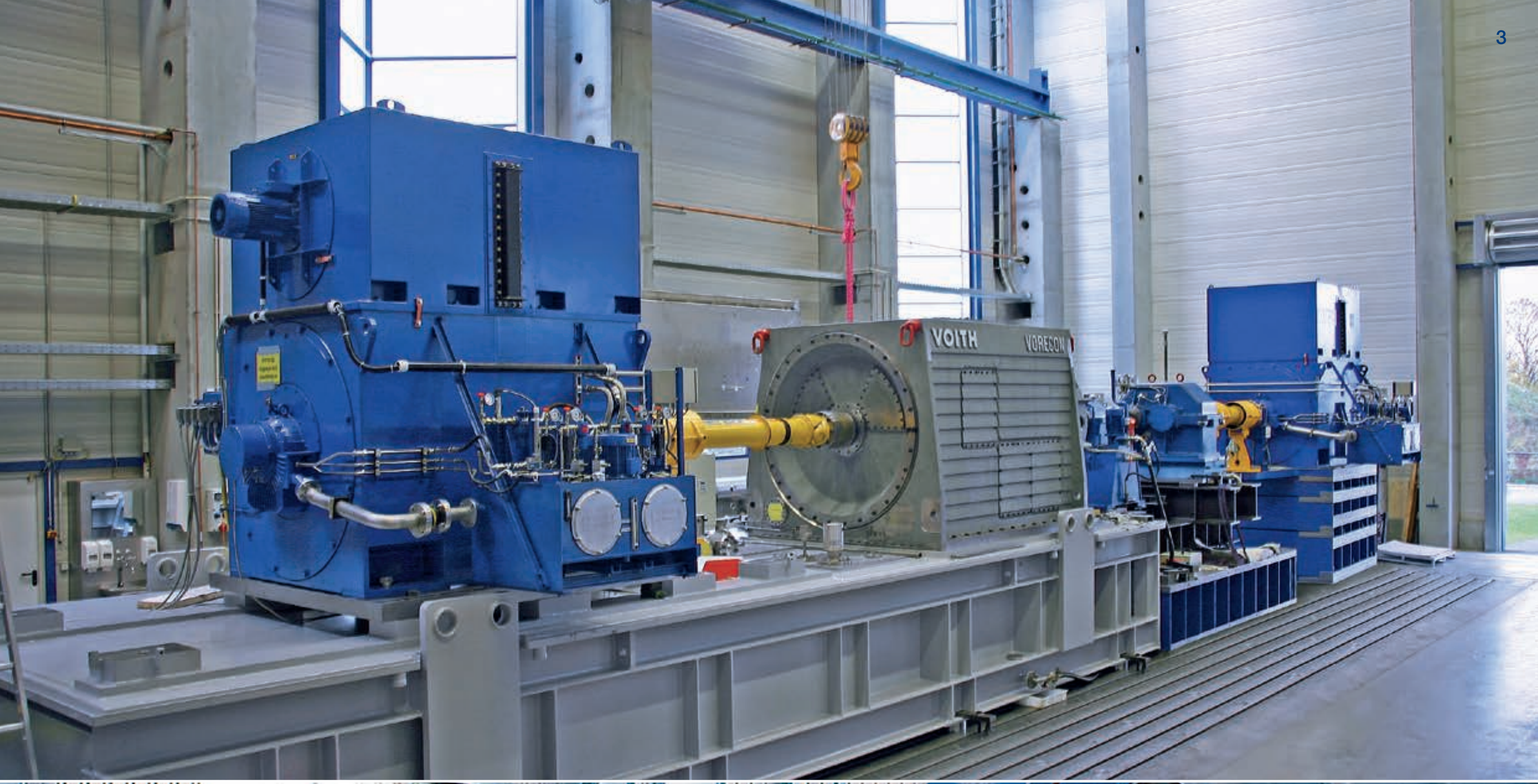


1 Rail vehicle drives

2 Paper machines

3 Test rigs

4 Special drives (mine hoist)



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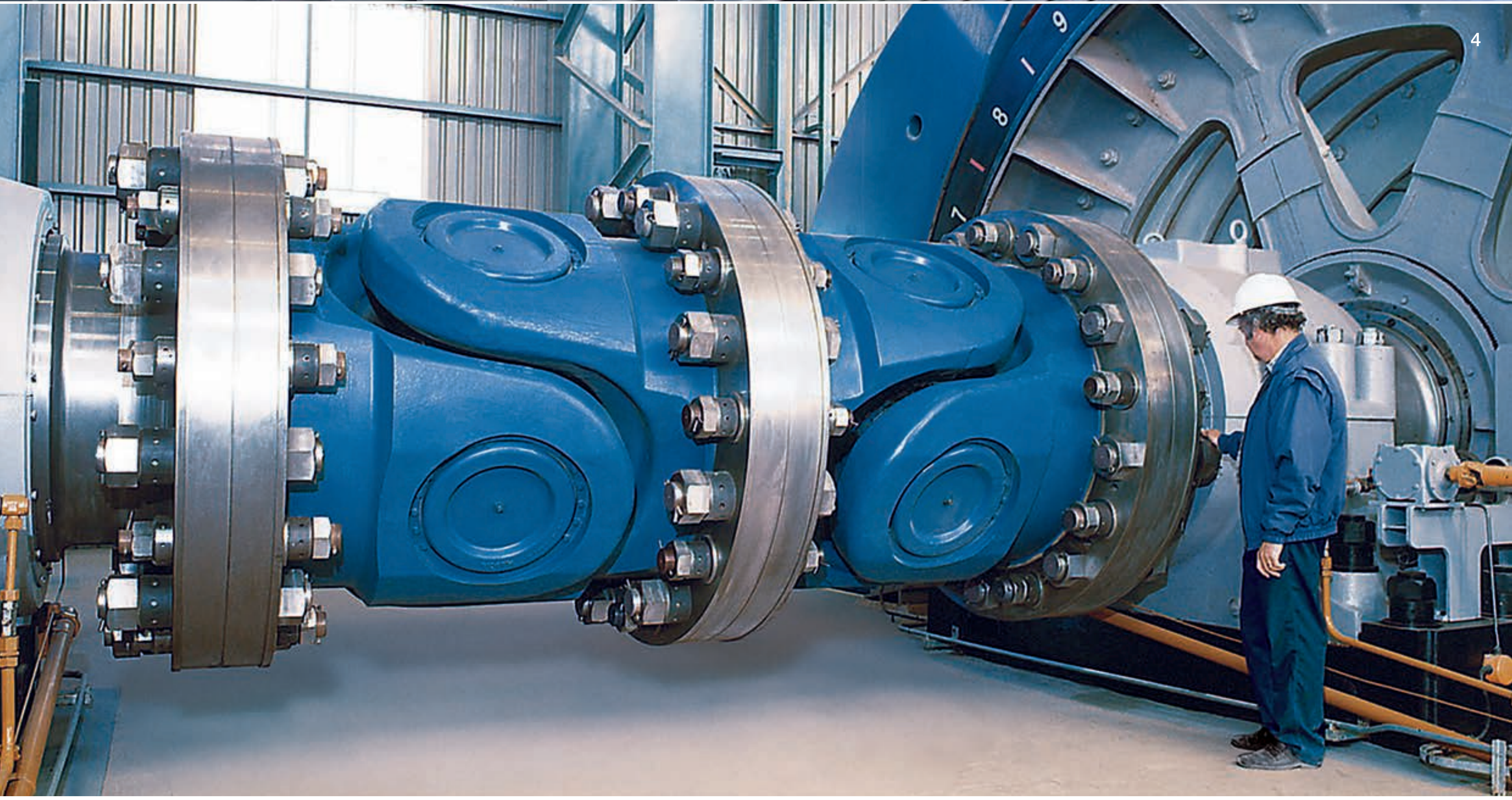
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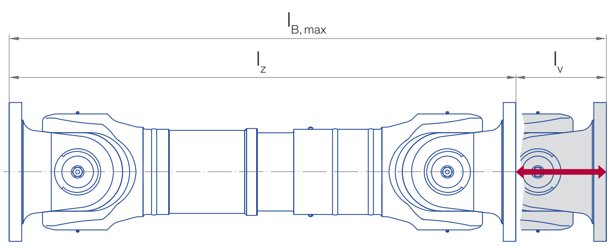
5 Definitions and abbreviations

5.1 Lengths

Universal joint shaft with length compensation



l_B: Operating length
(Please indicate with order.)

l_z: Shortest length of the universal joint shaft
(fully collapsed)

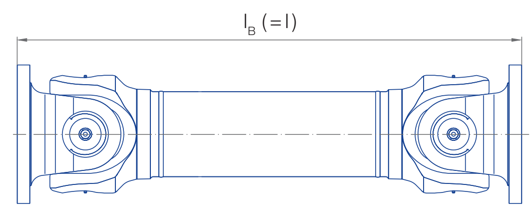
l_v: Available length compensation

The distance between the driving and the driven machines, together with any length changes during operation, determines the operating length:

Optimal operating length: $l_{B,opt} \approx l_z + \frac{l_v}{3}$

Maximum permissible operating length: $l_{B,max} = l_z + l_v$

Universal joint shaft without length compensation

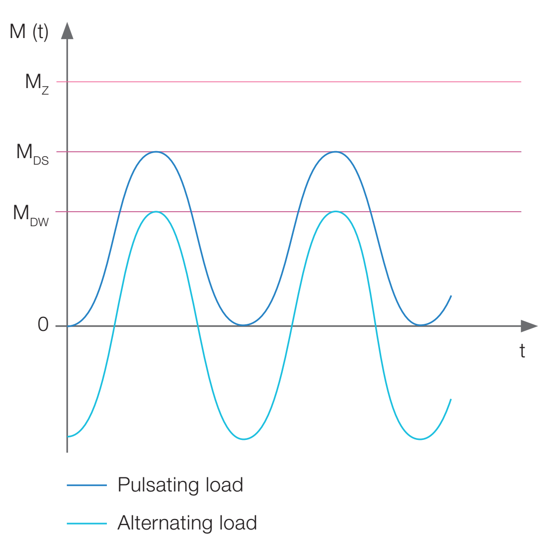


l_B: Operating length, corresponds to the universal joint shaft length l
(Please indicate with order.)

5.2 Torques

Components	Designation	Explanation
Components	**M_{DW}**	Reversing fatigue torque rating. The shaft will have an infinite fatigue life up to this torque level.
	M_{DS}	Pulsating one-way fatigue torque rating. The shaft will have an infinite fatigue life up to this torque level. Where: $M_{DS} \approx 1.5 \cdot M_{DW}$
	M_K	Maximum permissible torque. If this level is exceeded, plastic deformation may occur. Values available on request.
Bearing	**M_Z**	Permissible torque for rarely occurring peak loads. Bearing races may suffer plastic deformation at torque levels in excess of M_Z. This can lead to a reduced bearing life.
	CR	Load rating for bearings - when used with operating values, enables calculation of theoretical bearing life L_h (see Section 8.2.1, page 52).
Flange connections		Custom designed.

Torque definitions



Note

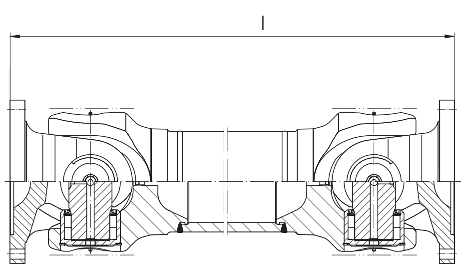
M_{DW}, M_{DS} and M_Z are load limits for the universal joint shaft. For torque values close to the load limit, the transmission capacity of the flange connection must be checked, especially in cases where friction lock is employed.

6 Technical Data

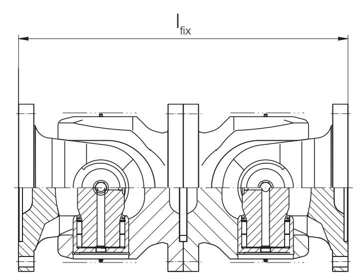
6.1 S Series

The S Series is the basic version of universal joint shaft and is designed for mid-range drives. The connection flanges are designed as friction flanges.

SF



SGK



	General specifications														ST[1]		
Size	M_z [kNm]	M_{DW} [kNm]	CR [kNm]	β_{max} [°]	a	k	b ±0.1	c H7	h B12	l_m	r	t	z	g	LA	l_v	$l_{z\,min}$
058.1	0.25	0.08	0.09	30	58	52	47	30	5	30	28 x 1.5	1.5	4	3.5	A, B	25	240
065.1	0.52	0.16	0.16	30	65	60	52	35	6	32	32 x 1.5	1.7	4	4	A, B	30	260
075.1	1.2	0.37	0.23	30	75	70	62	42	6	36	40 x 2	2.2	6	5.5	A, B	35	300
090.2	2.2	0.68	0.44	20	90	86	74.5	47	8	42	50 x 2	2.5	4	6	A, B, C	40	350
100.2	3.0	0.92	0.62	20	100	98	84	57	8	46	50 x 3	2.5	6	7	A, B, C	40	375
120.2	4.4	1.3	0.88	20	120	115	101.5	75	10	60	60 x 4	2.5	8	8	A, B, C	60	475
120.5	5.4	1.6	1.4	20	120	125	101.5	75	10	60	70 x 4	2.5	8	9	A, B, C	60	495
150.2	7.1	2.2	2.0	20	150	138	130	90	12	65	80 x 4	3	8	10	C	110	550
150.3	11	3.3	2.6	35	150	150	130	90	12	90	90 x 4	3	8	12	C	110	745
150.5	13	4.3	3.3	30	150	158	130	90	12	86	100 x 5	3	8	12	C	110	660
180.5	22	6.7	4.6	30	180	178	155.5	110	14	96	110 x 6	3.6	8	14	C	110	740
225.7	35	11	6.9	30	225	204	196	140	16	110	120 x 6	5	8	15	C	140	830

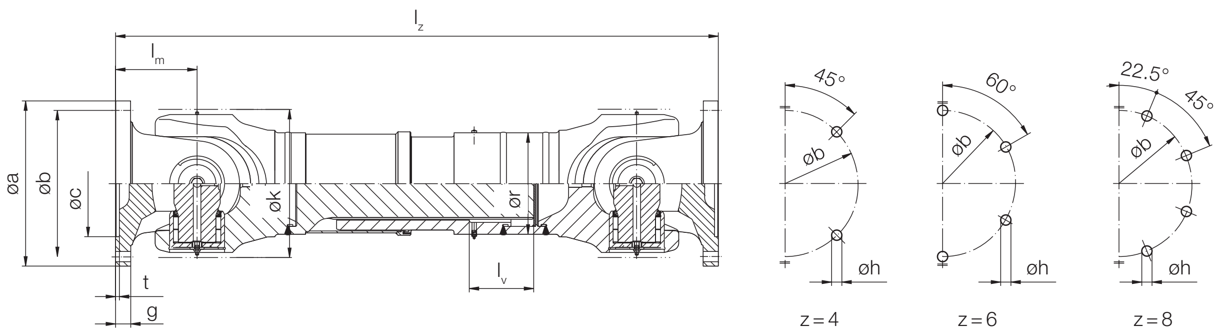
Dimensions in mm.

[1] Longer l_v available on request.

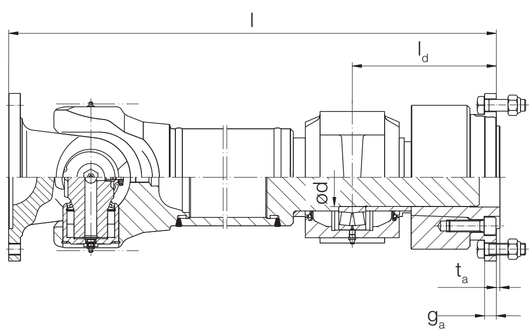
LA: Length compensation

A: Steel on steel, no profile protection
B: Steel on steel, with profile protection
C: Rilsan® coating on steel with profile protection
D: PTFE coating on steel, with profile protection

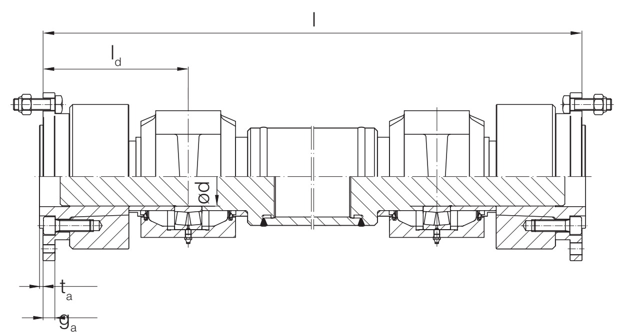
ST / STK



SFZ



SZ



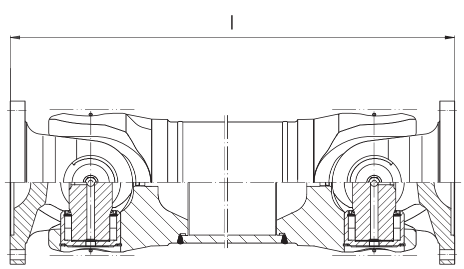
STK 1			STK 2			STK 3			STK 4[2]			SF	SGK	SFZ	SZ	SFZ, SZ			
LA	l_v	$l_{z\,fix}$	LA	l_v	$l_{z\,fix}$	LA	l_v	$l_{z\,fix}$	LA	l_v	$l_{z\,fix}$	l_{min}	l_{fix}	l_{min}	l_{min}	l_d	d	g_a	t_a
B	25	215	B	25	195	B	25	175	B	20	165	160	120	-	-	-	-	-	-
B	30	235	B	30	220	B	30	200	B	20	180	165	128	-	-	-	-	-	-
B	35	270	B	35	250	B	35	225	B	25	200	200	144	-	-	-	-	-	-
B, C	40	310	B, C	40	280	B, C	40	250	B, C	25	225	216	168	-	-	-	-	-	-
B, C	40	340	B, C	40	310	B, C	40	280	B, C	30	255	250	184	-	-	-	-	-	-
B, C	60	430	B, C	60	400	B, C	50	360	B, C	35	325	301	240	-	-	-	-	-	-
B, C	60	450	B, C	60	420	B, C	50	375	B, C	35	345	307	240	-	-	-	-	-	-
C	80	490	C	80	460	C	80	400	C	40	360	345	260	-	-	-	-	-	-
C	110	680	C	110	640	C	80	585	C	40	545	455	360	-	-	-	-	-	-
C	110	600	C	80	555	C	45	495	D	40	400	430	344	-	-	-	-	-	-
C	110	650	C	60	600	C	45	560	C	60	500	465	384	-	-	-	-	-	-
C	110	720	C	80	650	C	55	600	D	40	550	520	440	533	586	171	80	25	4

[2] Shorter l_z available on request.

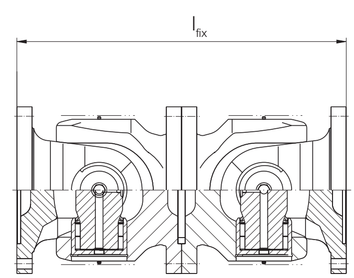
6.2 R Series

R Series universal joint shafts are the best solution for medium-sized torques and especially for high-speed drives. These universal joint shafts are of modular design and can be integrated into your drives with a great deal of flexibility. Flange connections are available in friction and positive locking designs.

RF



RGK



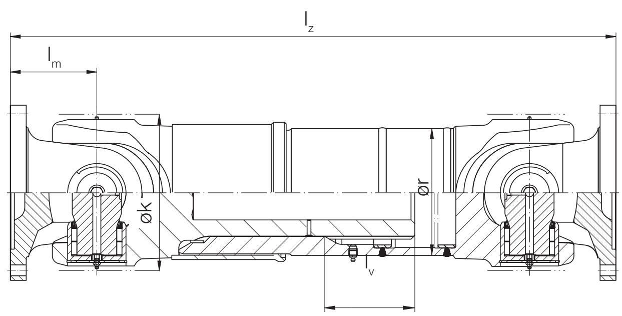
General specifications								RT			RTL[1]		
Size	M_z [kNm]	M_{DW} [kNm]	CR [kNm]	β_{max} [°]	k	l_m	r	LA	l_v	$l_{z\,min}$	LA	l_v	$l_{z\,min}$
198.8	32	16	8.6	25	198	110	160 x 10	C	110	780	-	-	-
208.8	55	20	11.4	15	208	120	170 x 12.5	B, C	140	815	B, C	370	1 110
250.8	80	35	19.1	15	250	140	200 x 12.5	B, C	140	895	B, C	370	1 215
285.8	115	50	26.4	15	285	160	220 x 12.5	B, C	140	1 060	B, C	370	1 350
315.8	170	71	36.6	15	315	180	240 x 16	B, C	140	1 120	B, C	370	1 450
350.8	225	100	48.3	15	350	194	292 x 22.2	B	140	1 240	B	400	1 640
390.8	325	160	67.1	15	390	215	323.9 x 25	B	170	1 410	B	400	1 730
440.8	500	250	100	15	440	260	368 x 28	B	190	1 625	B	400	1 945
490.8	730	345	130	15	490	270	406.4 x 32	B	220	1 780	B	400	2 090
550.8	1 000	500	185	15	550	305	470 x 32	B	220	1 950	B	400	2 250

Dimensions in mm.

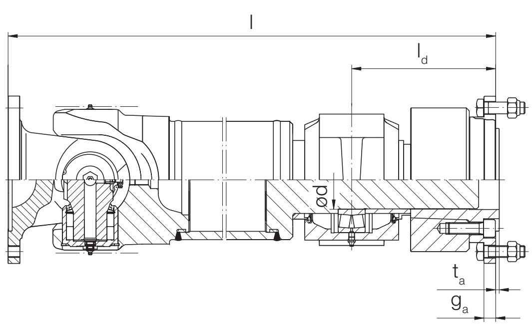
[1] Longer l_v available on request.

LA: Length compensation
B: Steel on steel, with profile protection
C: Rilsan® coating on steel with profile protection

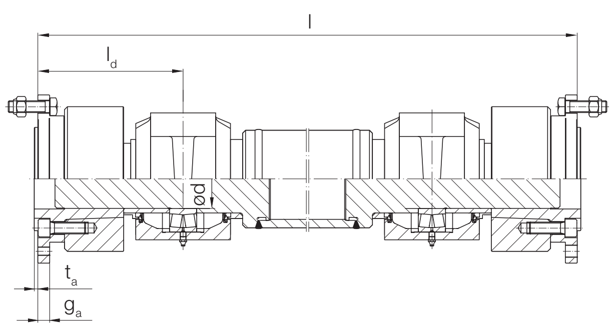
RT / RTL / RTK



RFZ



RZ

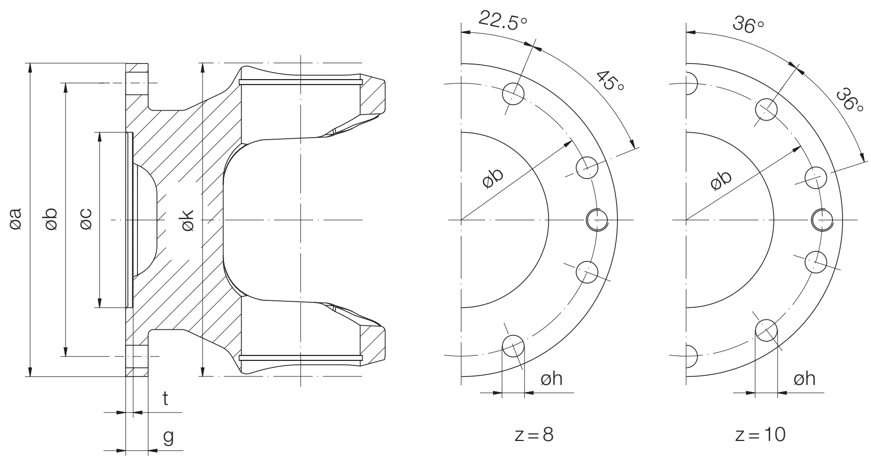


RTK 1			RTK 2[2]			RF	RGK	RFZ	RZ	RFZ, RZ			
LA	l_v	$l_{z\,fix}$	LA	l_v	$l_{z\,fix}$	l_{min}	l_{fix}	l_{min}	l_{min}	l_d	d	g_a	t_a
-	-	-	-	-	-	480	440	535	568	171	80	25	4
B, C	100	725	B, C	80	640	520	480	626	732	229	90	32	5
B, C	110	800	B, C	70	735	580	560	716	812	251	110	34	6
B, C	120	960	B, C	100	880	678	640	804	883	277	130	42	6
B, C	120	1 070	B, C	100	980	755	720	912	1 019	316.5	160	45	7
B	130	1 160	B	110	1 070	855	776	980	1 087	344.5	200	48	7
B	150	1 280	B	100	1 200	955	860	1 023	1 091	346.5	200	48	9
B	150	1 475	B	100	1 375	1 055	1 040	-	-	-	-	-	-
B	200	1 680	B	175	1 510	1 200	1 080	-	-	-	-	-	-
B	160	1 790	B	120	1 680	1 250	1 220	-	-	-	-	-	-

[2] Shorter l_z available on request.

Flange dimensions: Pages 20 to 23.

S flange: friction flange

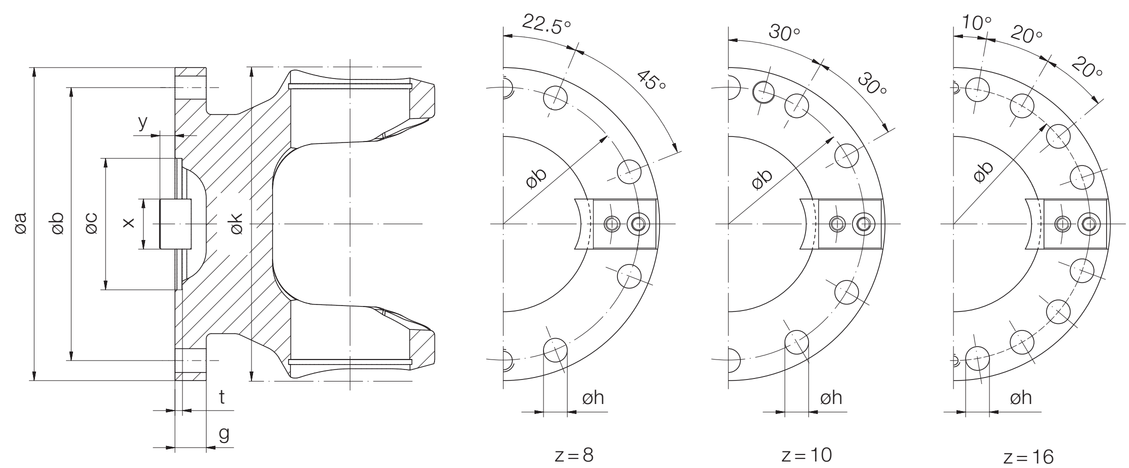


k	a	b ±0.2	c H7	g	h C12	t	z	Note
198	**225**	**196**	**140**	**15**	**16**	**5**	**8**	Standard
	250	218	140	18	18	6	8	
	285	245	175	20	20	7	8	
208	225	196	140	15	16	5	8	Torque M_{DW} = 18 kNm
	250	**218**	**140**	**18**	**18**	**6**	**8**	Standard
	285	245	175	20	20	7	8	
	315	280	175	22	22	7	8	
250	250	218	140	18	18	6	8	Torque M_{DW} = 25 kNm
	285	**245**	**175**	**20**	**20**	**7**	**8**	Standard
	315	280	175	22	22	7	8	
	350	310	220	25	22	8	10	
285	285	245	175	20	20	7	8	Torque M_{DW} = 36 kNm
	315	**280**	**175**	**22**	**22**	**7**	**8**	Standard
	350	310	220	25	22	8	10	
	390	345	250	32	24	8	10	
315	315	280	175	22	22	7	8	Torque M_{DW} = 52 kNm
	350	**310**	**220**	**25**	**22**	**8**	**10**	Standard
	390	345	250	32	24	8	10	
	435	385	280	40	27	10	10	
350	350	310	220	25	22	8	10	Torque M_{DW} = 75 kNm
	390	**345**	**250**	**32**	**24**	**8**	**10**	Standard
	435	385	280	40	27	10	10	
390	390	345	250	32	24	8	10	Torque M_{DW} = 100 kNm
	435	**385**	**280**	**40**	**27**	**10**	**10**	Standard

Dimensions in mm.

Additional flanges available on request.

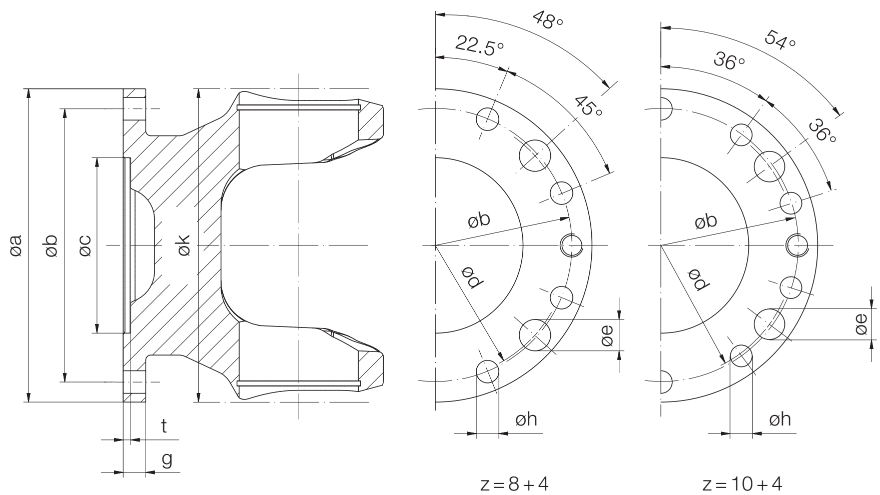
Q flange: flange with face key



k	a	b ±0.2	c H7	g	h	t	x h9	y	z	Note
	225	**196**	**105**	**20**	**17**	**5**	**32**	**9**	**8**	Standard
208	250	218	105	25	19	6	40	12.5	8	
	285	245	125	27	21	7	40	15	8	
	250	**218**	**105**	**25**	**19**	**6**	**40**	**12.5**	**8**	Standard
250	285	245	125	27	21	7	40	15	8	
	315	280	130	32	23	8	40	15	10	
	285	**245**	**125**	**27**	**21**	**7**	**40**	**15**	**8**	Standard
285	315	280	130	32	23	8	40	15	10	
	350	310	155	35	23	8	50	16	10	
	315	**280**	**130**	**32**	**23**	**8**	**40**	**15**	**10**	Standard
315	350	310	155	35	23	8	50	16	10	
	390	345	170	40	25	8	70	18	10	
	350	**310**	**155**	**35**	**23**	**8**	**50**	**16**	**10**	Standard
350	390	345	170	40	25	8	70	18	10	
	435	385	190	42	28	10	80	20	16	
	390	**345**	**170**	**40**	**25**	**8**	**70**	**18**	**10**	Standard
390	435	385	190	42	28	10	80	20	16	
	480	425	205	47	31	12	90	22.5	16	
	435	**385**	**190**	**42**	**28**	**10**	**80**	**20**	**16**	Standard
440	480	425	205	47	31	12	90	22.5	16	
	550	492	250	50	31	12	100	22.5	16	
490	**480**	**425**	**205**	**47**	**31**	**12**	**90**	**22.5**	**16**	Standard
	550	492	250	50	31	12	100	22.5	16	
550	**550**	**492**	**250**	**50**	**31**	**12**	**100**	**22.5**	**16**	Standard

Dimensions in mm. Additional flanges available on request.

K flange: flange with split sleeves

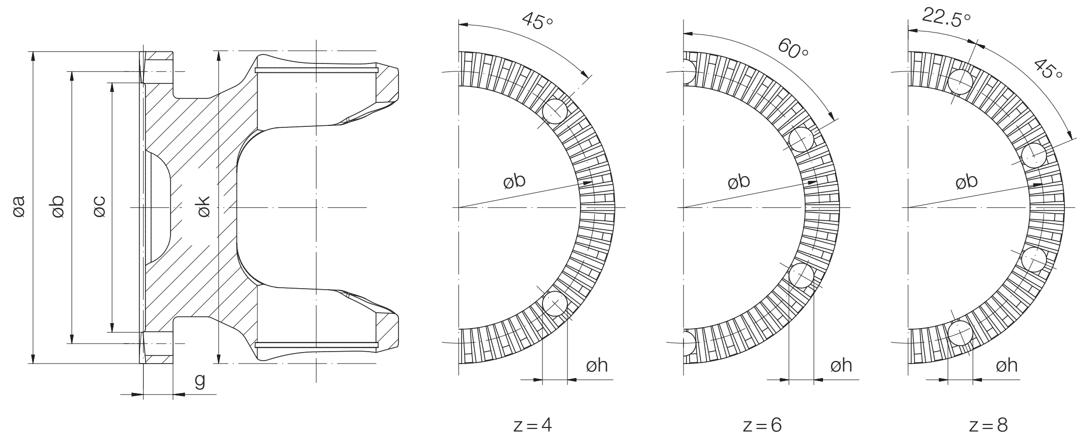


k	a	b ±0.2	c H7	g	h C12	t	z	d	e H12	Note
198	**225**	**196**	**140**	**15**	**16**	**5**	**8**	**192**	**21**	Standard
	250	218	140	18	18	6	8	214	25	
208	**250**	**218**	**140**	**18**	**18**	**6**	**8**	**214**	**25**	Standard
	285	245	175	20	20	7	8	240	28	
250	**285**	**245**	**175**	**20**	**20**	**7**	**8**	**240**	**28**	Standard
	315	280	175	22	22	7	8	270	30	
285	**315**	**280**	**175**	**22**	**22**	**7**	**8**	**270**	**30**	Standard
	350	310	220	25	22	8	10	300	32	
315	**350**	**310**	**220**	**25**	**22**	**8**	**10**	**300**	**32**	Standard
	390	345	250	32	24	8	10	340	32	
350	**390**	**345**	**250**	**32**	**24**	**8**	**10**	**340**	**32**	Standard
	435	385	280	40	27	10	10	378	35	
390	**435**	**385**	**280**	**40**	**27**	**10**	**10**	**378**	**35**	Standard

Dimensions in mm.

Additional flanges available on request.

H flange: flange with Hirth coupling



k	a	b ±0.2	c	g	h	u[1]	z	Note
208	**225**	**196**	**180**	**20**	**17**	**48**	**4**	Standard
	250	218	200	25	20	48	4	
250	**250**	**218**	**200**	**25**	**20**	**48**	**4**	Standard
	285	245	225	27	21	60	4	
285	**285**	**245**	**225**	**27**	**21**	**60**	**4**	Standard
	315	280	250	32	24	60	4	
315	**315**	**280**	**250**	**32**	**23**	**60**	**4**	Standard
	350	310	280	35	24	72	6	
350	**350**	**310**	**280**	**35**	**23**	**72**	**6**	Standard
	390	345	315	40	25	72	6	
390	**390**	**345**	**315**	**40**	**25**	**72**	**6**	Standard
	435	385	345	42	28	96	6	
440	**435**	**385**	**345**	**42**	**28**	**96**	**6**	Standard
	480	425	370	47	31	96	8	
490	**480**	**425**	**370**	**47**	**31**	**96**	**8**	Standard
	550	492	440	50	31	96	8	
550	**550**	**492**	**440**	**50**	**31**	**96**	**8**	Standard

Dimensions in mm.
Bore positioned on tooth gap.
[1] Number of teeth on Hirth coupling.

Additional flanges available on request.

6.3 CH Series

The CH Series is the standard for high and maximum torque applications. CH universal joint shafts are individually designed, that is, they are built to customer specifications. They precisely match the requirements of the drive. Flanges and flange yokes are available in a wide variety of designs and materials.

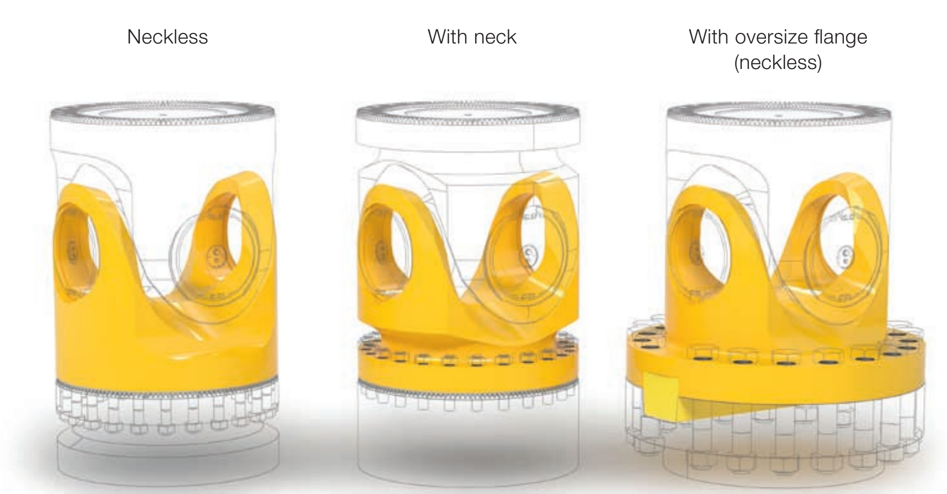
6.3.1 Flange yokes

We use our wide variety of one-piece flange yoke (integrated) designs to adapt the universal joint shaft to your drive. Your universal joint shaft is optimally dimensioned to achieve the best possible balance between performance, reliability, and cost.

Designs

Design models	Neckless	**Standard**
	With neck	M_{DW} approx. 5 % less than with standard design
	With oversize flange	M_{DW} same as for standard design
Materials	Forged steel	**Standard**
	Cast steel	M_{DW} approx. 20 % less than with standard design

Flange yoke



6.3.2 Joint and bearing concept

The concept underlying the CH Series bearings is based on decades of experience in designing high-performance universal joint shafts. During its development, engineers focused on low life cycle costs and a high level of operational reliability.

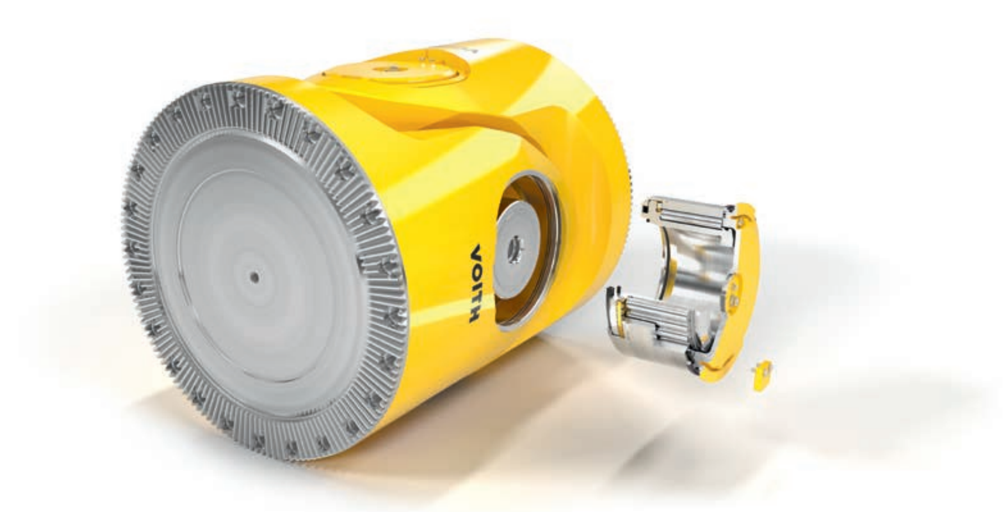
How we build it

- Radial and axial bearings are combined to a single unit (cassette bearings).
- The radial and axial bearings are low-friction roller bearings.
- Inner and outer rings are produced from special bearing steel.
- The geometry of the flange yokes has been optimized to achieve the lowest notch stresses possible.
- Journal crosses are subjected to a special surface layer treatment.
- The axial bearing and journal cross are flexibly connected to each other.

Your benefits

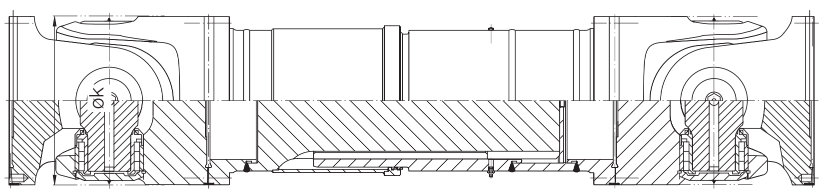
+ The roller bearings can be individually replaced. You save maintenance costs.
+ The bearings have a very long service life. The productivity of your system increases.
+ Journal crosses can be re-used when the bearing unit is replaced. This keeps your maintenance costs low.
+ The universal joint shaft has a high fatigue strength. This makes it safe for rolling high-strength steels and the high durability of the universal joint shaft has a positive effect on productivity.

Joint and bearing concept

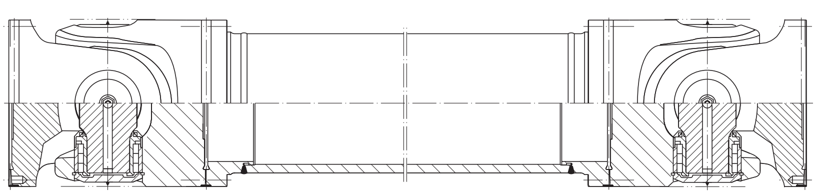


6.3.3 Technical data

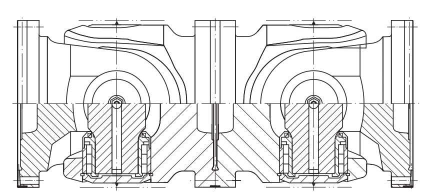
CHT



CHF



CHGK



Dimensions	350.8 to 550.8	590.40 to 1460.40
Torque M_{DW} (Standard design, forged steel)	140 to 560 kNm	890 to 13 500 kNm
Deflection angle β_{max}	10°	10° (greater deflection angles available on request)
Basic size steps for rotation diameter k	350, 390, 440, 490, 550 mm	590, 650, 710, 770, 830, 890, 950, 1 010, 1 090, 1 170, 1 250, 1 320, 1 400 mm (intermediate step sizes available on request)
Bearings	without inner ring	with inner ring
Designs	CHT, CHF, CHGK	CHT, CHF, CHGK

High-performance universal joint shafts in the assembly hall; CH Series

Assembly hall for Voith universal joint shafts

6.4 E Series

E Series universal joint shafts are intended for high-performance drives with maximum torques. The principal features of this series offer the highest possible universal joint torque capacity and increased bearing life.

6.4.1 Joints

E Series joints offer the highest possible torque capacity of all the joint series. A high-performance universal joint shaft can either be fitted on both sides with an E joint or can feature an E joint combined with a CH joint.

How we build it

- The journal crosses are more highly reinforced.
- The flange yoke is two-part (semi-integrated). It is equipped with aligned serrations on the axis of symmetry. The parting line is positioned in a cross-sectional area that is subject to relatively low stresses.
- The geometry of the flange yokes has been optimally designed for force flow.
- All the joint components have been optimized for high torque capacity.

Your benefits

+ **An E Series universal joint shaft transmits up to 20 % more torque than a CH Series shaft with the same joint diameter. The E Series is ideal for use in areas with limited installation space.**
+ **These universal joint shafts possess very high fatigue strength. This makes operational reliability especially high, for example, when rolling high-strength steels.**

High-performance universal joint shaft size comparison; CH joint (left) and E joint (right)

6.4.2 Bearing concept

The concept underlying E Series bearings is based on maximum use of installation space with the largest possible bearings and journal crosses.

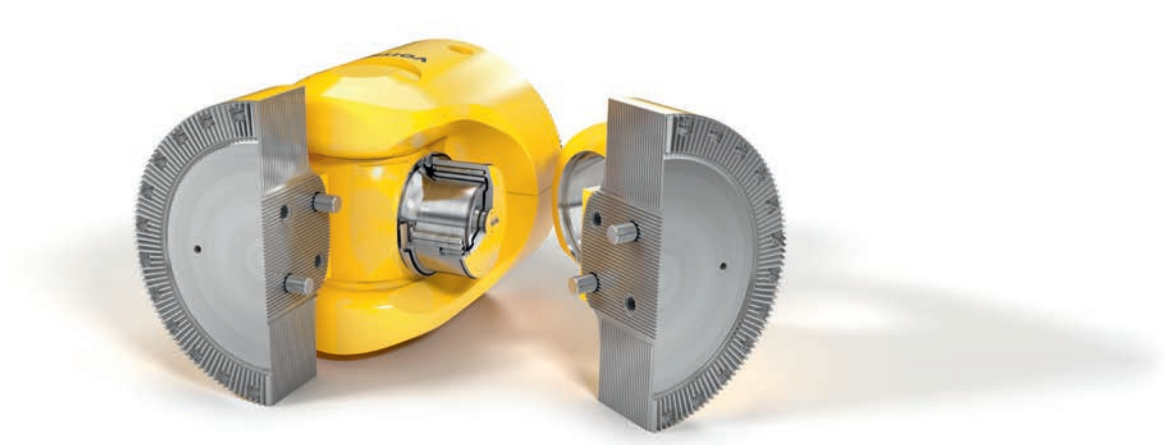
How we build it

- The bearings are low-friction roller bearings.
- Inner and outer rings of special bearing steel form the bearing races.
- The rolling elements are optimally embedded, with the best possible leverage ratios at the journal cross.
- The roller bearings, including the lubrication, have been optimized for long bearing service life.

Your benefits

+ **The bearing service life is 40 to 80 % longer than for CH Series universal joint shafts. A major feature of the E Series is its very long operating life. This reduces downtime and maximizes productivity.**
+ **The roller bearings can be individually replaced and the journal crosses can be re-used when the bearing unit is replaced. This means reduced maintenance costs for you.**

Joint and bearing concept



6.4.3 Technical data

Dimensions	580.30 to 1220.30
Torque M_{DW} (Standard design, forged steel)	1 010 to 9 380 kNm
Deflection angle β_{max}	5, 10, 15° (selectable)
Basic size steps for rotation diameter k	580, 640, 700, 760, 820, 880, 940, 1 000, 1 080, 1 160 mm (intermediate step sizes available on request)
Designs	ET, EF, EGK

High-performance universal joint shafts in the assembly hall; E joint (left)

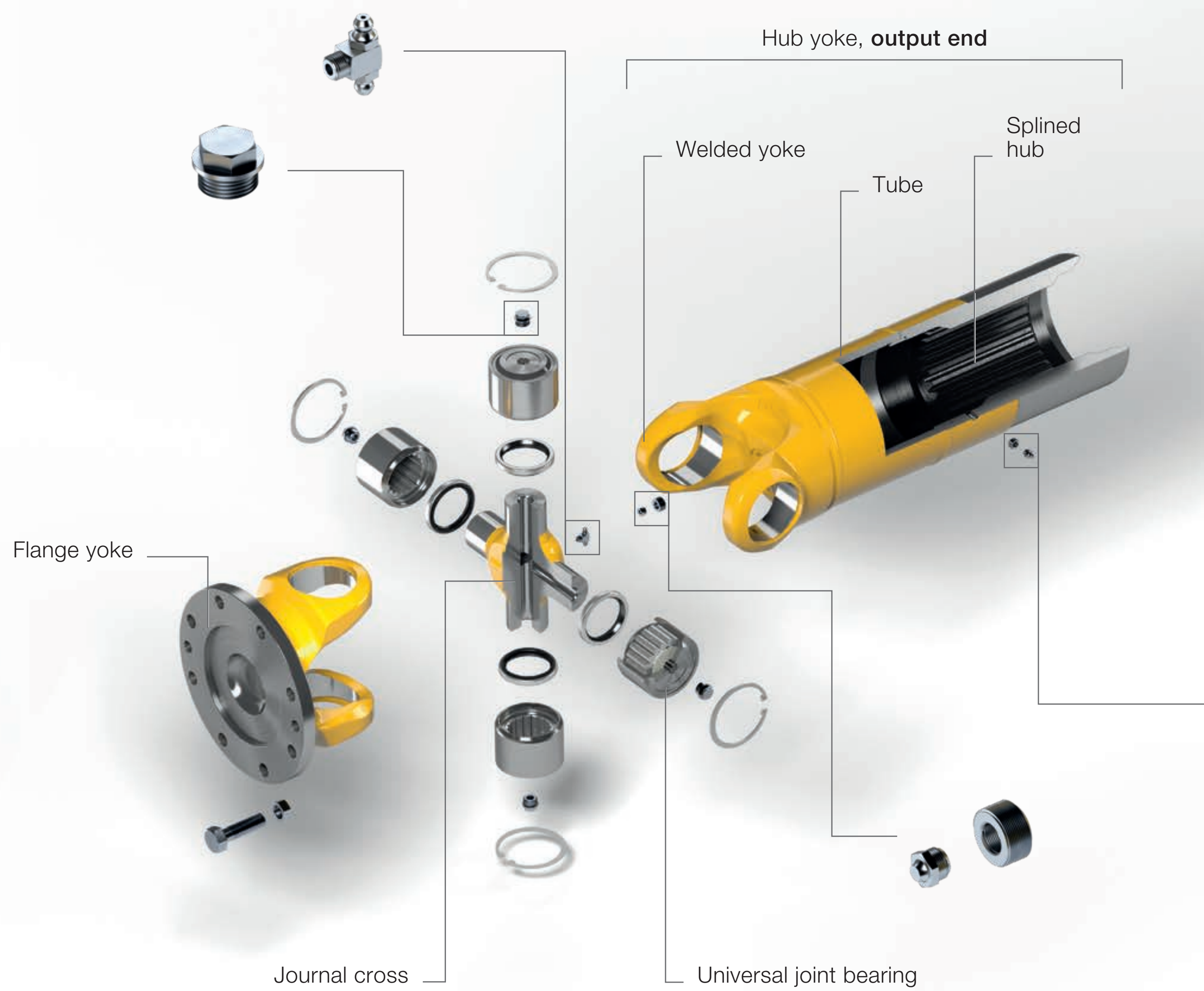
7 Engineering Basics

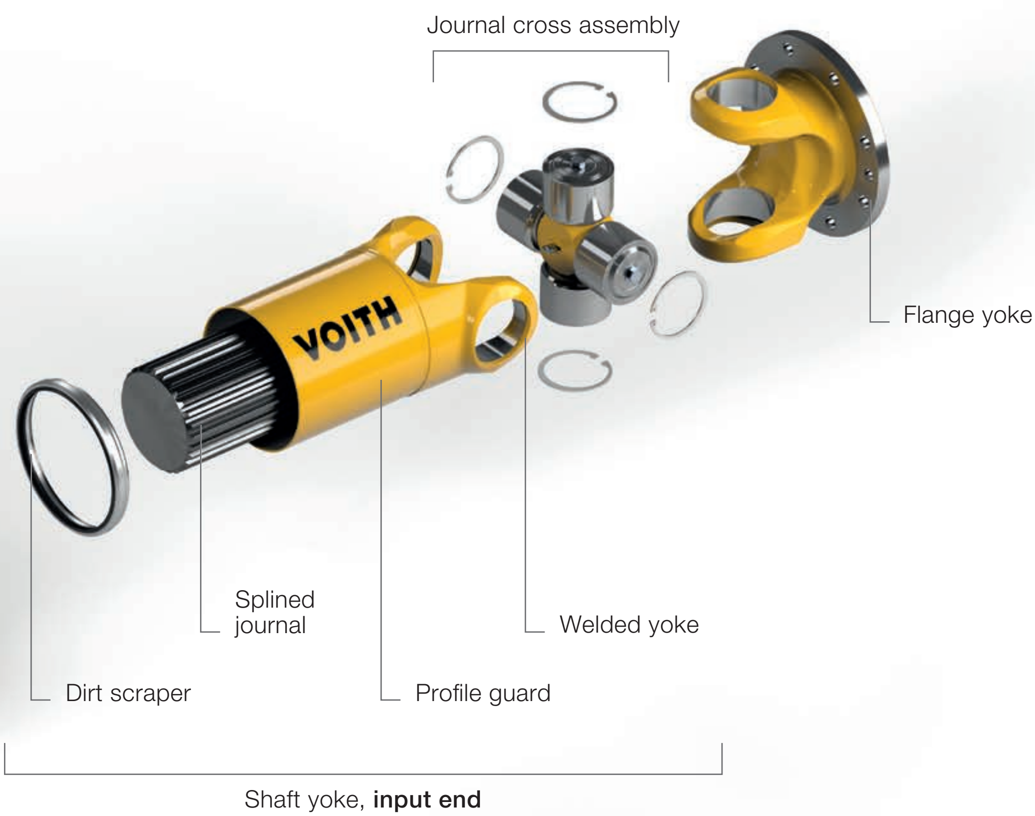
7.1 Major components of a Voith universal joint shaft

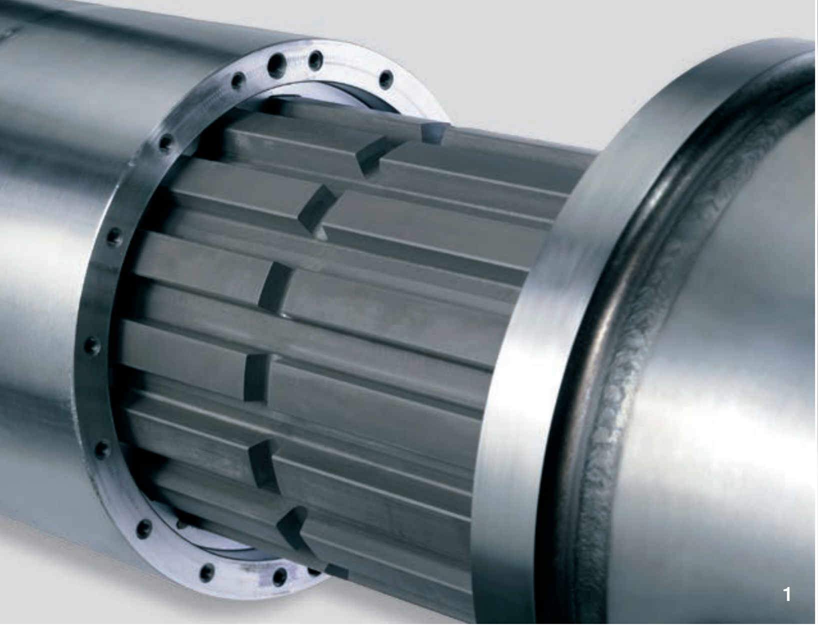
Design

Irrespective of the series, all versions and sizes of Voith universal joint shafts share many of the same attributes designed to ensure reliable operation:

- Yokes and flange yokes with optimized geometry
- Drop-forged journal crosses
- Low-maintenance roller bearings with maximum load carrying capacity
- Use of high-strength tempered and case-hardened steels
- Superior welded joints




Journal cross assembly
Flange yoke
Splined journal
Welded yoke
Dirt scraper
Profile guard
Shaft yoke, **input end**



1 SAE profile (straight flank profile)

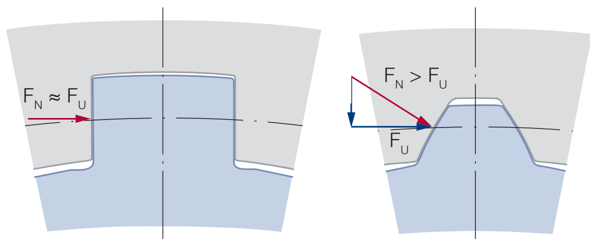
2 Involute profile

7.2 Length compensation with spline shaft profile

Length compensation is required in the universal joint shaft for many applications. In comparison with other drive elements, length compensation for universal joint shafts is achieved through the center section and offset is achieved through the joints.
Two types of length compensation are utilized in Voith universal joint shafts: the SAE profile (straight flank profile) and the involute profile. The universal joint shaft series and size determine the type of length compensation.

For loads placed on smaller universal joint shafts, the involute profile is a suitable solution with a good cost / benefit ratio. The SAE profile (straight flank profile) is a better solution for large high-performance universal joint shafts.

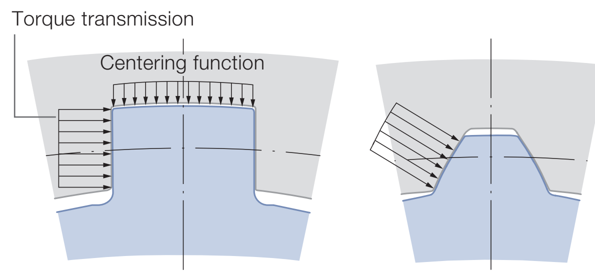
Force introduced during torque transmission



SAE profile
(straight flank profile)

Involute profile

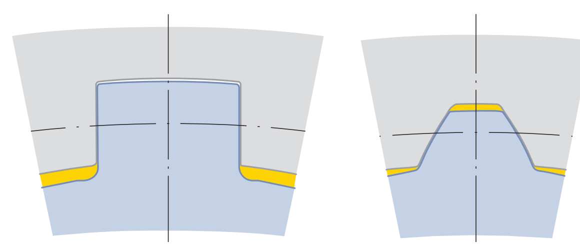
Torque transmission and centering



SAE profile
(straight flank profile)

Involute profile

Spline Lubrication



SAE profile
(straight flank profile)

Involute profile

Length compensation with SAE profile (straight flank profile)

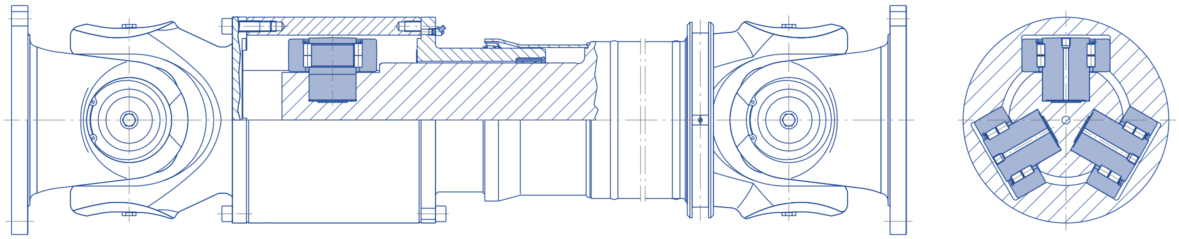
Features	Advantages	Benefits
Straight flank, diameter-centered profile	Separation of torque transmission and centering functions	**+ Long service life**
Force is applied orthogonally	Lower normal forces and thus lower displacement forces	**+ Ease of movement**
Large contact surfaces	Low surface pressure	**+ Long service life**
Favorable pairing of materials for hub and spline shaft Spline shaft nitrited as standard	High wear resistance	**+ Long service life**
Patented lubricating mechanism in the grease distribution groove for uniform distribution of grease over the entire diameter of the profile	Tooth shape incorporates lubricant res-ervoir for reliable supply of lubricant to sliding surfaces	**+ Extended maintenance intervals**

7.3 Length compensation with roller bearing – tripod universal joint shafts

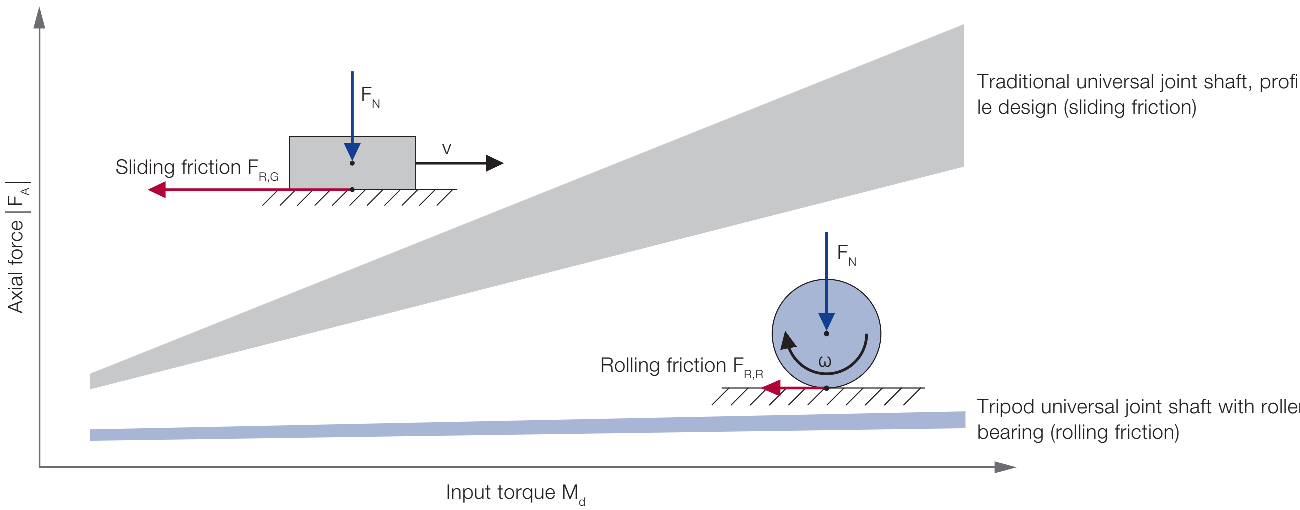
Tripod universal joint shafts consist of standard joints with a special center section. Roller bearings in the center section are used to drastically reduce axial displacement forces in length compensation. This keeps axial displacement forces very low, almost constant, across the entire torque range.

The center section consists of a guide shaft and a guide hub. Three bolts with roller bearings are located at one end of the guide shaft. The bolts are offset 120° from each other. The guide hub has three corresponding grooves to accept the roller bearings.
Universal joint shafts of this type are ideal for drives that are required to constantly compensate wide axial movements.

Basic design of the tripod universal joint shaft



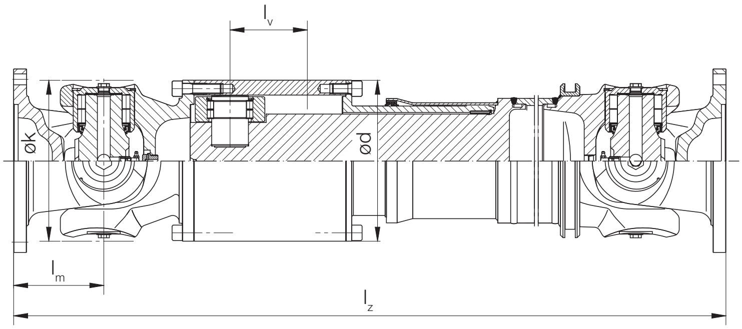
Comparison of axial displacement forces



Length compensation with roller bearings

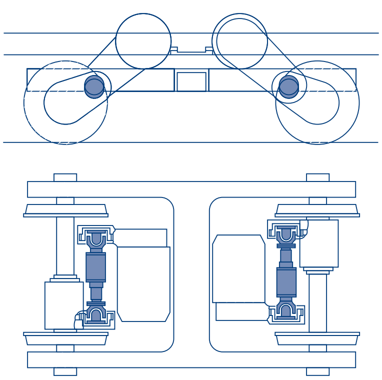
Features	Advantages	Benefits
Length compensation with roller bearings	Low and virtually constant axial displacement forces	**+ Lower costs for axial bearings and suspension systems for connected assemblies**
	Low-wear length compensation	**+ Low maintenance costs** **+ High availability**
Hardened groove sides in guide hub	Long service life	**+ High availability**
	Low wear	**+ Low maintenance costs**
	No change in specified clearance	**+ No vibrations**
Uniform circumferential forces on all roller bearings	Stable balancing over entire service life	**+ No costs for rebalancing**
Sealed guide hub	Secure roller bearing lubrication	**+ Low service costs**
Defined, wide-support centering in roller and slide bushing planes	Extremely smooth operation	**+ Low noise emissions**

RTR tripod

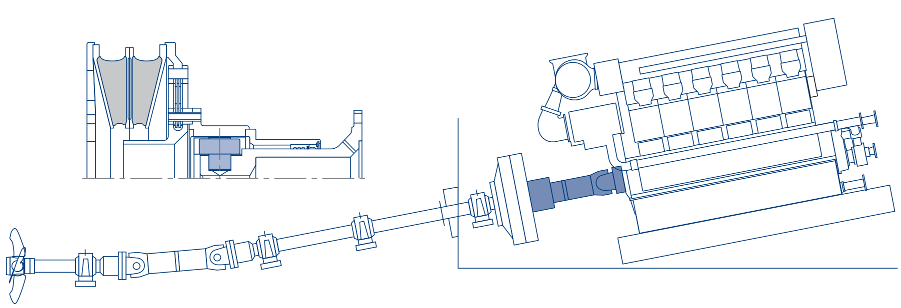


Application examples

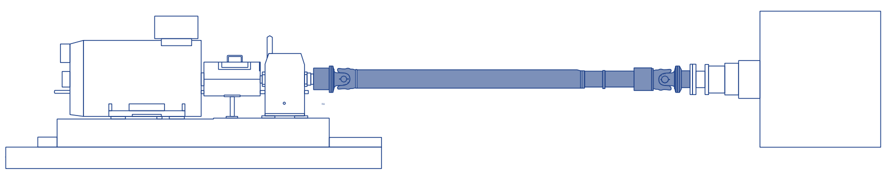
In rail vehicles



In ships and boats



In paper machines



Size	M_z [kNm]	M_{DW} [kNm]	$l_{z\,min}$	l_v	l_m	k	d
198.8	16	10	750	50	110	198	180
208.8	28	16	810	60	120	208	208
250.8	45	23	940	60	140	250	250
285.8	61	35	1 140	120	160	285	285
315.8	94	50	1 260	120	180	315	315
350.8	150	71	1 400	120	194	350	350
390.8	200	100	1 550	120	215	390	390

Dimensions in mm.
Flange dimensions: Pages 20 to 23.

Custom designs available on request.

Advantages and benefits

Tripod universal joint shafts transmit the torque from the drive motors to the drive wheels. The drive motors are located in the railcar body, the drive wheels in the spring-mounted bogie.

- **Small unsprung masses reduce the load on the bogie, drive, rails, and rail line**
- **Positive travel (unobstructed sinusoidal pattern) minimizes the wear between rail and wheel**
- **Good dynamic behavior increases safety and improves travel comfort**

Together with a highly flexible coupling, tripod universal joint shafts transmit the torque in the shaft line.

- **High degree of impact resistance**
- **Structure-borne noise is well insulated**
- **Improved travel comfort**

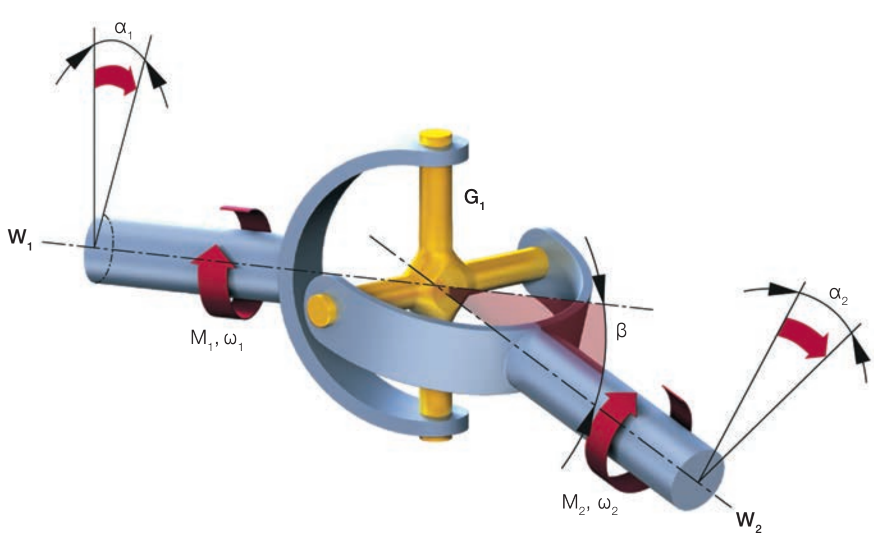
Tripod universal joint shafts in the drive of the Sirius Roll-up SensoRoll.

- **Smooth displacement of the SensoRoll in the direction of paper travel for every tambour**
- **Drum has a hard wrapped core and a larger outer wrap diameter**
- **Long uptime of the roller bearing length compensation**

7.4 Universal joint kinematics

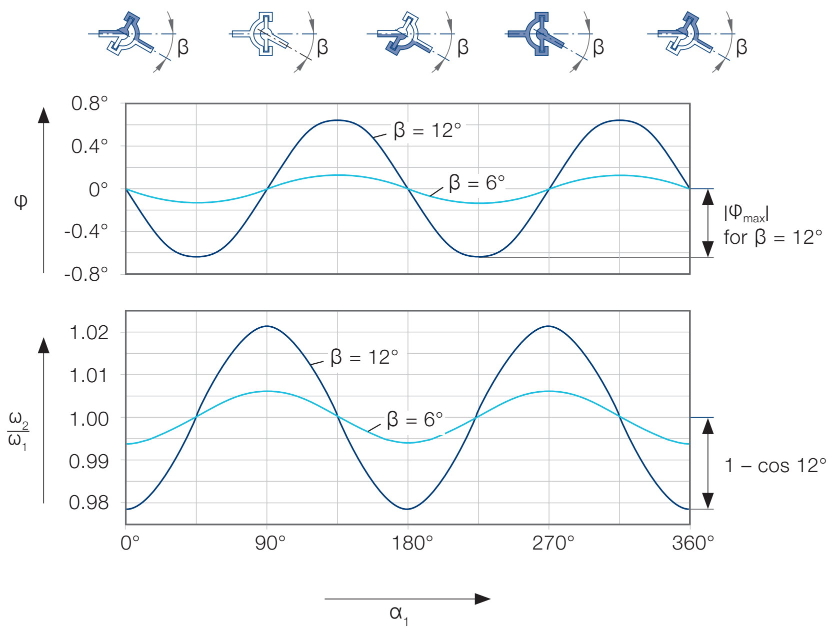
- When the shaft is being driven uniformly W_1 (ω_1 = const.), the output shaft W_2 rotates at an angular velocity that changes over time ($\omega_2 \neq$ const.).
- The angular velocity of the output shaft ω_2 and the differential angle $\varphi = (\alpha_1 - \alpha_2)$ vary in a sinusoidal manner and their magnitudes are a function of the deflection angle β.
- This characteristic of universal joints is called the gimbal error and must be taken into consideration when selecting a universal joint shaft.

Universal joint



G_1	Standard universal joint
W_1	Input shaft
W_2	Output shaft
α_1, α_2	Angle of rotation
β	Deflection angle
M_1, M_2	Torques
ω_1, ω_2	Angular velocities

Movement ratios



- With one rotation of the shaft W_1, the differential angle φ changes four times, as does the angular velocity ω_2.
- During the course of one rotation, the shaft W_2 twice passes through the points of maximum acceleration and deceleration.
- At larger deflection angles β and higher velocities, considerable forces of inertia can be generated.

The following equations apply:

$$\varphi = \alpha_1 - \alpha_2 \tag{1}$$

$$\frac{\tan \alpha_1}{\tan \alpha_2} = \cos \beta \tag{2}$$

$$\tan \varphi = \frac{\tan \alpha_1 \cdot (\cos \beta - 1)}{1 + \cos \beta \cdot \tan^2 \alpha_1} \tag{3}$$

This yields the angular velocity ratio between shaft sections W_1 and W_2:

$$\frac{\omega_2}{\omega_1} = \frac{\cos \beta}{1 - \sin^2 \beta \cdot \sin^2 \alpha_1} \tag{4}$$

with the maximums

$$\left.\frac{\omega_2}{\omega_1}\right|_{max} = \frac{1}{\cos \beta} \quad \text{at} \quad \alpha_1 = 90° \text{ or } \alpha_1 = 270° \tag{4a}$$

and the minimums

$$\left.\frac{\omega_2}{\omega_1}\right|_{min} = \cos \beta \quad \text{at} \quad \alpha_1 = 0° \text{ or } \alpha_1 = 180° \tag{4b}$$

As regards the torque ratio, the following equation applies:

$$\frac{M_2}{M_1} = \frac{\omega_1}{\omega_2} \tag{5}$$

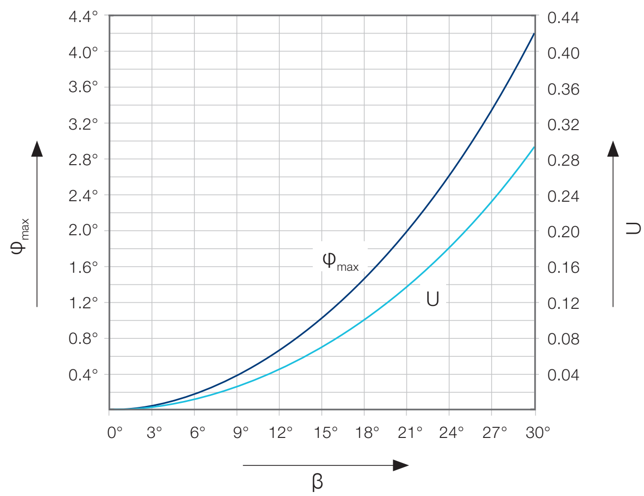
with the maximums

$$\left.\frac{M_2}{M_1}\right|_{max} = \frac{1}{\cos \beta} \quad \text{at} \quad \alpha_1 = 90° \text{ or } \alpha_1 = 270° \tag{5a}$$

and the minimums

$$\left.\frac{M_2}{M_1}\right|_{min} = \cos \beta \quad \text{at} \quad \alpha_1 = 0° \text{ or } \alpha_1 = 180° \tag{5b}$$

Variation factor, differential angle



One indicator of the variation is the variation factor U:

$$U = \left.\frac{\omega_2}{\omega_1}\right|_{max} - \left.\frac{\omega_2}{\omega_1}\right|_{min} = \frac{1}{\cos\beta} - \cos\beta = \tan\beta \cdot \sin\beta$$

(6)

Finally, as regards the maximum differential angle φ_{max}, the following equation applies:

$$\tan\varphi_{max} = \pm\frac{1 - \cos\beta}{2 \cdot \sqrt{\cos\beta}}$$

(7)

Conclusions

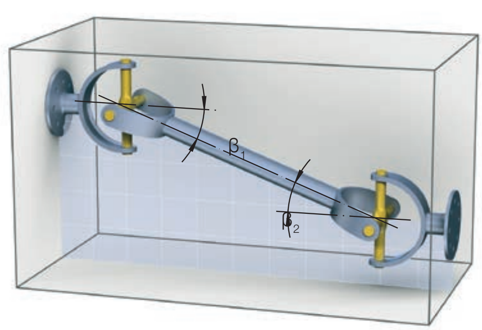
A single universal joint should only be used if the following conditions are met:

- **The variation in the rotational speed of the output shaft is of secondary importance.**
- **The deflection angle is very small ($\beta < 1°$).**
- **The forces transmitted are low.**

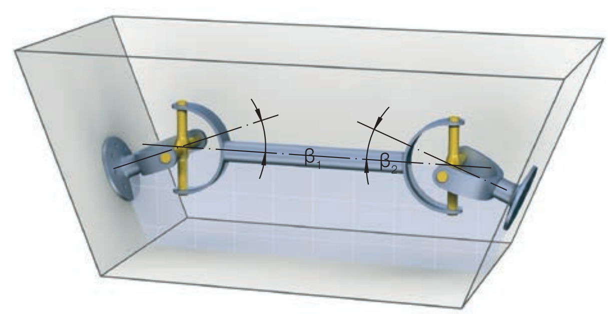
7.5 Double universal joint

Section 7.4 shows that the output shaft W_2 always rotates at the varying angular velocity ω_2 when connected via a single universal joint at a given deflection angle β because of the influence of the universal joint.
If, however, two universal joints G_1 and G_2 are connected together correctly in the form of a universal joint shaft in a Z or W arrangement, the variations in the speeds of the input and output shaft cancel each other completely.

Universal joint shaft in Z arrangement, input and output shafts are located parallel to one another in one plane



Universal joint shaft in W arrangement, input and output shafts intersect one another in one plane

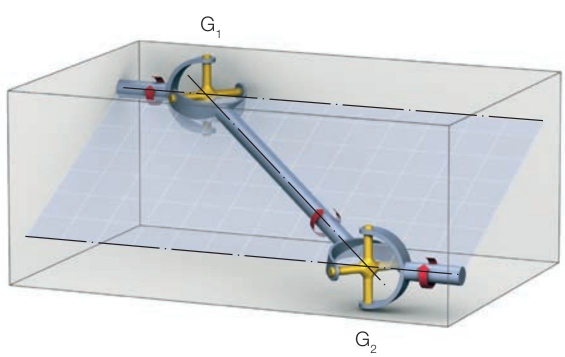


Conditions for synchronous rotation of input and output shafts:

The three conditions A, B, and C ensure that joint G_2 operates with a phase shift of 90° and fully compensates for the gimbal error of joint G_1. This universal joint shaft arrangement is considered the ideal universal joint shaft arrangement, providing complete motion compensation.

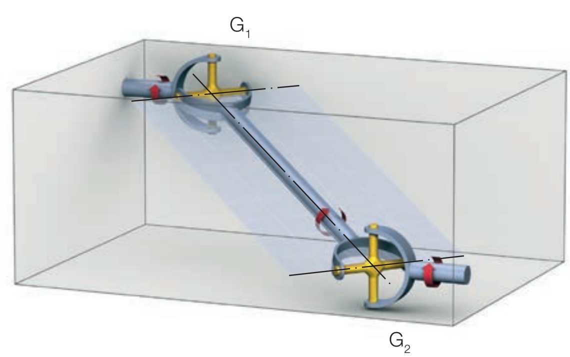
It is precisely what designers should be trying to achieve in practice. If any one of the three conditions is not met, then the universal joint shaft is no longer operating at constant input and output speeds, i.e., it is no longer homokinetic. When this happens, talk with your Voith representative.

All of the components of the universal joint shaft are located in one plane



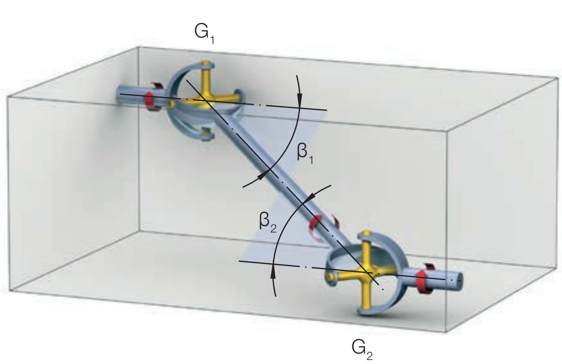
A

Both yokes of the center section of the shaft are located in one plane



B

The deflection angles β_1 and β_2 of the two joints are identical



C

7.6 Bearing forces on input and output shafts

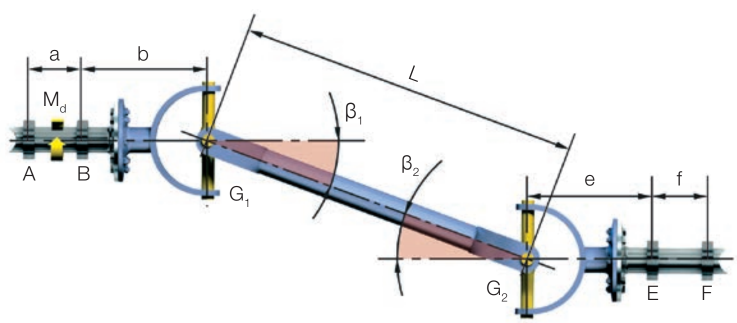
7.6.1 Radial bearing forces

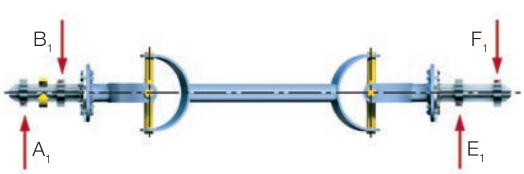
The deflection of the universal joint shaft also subjects the connection bearings to radial loads. The radial forces on the bearings vary from no force to maximum force, twice per revolution.

Designation and formulas

G_1, G_2	Universal joints
A, B, E, F	Connection bearings
M_d	Input torque
$A_{1/2}$, $B_{1/2}$, $E_{1/2}$, $F_{1/2}$	Bearing forces
α_1	Angle of rotation
β_1, β_2	Deflection angles

Maximum radial bearing forces with universal joint shafts in a Z arrangement

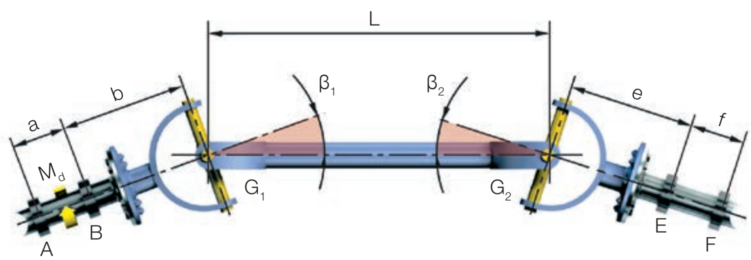


	$\beta_1 \neq \beta_2$	$\beta_1 = \beta_2$
$\alpha_1 = 0°$ 	$A_1 = M_d \cdot \frac{b \cdot \cos\beta_1}{L \cdot a} \cdot (\tan\beta_1 - \tan\beta_2)$	$A_1 = 0$
	$B_1 = M_d \cdot \frac{(a + b) \cdot \cos\beta_1}{L \cdot a} \cdot (\tan\beta_1 - \tan\beta_2)$	$B_1 = 0$
	$E_1 = M_d \cdot \frac{(e + f) \cdot \cos\beta_1}{L \cdot f} \cdot (\tan\beta_1 - \tan\beta_2)$	$E_1 = 0$
	$F_1 = M_d \cdot \frac{e \cdot \cos\beta_1}{L \cdot f} \cdot (\tan\beta_1 - \tan\beta_2)$	$F_1 = 0$
$\alpha_1 = 90°$ 	$A_2 = M_d \cdot \frac{\tan\beta_1}{a}$	$A_2 = M_d \cdot \frac{\tan\beta_1}{a}$
	$B_2 = M_d \cdot \frac{\tan\beta_1}{a}$	$B_2 = M_d \cdot \frac{\tan\beta_1}{a}$
	$E_2 = M_d \cdot \frac{\sin\beta_2}{f \cdot \cos\beta_1}$	$E_2 = M_d \cdot \frac{\tan\beta_1}{f}$
	$F_2 = M_d \cdot \frac{\sin\beta_2}{f \cdot \cos\beta_1}$	$F_2 = M_d \cdot \frac{\tan\beta_1}{f}$

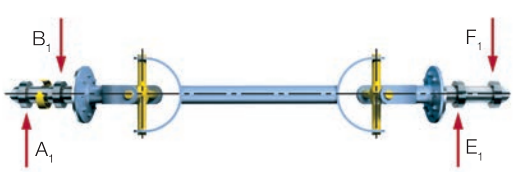
Designation and formulas

G_1, G_2	Universal joints
A, B, E, F	Connection bearings
M_d	Input torque
$A_{1/2}, B_{1/2}, E_{1/2}, F_{1/2}$	Bearing forces
α_1	Angle of rotation
β_1, β_2	Deflection angles

Maximum radial bearing forces on universal joint shafts in a W arrangement



$\alpha_1 = 0°$



$\beta_1 \neq \beta_2$

$$A_1 = M_d \cdot \frac{b \cdot \cos \beta_1}{L \cdot a} \cdot (\tan \beta_1 + \tan \beta_2)$$

$$B_1 = M_d \cdot \frac{(a + b) \cdot \cos \beta_1}{L \cdot a} \cdot (\tan \beta_1 + \tan \beta_2)$$

$$E_1 = M_d \cdot \frac{(e + f) \cdot \cos \beta_1}{L \cdot f} \cdot (\tan \beta_1 + \tan \beta_2)$$

$$F_1 = M_d \cdot \frac{e \cdot \cos \beta_1}{L \cdot f} \cdot (\tan \beta_1 + \tan \beta_2)$$

$\beta_1 = \beta_2$

$$A_1 = 2 \cdot M_d \cdot \frac{b \cdot \sin \beta_1}{L \cdot a}$$

$$B_1 = 2 \cdot M_d \cdot \frac{(a + b) \cdot \sin \beta_1}{L \cdot a}$$

$$E_1 = 2 \cdot M_d \cdot \frac{(e + f) \cdot \sin \beta_1}{L \cdot f}$$

$$F_1 = 2 \cdot M_d \cdot \frac{e \cdot \sin \beta_1}{L \cdot f}$$

$\alpha_1 = 90°$

$\beta_1 \neq \beta_2$

$$A_2 = M_d \cdot \frac{\tan \beta_1}{a}$$

$$B_2 = M_d \cdot \frac{\tan \beta_1}{a}$$

$$E_2 = M_d \cdot \frac{\sin \beta_2}{f \cdot \cos \beta_1}$$

$$F_2 = M_d \cdot \frac{\sin \beta_2}{f \cdot \cos \beta_1}$$

$\beta_1 = \beta_2$

$$A_2 = M_d \cdot \frac{\tan \beta_1}{a}$$

$$B_2 = M_d \cdot \frac{\tan \beta_1}{a}$$

$$E_2 = M_d \cdot \frac{\tan \beta_1}{f}$$

$$F_2 = M_d \cdot \frac{\tan \beta_1}{f}$$

7.6.2 Axial bearing forces

In principle, the kinematics of a universal joint shaft do not generate any axial forces. However, axial forces that need to be absorbed by connection bearings do occur in universal joint shafts with length compensation for two reasons:

1. Force $F_{ax,1}$ as a result of friction in the length compensation

As the length changes during the transmission of torque, friction is generated between the flanks of the profiles in the length compensation. For the frictional force $F_{ax,1}$, which acts in an axial direction, the following applies:

$$F_{ax,1} = \mu \cdot M_d \cdot \frac{2}{d_m} \cdot \cos \beta$$

where:

- μ Coefficient of friction;
  - $\mu \approx 0.11 - 0.14$ for steel on steel (lubricated)
  - $\mu \approx 0.07$ for Rilsan® plastic coating on steel
  - $\mu \approx 0.04$ for PTFE coating on steel
- M_d Input torque
- d_m Pitch circle diameter of the profile
- β Deflection angle

2. Force $F_{ax,2}$ as a result of the pressure build-up in the length compensation during lubrication

During the lubrication of the length compensation, an axial force $F_{ax,2}$ occurs as a function of the pressure applied while lubricating. Follow the information on this subject provided in the installation and operating instructions.

7.7 Balancing universal joint shafts

As with any other real body, the distribution of mass about the axis of rotation for a universal joint shaft is not uniform. This can lead to out-of-balance operation, which must be corrected on a case-by-case basis. Depending on the operating speed and the specific application, Voith universal joint shafts are dynamically balanced in two planes.
The balancing procedure used by Voith for universal joint shafts is based on the specifications in DIN ISO 21940-11 ("Mechanical vibration – Balance quality requirements for rotors in a constant (rigid) state – Part 1: Specification and verification of balance tolerances"). An extract from this standard lists the following approximate values for balance quality levels:

Benefits of balancing

- **+ Prevents vibrations, resulting in smoother operation**
- **+ Longer universal joint shaft service life**

Type of machine – general examples	Balance quality level G
Complete piston engines for cars, trucks and locomotives	G 100
Cars: Wheels, rims, wheel sets, **universal joint shafts**; crank drives with mass balancing on elastic mounts	G 40
Agricultural machinery; crank drives with mass balancing on rigid mounts; grinders, mills and shredders; input shafts (**cardan shafts**, propeller shafts)	G 16
Jet engines; centrifuges; electric motors and generators with a shaft height of at least 80 mm and a maximum rated speed of up to 950 rpm; electric motors with a shaft height of less than 80 mm; fans; gearboxes; general industrial machinery; machine tools; paper machines; process engineering equipment; pumps; turbochargers; hydro-power turbines	G 6.3
Compressors; computer drives; electric motors and generators with a shaft height of at least 80 mm and a maximum rated speed over 950 rpm; gas turbines, steam turbines; machine tool drives; textile machinery	G 2.5

1 Balancing machine

2 Balancing of universal joint shafts

Depending on the application and maximum operating speed, balance quality levels for universal joint shafts are located in the range between G 40 and G 6.3. The reproducibility of measurements may be subject to wider tolerances due to the influence of various physical factors. Such factors include:

- Design characteristics of the balancing machine
- Accuracy of the measurement method
- Tolerances in the connections to the universal joint shaft
- Radial and axial clearances in the universal joint bearings
- Deflection play in length compensation
- Grease distribution in the sliding area (Universal joint shafts were always balanced in non-greased condition)

8 Selection aids

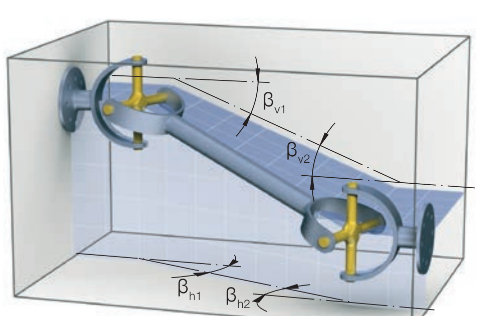
How a universal joint shaft is designed depends on a number of factors. Using reliable calculations and testing will prevent hazardous situations in the surrounding area. Another factor to be considered is the costs that arise over the entire product life cycle.

The design procedures described in this chapter are only intended to provide approximate guidelines. When making a final decision about a universal joint shaft, you can rely on our sales engineers for their technical knowledge and many years of experience. We will be happy to advise you.

The following factors have a major influence upon any decision regarding universal joint shafts

- **Operating variables**
- **Main selection criterion: Bearing life or durability**
- **Installation space**
- **Connection bearings**

8.1 Definitions of operating variables

Symbol	Common unit	Explanation
P_N	[kW]	**Rated power** of the drive motor
n_N	[rpm]	**Rated speed** of the drive motor
M_N	[kNm]	**Rated torque** of the drive motor, where: $M_N = \frac{60}{2\pi \cdot n_N} \cdot P_N \approx 9{,}55 \cdot \frac{P_N}{n_N}$ with M_N in kNm, n_N in rpm and P_N in kW
M_E	[kNm]	**Equivalent torque** Equivalent torque is an important operating variable in cases where bearing life is the main criterion in the selection of a universal joint shaft. It takes operating conditions into account and can be calculated for situations involving combined loads (see Section 8.2.1). If there is limited amount of available information on the operating conditions, the rated torque can be used as an initial estimate.
n_E	[rpm]	**Equivalent speed** Equivalent speed is an important operating variable in cases where bearing life is the main criteria in the selection of a universal joint shaft. It takes operating conditions into account and can be calculated for situations involving combined loads (see Section 8.2.1). If there is a limited information available on the operating conditions, the rated speed can be used as an initial estimate.
M_{max}	[kNm]	**Peak torque** Peak torque is the maximum torque that occurs during normal operation.
n_{max}	[rpm]	**Maximum speed** Maximum speed is the highest speed that occurs during normal operation.
n_{z1}	[rpm]	**Maximum permissible speed as a function of the deflection angle during operation** The center section of a universal joint shaft in a Z or W arrangement ($\beta \neq 0°$) does not rotate uniformly. It is subjected to a mass acceleration torque that depends upon the speed and the deflection angle. To ensure smooth operation and prevent excessive wear, the mass acceleration torque is limited by ensuring the maximum speed of the universal joint shaft n_{z1} is not exceeded. To learn more, see Section 8.3.1.
n_{z2}	[rpm]	**Maximum permissible speed taking bending vibrations into account** A universal joint shaft is an elastic body when bending. At a critical bending speed (whirling speed), the frequency of the bending vibrations equals the natural frequency of the universal joint shaft. The result is high loading on all of the universal joint shaft components. The maximum speed of the universal joint shaft must be significantly lower than this critical speed. To learn more, see Section 8.3.2.
β	[°]	**Deflection angle during operation** Deflection angle of the two joints in a Z or W arrangement, where: $\beta = \beta_1 = \beta_2$ If three-dimensional deflection is present, the resultant deflection anglel β_R is determined as follows: $\tan \beta_R = \sqrt{\tan^2 \beta_h + \tan^2 \beta_V}$ where: $\beta = \beta_R$ 

8.2 Size selection

There are essentially two selection criteria when choosing the size of a universal joint shaft:

1. Service life of the roller bearings in the joints

2. Operational durability, including torque capacity and/or load limit

As a rule, the application determines the primary selection criterion. A selection based upon bearing life is usually made in cases where drives require a long service life and pronounced torque spikes never occur or happen only briefly (for instance, during start-up). Typical examples include drives in paper machinery, pumps and fans. In all other applications, the selection is made on the basis of operational durability.

8.2.1 Selection based upon bearing life

The procedure used for calculating the bearing life is based upon the specifications in DIN ISO 281 ("Roller bearings – Dynamic load ratings and nominal service life").

However, this standard fails to take a number of factors into account when applied to universal joint shafts; for instance, the support of the bearings, i.e., deformation of the bore under load. Up to now, it has only been possible to assess these factors qualitatively.

The theoretical bearing life in a universal joint shaft can be calculated using the following equation:

$$L_h = \frac{1{,}5 \cdot 10^7}{n_E \cdot \beta \cdot K_B} \cdot \left(\frac{CR}{M_E}\right)^{\frac{10}{3}}$$

where:

L_h is the theoretical bearing life in hours [h]

CR Load rating of the universal joint in kNm (see tables in Section 6)

β Deflection angle in degrees [°]; in the case of three-dimensional deflection, the resulting deflection angle β_R is used; in any case, however, a minimum angle of 2° must be applied

K_B Operational factor

n_E Equivalent speed in rpm

M_E Equivalent torque in kNm

Operational factor

Torque spikes occur in drives with diesel engines that can be accounted for using the operational factor K_B:

Driving machine	Operational factor K_B
Electric motor	1
Diesel engine	1.2

Equivalent operating values

The equation for the theoretical bearing life assumes a constant load and speed. If the load changes in increments, the equivalent operating values can be determined that produce the same bearing fatigue as the actual loads. The equivalent operating values are ultimately the equivalent speed n_E and the equivalent torque M_E.
If a universal joint shaft transmits the torque M_i for a time period T_i at a speed of n_i, then the first task is to define a time segment q_i that normalizes the time period T_i with respect to the overall duration of operation T_{ges}:

$$q_i = \frac{T_i}{T_{ges}} \quad \text{where} \quad \sum_{i=1}^{u} q_i = q_1 + q_2 + \ldots + q_u = 1$$

Using this, the equivalent operating values can be determined:

$$n_E = \sum_{i=1}^{u} q_i \cdot n_i = q_1 \cdot n_1 + q_2 \cdot n_2 + \ldots + q_u \cdot n_u$$

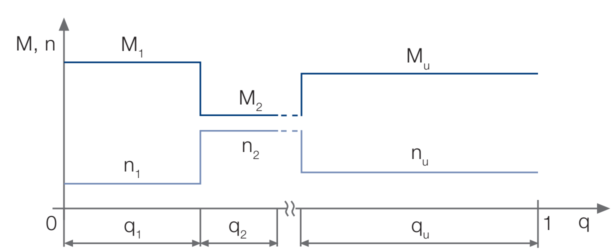
$$M_E = \left(\frac{\sum_{i=1}^{u} q_i \cdot n_i \cdot M_i^{\frac{10}{3}}}{n_E} \right)^{\frac{3}{10}}$$

$$= \left(\frac{q_1 \cdot n_1 \cdot M_1^{\frac{10}{3}} + q_2 \cdot n_2 \cdot M_2^{\frac{10}{3}} + \ldots + q_u \cdot n_u \cdot M_u^{\frac{10}{3}}}{n_E} \right)^{\frac{3}{10}}$$

Conclusions

- **The calculated bearing life is a theoretical value that is usually significantly exceeded in practice.**
- **The following additional factors affect the bearing life, sometimes to a significant degree:**
  - Quality of the bearings
  - Quality (hardness) of the journals
  - Lubrication
  - Overloading that results in plastic deformation
  - Quality of the seals

Incremental variation of the load on a universal joint shaft



8.2.2 Making a choice based on operational durability

Operational durability calculations can be made using a load spectrum. In practice, however, sufficiently accurate load spectra are seldom available. In cases like this, we are forced to fall back on the quasi-static dimensioning procedure. With this approach, the expected peak torque M_{max} is compared with the torques M_{DW}, M_{DS} and M_Z (see Section 5.2). The following estimate applies for peak torque:

$M_{max} \approx K_3 \cdot M_N$

K_3 is called the shock factor. These are empirical values based upon decades of experience in designing universal joint shafts.

The peak torque determined in this manner must meet the following requirements:

1. **$M_{max} \leq M_{DW}$ for alternating load**
2. **$M_{max} \leq M_{DS}$ for pulsating load**
3. **Individual and rarely occurring torque spikes must not exceed the value M_Z. The permissible duration and frequency of these torque spikes depends upon the application; please contact Voith for more information.**

Shock load	Shock factor K_3	Typical driven machinery
Minimal	1.1 – 1.3	• Generators (under a uniform load) • Centrifugal pumps • Conveying equipment (under a uniform load) • Machine tools • Woodworking machinery
Moderate	1.3 – 1.8	• Multi-cylinder compressors • Multi-cylinder piston pumps • Light-section rolling mills • Continuous wire rolling mills • Primary drives in locomotives and other rail vehicles
Severe	2 – 3	• Transport roller tables • Continuous pipe mills • Continuously operating main roller tables • Medium-section rolling mills • Single-cylinder compressors • Single-cylinder piston pumps • Fans • Mixers • Excavators • Bending machines • Presses • Rotary drilling and boring equipment • Secondary drives in locomotives and other rail vehicles
Very severe	3 – 5	• Reversing main roller tables • Coiler drives • Scale breakers • Cogging/roughing stands
Extremely severe	6 – 15	• Roll stand drives • Plate shears • Coiler pressure rolls

8.3 Operating speeds

8.3.1 Maximum permissible speed n_{z1} as a function of the deflection angle

Section 7.4 shows that a universal joint exhibits a varying output motion. A universal joint shaft is a connection of two universal joints in series with one another. Under the conditions described in Section 7.5, a universal joint shaft in a Z or W arrangement exhibits homokinetic motion between the input and output. Nevertheless, the center section of the universal joint shaft still rotates at the periodically varying angular velocity ω_2.

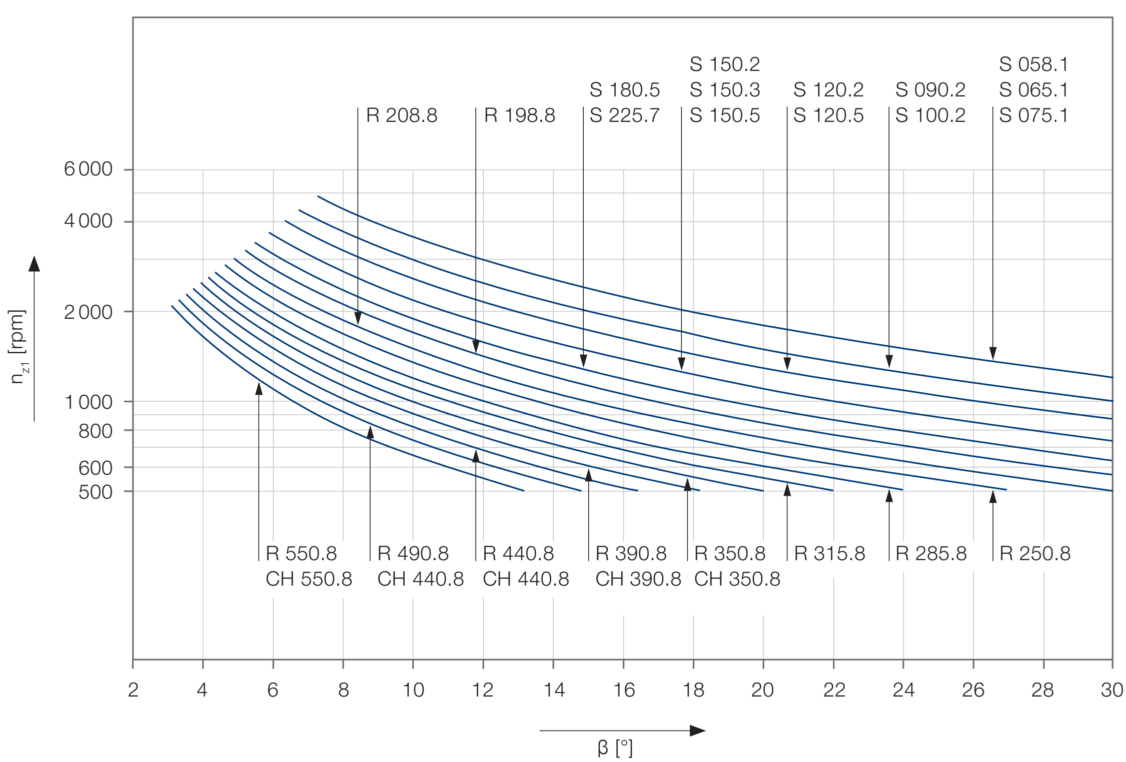
The center section of the universal joint shaft exhibits a mass moment of inertia, thus creating a moment of resistance to the angular acceleration $d\omega_2 / dt$. On universal joint shafts with length compensation, this alternating mass acceleration moment can cause clattering sounds in the profile. The consequences include less smooth operation and increased wear.

In addition, the mass acceleration torque can affect the entire driveline on universal joint shafts with length compensation, as well as universal joint shafts without length compensation. One example of this is torsional vibrations.

These adverse effects can be prevented by ensuring that the following conditions are met:

$\mathbf{n_{max} \leq n_{z1}}$

Approximate values of n_{z1} as a function of β



8.3.2 Maximum permissible speed n_{z2} as a function of operating length

Every universal joint shaft has a critical bending speed (whirling speed) at which the frequency of the bending vibrations reaches the natural frequency of the shaft. The result is high loading on all components of the universal joint shaft, leading to the possibility of it being damaged or destroyed in adverse situations.

Calculating this critical bending speed for a real universal joint shaft in a driveline is a complex task – Voith uses numerical computing programs to ensure the accuracy of the calculations.

The critical bending speed depends essentially upon three factors:

- Operating length l_B
- Deflection resistance of the universal joint shaft
- Connecting conditions at the input and output ends

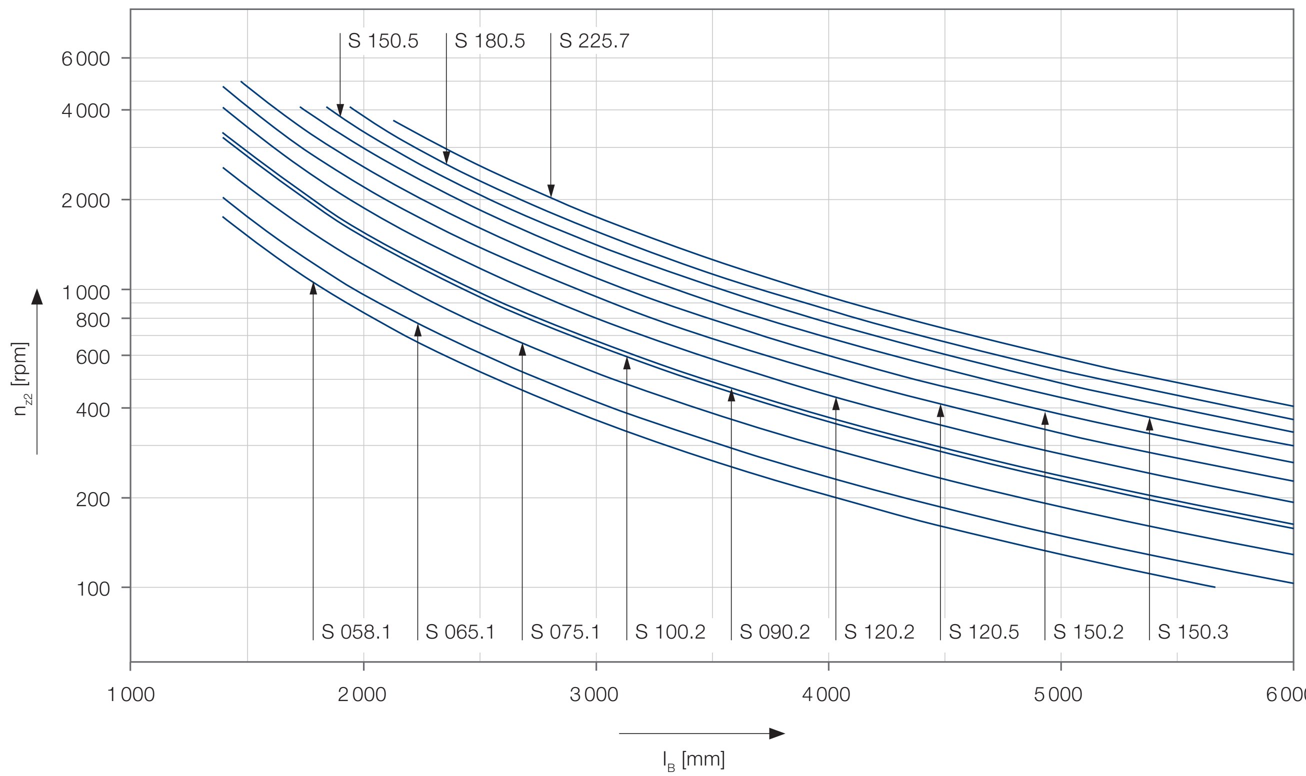
The maximum permissible speed n_{z2} is determined in such a way that provides a safety allowance with respect to the critical bending speed that is suitable for the particular application.

For safety reasons and to prevent the failure of the universal joint shaft, please ensure the following condition is met:

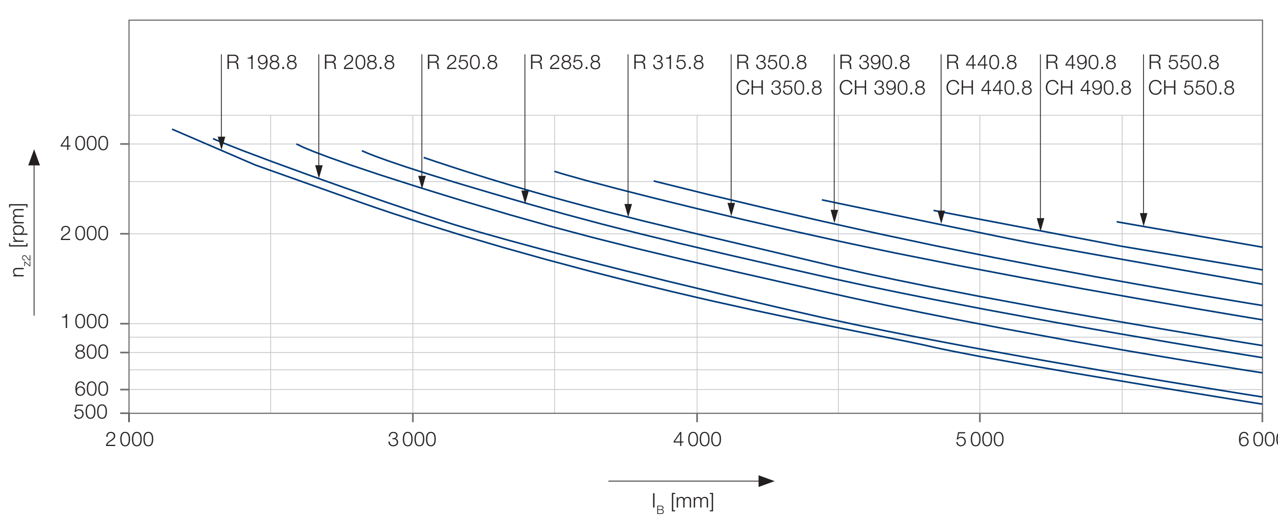
$$n_{max} \leq n_{z2}$$

For normal connecting and operating conditions, it is possible to specify approximate values for the maximum permissible speeds n_{z2} as a function of operating length l_B:

Approximate values of n_{z2} as a function of l_B for the S Series



Approximate values of n_{z2} as a function of l_B for the R and CH Series



8.4 Masses

Size	Tube values based on length	Universal joint shafts with length compensation				
	m'_R [kg/m]	$m_{L\,min}$ [kg]	$m_{L\,min}$ [kg]	$m_{L\,min}$ [kg]	$m_{L\,min}$ [kg]	$m_{L\,min}$ [kg]
	/SF	**ST**	**STL**	**STK1**	**STK2**	**STK3**
058.1	1.0	1.1	Values available on request	1.1	1.0	1.0
065.1	1.1	1.7		1.7	1.6	1.5
075.1	2.0	2.7		2.5	2.4	2.3
090.2	2.4	4.8		4.3	4.1	4.0
100.2	3.5	6.1		5.8	5.5	5.3
120.2	5.5	10.8		10.2	9.8	9.2
120.5	6.5	14.4		13.7	13.2	12.3
150.2	7.5	20.7		20.7	20.1	17.1
150.3	8.5	32.0		27.0	25.9	27.4
150.5	11.7	36.4		36.5	34.9	32.4
180.5	15.4	51.7		48.5	46.7	43.1
225.7	16.9	65		66	64	60
	RT/RTL/RF	**RT**	**RTL**	**RTK1**	**RTK2**	
198.8	37.0	92	-	-	-	
208.8	49	135	165	126	110	
250.8	58	199	222	179	165	
285.8	64	291	323	334	246	
315.8	89	400	495	387	356	
350.8	148	561	624	546	488	
390.8	185	738	817	684	655	
440.8	235	1 190	1 312	1 050	1 025	
490.8	296	1 452	1 554	1 350	1 300	
550.8	346	2 380	2 585	2 170	2 120	

Values for dimensions and series not listed are available on request.

Symbol	Explanation	
m'_R	Mass of the tube per 1 m of length	
		Universal joint shafts with length compensation
$m_{L\,min}$	Mass of the universal joint shaft for a length of…	$l_{z\,min}$
Calculations for the entire universal joint shaft:		
m_{ges}	Total mass	$m_{ges} = m_{L\,min} + (l_z - l_{z\,min}) \cdot m'_R$

	Universal joint shafts without length compensation	Joint coupling
$m_{L\,min}$ [kg]	$m_{L\,min}$ [kg]	$m_{L\,fix}$ [kg]
STK4	SF	SGK
0.9	0.9	0.8
1.4	1.2	1.0
2.1	2.0	1.0
3.8	3.6	3.2
5.1	4.5	4.2
8.6	7.7	7.4
11.5	10.5	9.2
15.8	15.2	13.8
26.0	22.1	16.6
29.4	25.3	21.6
40.9	32.4	30.6
56	36	36
	RF	RGK
	56	59
	78	85
	115	127
	182	191
	250	270
	377	370
	506	524
	790	798
	1 014	1 055
	1 526	1 524

Universal joint shafts without length compensation

l_{min}

$m_{ges} = m_{L\,min} + (l - l_{min}) \cdot m'_R$

8.5 Connection flanges and bolted connections

When installing Voith universal joint shafts in a driveline, the connection flanges and bolted connections must satisfy a number of requirements:

1. Design

- When using a universal joint shaft without length compensation, a connection flange ("wobbler") that is movable in a longitudinal direction is required so that the universal joint shaft can slide over the spigot. The connection flange also absorbs other changes in length, for instance, due to thermal expansion or changes in the deflection angle.

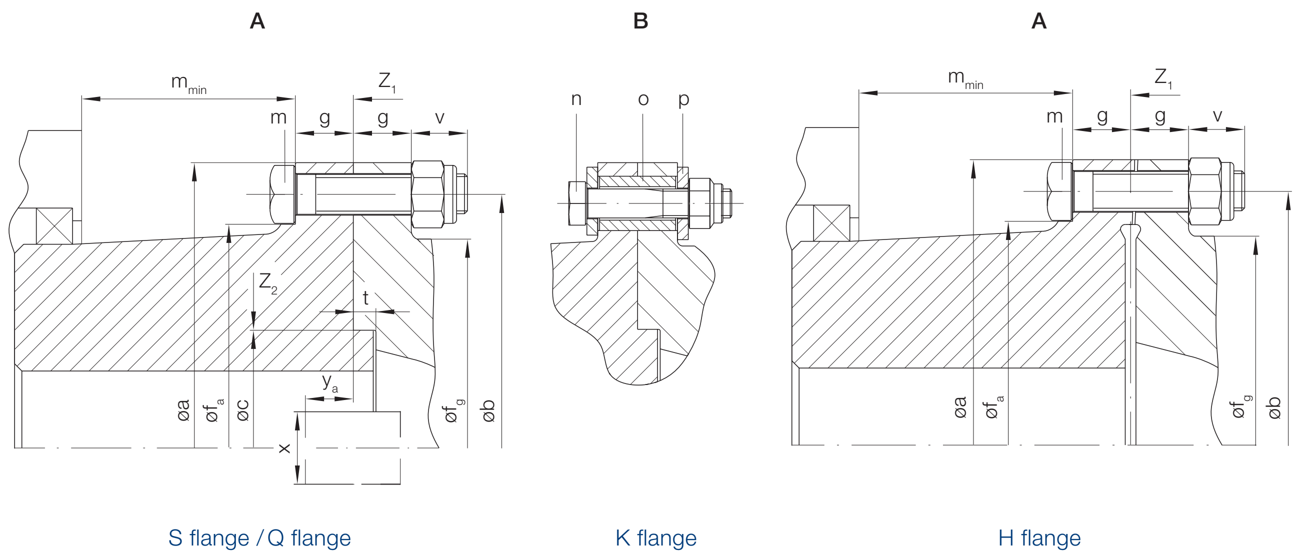
2. Material

- The connection flange material is designed for use with strength class 10.9 bolts (per ISO 4014 / 4017 or DIN 931 - 10.9).
- Special case for the S and R Series:
  If the material used for the connection flanges does not permit the use of bolts of strength class 10.9, the torques that can be transmitted by the flange connection are reduced. The specified tightening torques for the bolts must be reduced accordingly.

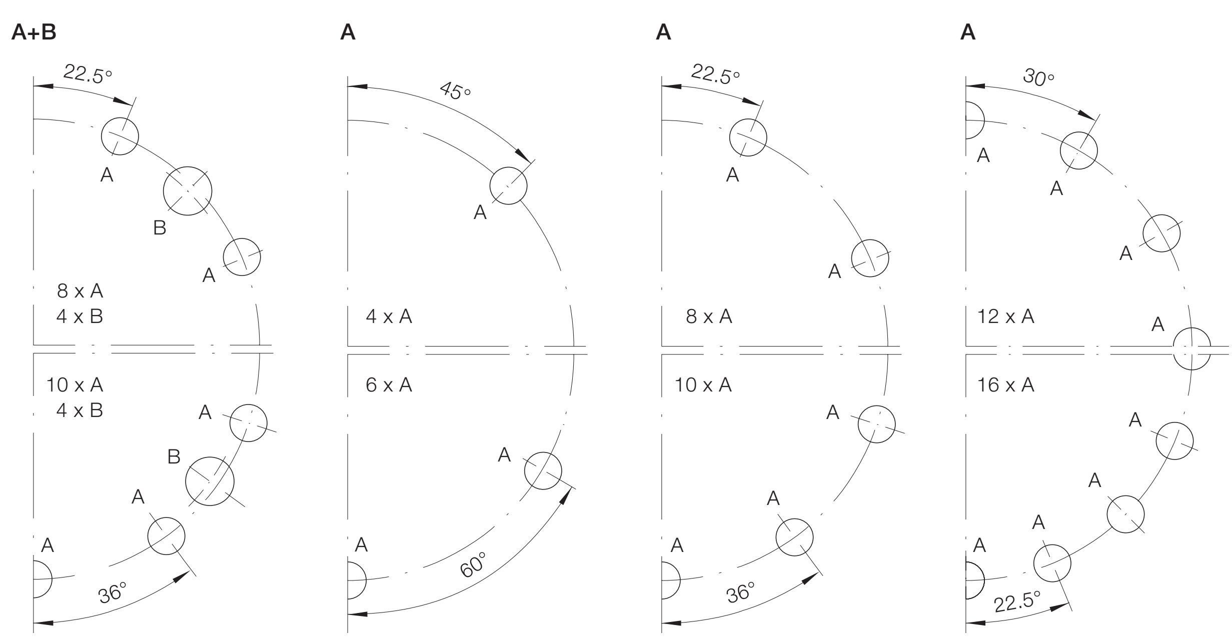
3. Dimensions, bolted connections

- On universal joint shafts of the S and R Series, the dimensions of the connection flanges must match those of the universal joint shaft, except for the spigot diameter c. The spigot diameter includes clearance (fit H7 / h6).
- On universal joint shafts with an H flange, the dimensions of the connection flanges are identical to those of the universal joint shaft. The Hirth couplings are self-centering.
- On S and R Series universal joint shafts, the relief diameter f_g on the universal joint shaft flange is not suitable for locking hex head bolts or nuts. A relief diameter f_a on the connection flange is suitable for this purpose.

Flange connection for universal joint shafts of the S and R Series



Fastener hole pattern for flange connections on the S and R Series of universal joint shafts



Connection flange dimensions												Bolted connection (A)			
Remarks											1	2	3	4	5
Size	a	b ±0.1	c H7	f_a -0.3	f_g	g	t	v	x P9	y_a +0.5	Z_1, Z_2	z	z	z	m Bolt
S flange / K flange															
058.1	58	47	30	38.5		3.5	1.2 -0.15	9			0.05	4			M5 x 16
065.1	65	52	35	41.5		4	1.5 -0.25	12			0.05	4			M6 x 20
075.1	75	62	42	51.5		5.5	2.3 -0.2	14			0.05	6			M6 x 25
090.2	90	74.5	47	61		6	2.3 -0.2	13			0.05	4			M8 x 25
100.2	100	84	57	70.5		7	2.3 -0.2	11			0.05	6			M8 x 25
120.2	120	101.5	75	84		8	2.3 -0.2	14			0.05	8			M10 x 30
120.5	120	101.5	75	84		9	2.3 -0.2	13			0.05	8			M10 x 30
150.2	150	130	90	110.3		10	2.3 -0.2	20			0.05	8			M12 x 40
150.3	150	130	90	110.3		12	2.3 -0.2	18			0.05	8			M12 x 40
150.5	150	130	90	110.3		12	2.3 -0.2	18			0.05	8			M12 x 40
180.5	180	155.5	110	132.5		14	2.3 -0.2	21			0.05	8			M14 x 45
225.7	225	196	140	171	159	15	4 -0.2	25			0.06	8			M16 x 55
198.8	225	196	140	171	159	15	4 -0.2	25			0.06	8			M16 x 55
208.8	250	218	140	190	176	18	5 -0.2	24			0.06	8			M18 x 60
250.8	285	245	175	214	199	20	6 -0.5	30			0.06	8			M20 x 70
285.8	315	280	175	247	231	22	6 -0.5	31			0.06	8			M22 x 75
315.8	350	310	220	277	261	25	7 -0.5	30			0.06	10			M22 x 80
350.8	390	345	250	308	290	32	7 -0.5	36			0.06	10			M24 x 100
390.8	435	385	280	342	320	40	8 -0.5	40			0.06	10			M27 x 120
Q flange															
208.8	225	196	105	171	159	20	4 -0.2	25	32	9.5	0.06		8		M16 x 65
250.8	250	218	105	190	176	25	5 -0.2	25	40	13	0.06		8		M18 x 75
285.8	285	245	125	214	199	27	6 -0.5	26	40	15.5	0.06		8		M20 x 80
315.8	315	280	130	247	231	32	7 -0.5	31	40	15.5	0.06		10		M22 x 95
350.8	350	310	155	277	261	35	7 -0.5	30	50	16.5	0.06		10		M22 x 100
390.8	390	345	170	308	290	40	7 -0.5	40	70	18.5	0.06		10		M24 x 120
440.8	435	385	190	342	320	42	9 -0.5	38	80	20.5	0.1		16		M27 x 120
490.8	480	425	205	377	350	47	11 -0.5	46	90	23	0.1		16		M30 x 140
550.8	550	492	250	444	420	50	11 -0.5	40	100	23	0.1		16		M30 x 140
H flange															
208.8	225	196	180	171	159	20		25			18			4	M16 x 65
250.8	250	218	200	190	175	25		25			20			4	M18 x 75
285.8	285	245	225	214	199	27		26			21			4	M20 x 80
315.8	315	280	250	247	230	32		31			23			4	M22 x 95
350.8	350	310	280	277	261	35		30			24			6	M22 x 100
390.8	390	345	315	308	290	40		40			25			6	M24 x 120
440.8	435	385	345	342	322	42		36			28			6	M27 x 120
490.8	480	425	370	377	350	47		36			31			8	M30 x 130
550.8	550	492	440	444	420	50		40			32			8	M30 x 140

Dimensions in mm.

		Bolted connection with split sleeve (B)				
6	7	8	9	10	11	12
M_A [Nm]	EB	z	n Bolt	o Sleeve	p Washer	M_A [Nm]
7	No					
13	No					
13	No					
31	No					
31	No					
63	No					
63	No					
109	No					
109	No					
109	No					
175	No					
265	No	4	M12 x 60	21 x 28	13	82
265	Yes	4	M12 x 60	21 x 28	13	82
365	No	4	M14 x 70	25 x 32	15	130
515	No	4	M16 x 75	28 x 36	17	200
695	Yes	4	M16 x 80	30 x 40	17	200
695	Yes	4	M18 x 90	32 x 45	19	274
890	No	4	M18 x 110	32 x 60	19	274
1 310	No	4	M20 x 110	35 x 60	21	386
265	No					
365	No					
515	No					
695	No					
695	No					
890	No					
1 310	No					
1 780	No					
1 780	No					
265	No					
365	No					
515	No					
695	No					
695	No					
890	No					
1 310	No					
1 780	No					
1 780	No					

Symbol	Explanation	Remarks	Additional information
a	Flange diameter		
b	Bolt circle diameter		
c	Spigot diameter		
f_a	Flange diameter, bolt side		
f_g	Flange diameter, nut side		
g	Flange thickness		
t	Spigot depth in connection flange		
v	Length from the contact surface of the nut to the end of the hexagon head bolt		
x	Width of face key		in universal joint shaft connection flanges with a face key
y_a	Depth of face key		in universal joint shaft connection flanges with a face key
Z_1	Axial run-out	1	Permissible values for deviation in axial runout Z_1 and concentricity Z_2 at operating speeds below 1 500 rpm. At operating speeds of 1 500 rpm to 3 000 rpm, reduce the values by half!
Z_2	Concentricity		
m	ISO 4014 / 4017-10.9 or DIN 931-10.9 hex head bolt with DIN 985-10 hex nut	2	z each per standard connection flange
		3	z each per connection flange with face key
		4	z each per connection flange with Hirth coupling
		5	Dimension of hexagon head bolt with nut
		6	Tightening torque for a coefficient of friction μ = 0.12 and 90 % utilization of the bolt yield utilization of the bolt yield point
m_{min}	Minimum length for the installation of bolts		Length of the hexagon head bolt m including the height of the bolt head
EB	Insertion options	7	Bolts are inserted from the joint side; if hex head bolts cannot be inserted from the joint side or the connection flange side, studs must be used
n	ISO 4014 / 4017-10.9 or DIN 931-10.9 hex head bolt with DIN 985-10 hex nut	8	z each per connection flange
		9	Dimension of hexagon head bolt with nut
		12	Tightening torque for a coefficient of friction μ = 0.12 and 90 % utilization of the bolt yield utilization of the bolt yield point
o	Split sleeve	10	Outer diameter x length of the split sleeve [mm x mm]
p	Washer	11	Washer interior diameter [mm]

Universal Joint Service Center in China

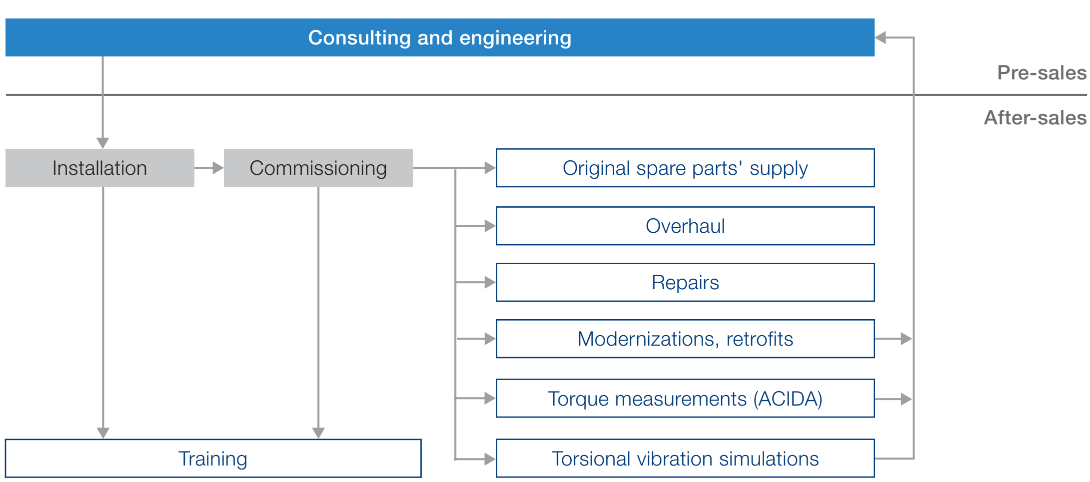
Offices worldwide

9 Service

For us, service means quality and dependability that exceeds the expectations of our customers.

We stand by you, anywhere in the world, for the entire service life of your system. You can count on us, from planning and commissioning to maintenance.
Voith's Universal Joint Shaft Service will increase the availability and service life of your system.

Voith Universal Joint Shaft Service



9.1 Installation and commissioning

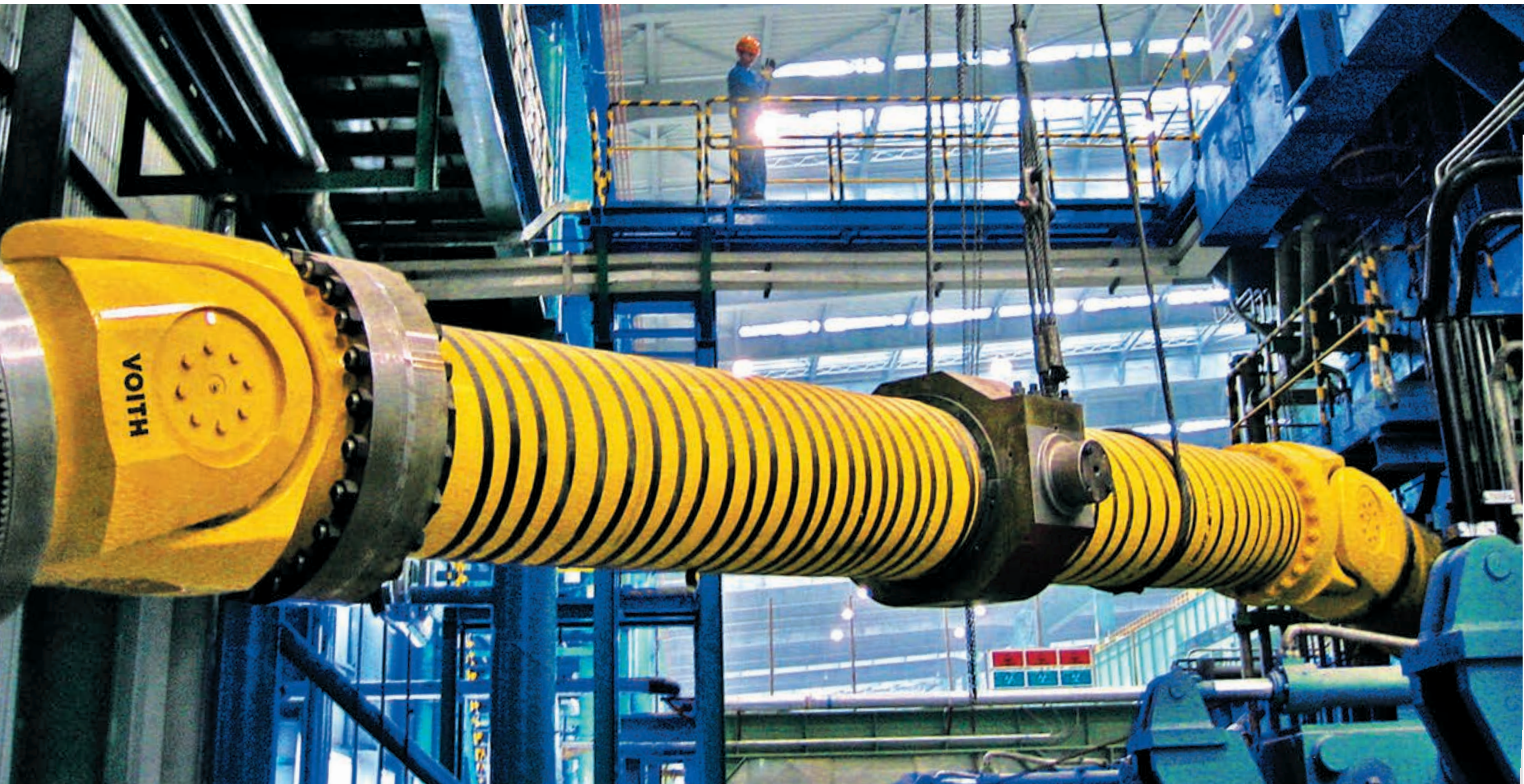
Correct installation of a universal joint shaft is a must for trouble-free commissioning.
A systematic commissioning procedure with extensive operational testing is an important factor in achieving maximum reliability and a long operational life for your universal joint shaft and the system as a whole.

What we offer

- Installation and commissioning by our service experts
- Training for operating and maintenance personnel

Your benefits

+ **Immediate access to expert know-how during the entire start-up phase**
+ **Assurance of trouble-free and professional commissioning for your universal joint shaft**



9.2 Training

Efficiency, reliability and availability are essential factors in ensuring the success of your system. This requires having the best-trained employees in technology and servicing. Initial and ongoing training are indispensable investments that will ensure the efficient operation of your universal joint shafts.

Our training programs arm your staff with specific technical knowledge about our products. Your staff will be up to speed with the latest Voith technology – in theory and in practice.

What we offer

- Product training at Voith or on-site at your location
- Theoretical and practical maintenance and repair training

Your benefits

- **+ Safer use of Voith products**
- **+ Prevention of operating and maintenance errors**
- **+ Better understanding of Voith technology in the driveline**

9.3 Voith original spare parts

Using original spare and wear parts will help reduce operating risk. Only original parts are manufactured with Voith know-how and can guarantee reliable and safe operation of your Voith products.
High availability and efficient logistics guarantee quick delivery of parts around the world.

What we offer

- Most original spare and wear parts warehoused at our service branches
- Same-day shipment of in-stock parts (for orders received by 11 a.m.)
- Consultation with your spare parts management staff
- Preparation of project-specific spare and wear parts packages
- Spare parts also available for older generations of Voith universal joint shafts

Your benefits

+ Safe and reliable operation of all components
+ The highest quality parts that fit exactly
+ Maximum service life of drive elements
+ Manufacturer's warranty
+ High degree of system availability
+ Fast spare parts delivery

Journal crosses

Flange yokes

9.4 Overhaul and maintenance

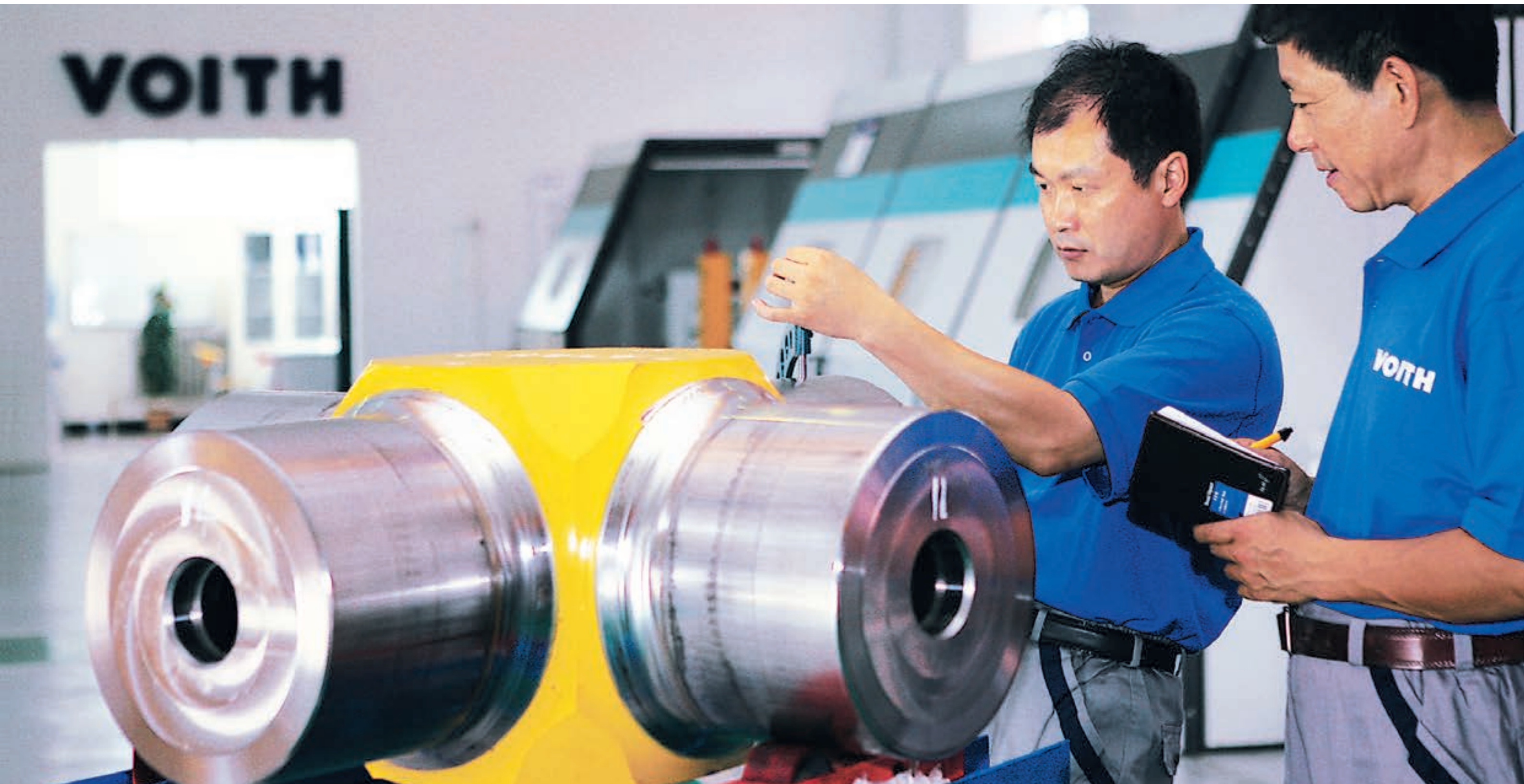
Constant operation subjects universal joint shafts to natural wear, which is also influenced by the environment.
Regular professional overhauls of your universal joint shaft will prevent damage and reduce the risk of expensive production downtimes. You get operational reliability while saving money in the long term.

What we offer

- Maintenance or complete overhaul by our service experts with all the special tools and fixtures necessary
- Use of original spare and wear parts
- Consultation regarding your maintenance strategy

Your benefits

+ The security that professional maintenance provides
+ Manufacturer's warranty
+ Increased system availability



9.5 Repairs and reconditioning

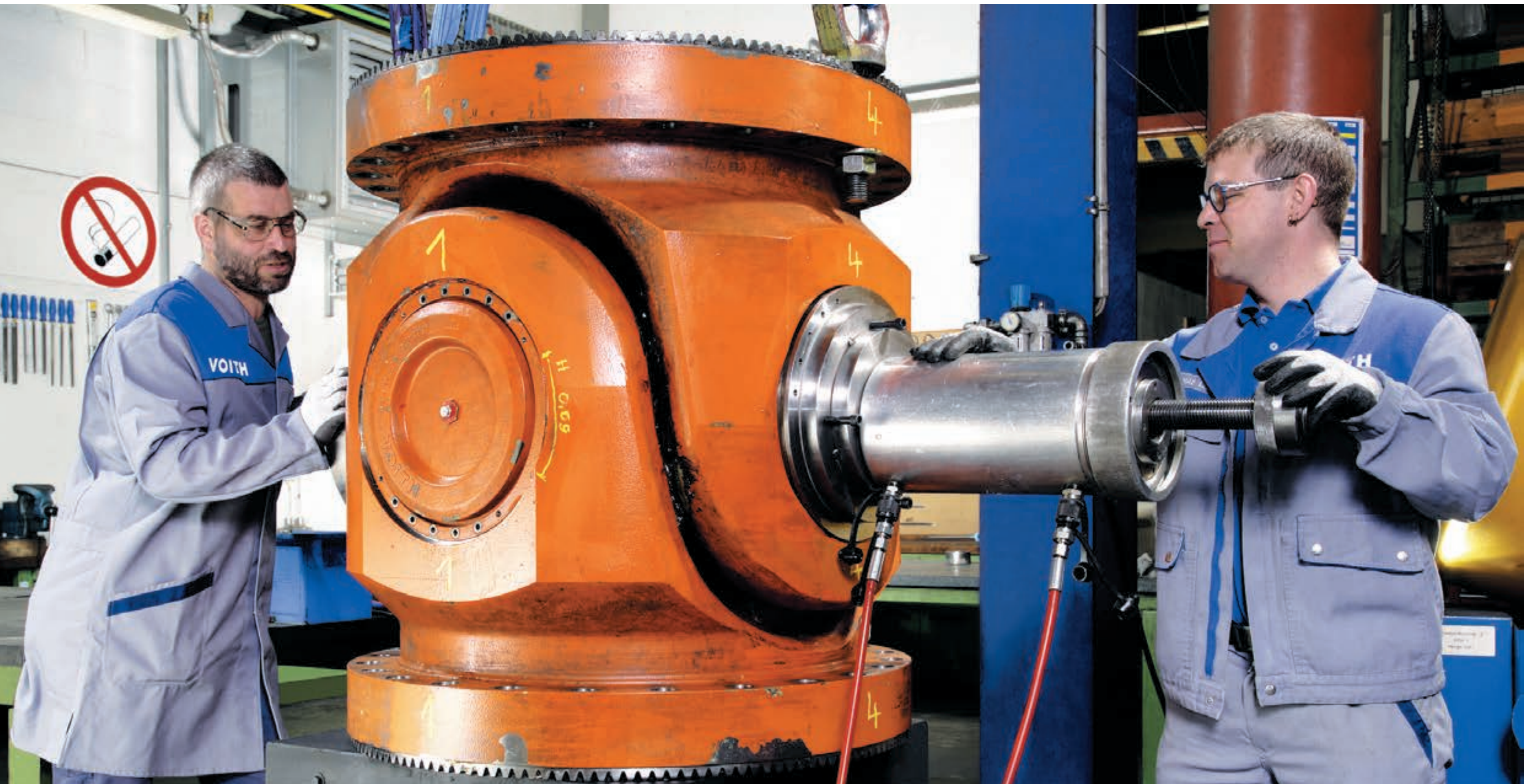
Even the best preventive maintenance cannot rule out unplanned downtime due to equipment failure. When this happens, the priority is to repair the components and equipment as quickly as possible.
As the manufacturer, we not only have a wealth of knowledge about universal joint shafts, but we also possess the necessary technical competence, experience, and tools to ensure professional and speedy repair. Our service technicians can quickly assess damage and provide suggestions for rapid correction.

What we offer

- Fast and professional repairs that meet our safety standards on-site at your location or at one of our certified Voith Service Centers around the world
- Experienced damage assessment, including vulnerability analysis
- Fast delivery of original spare parts

Your benefits

+ The security that a proper repair provides
+ Manufacturer's warranty
+ The shortest possible outage and downtime
+ Prevention of repeat outages or malfunctions



9.6 Modernizations and retrofits

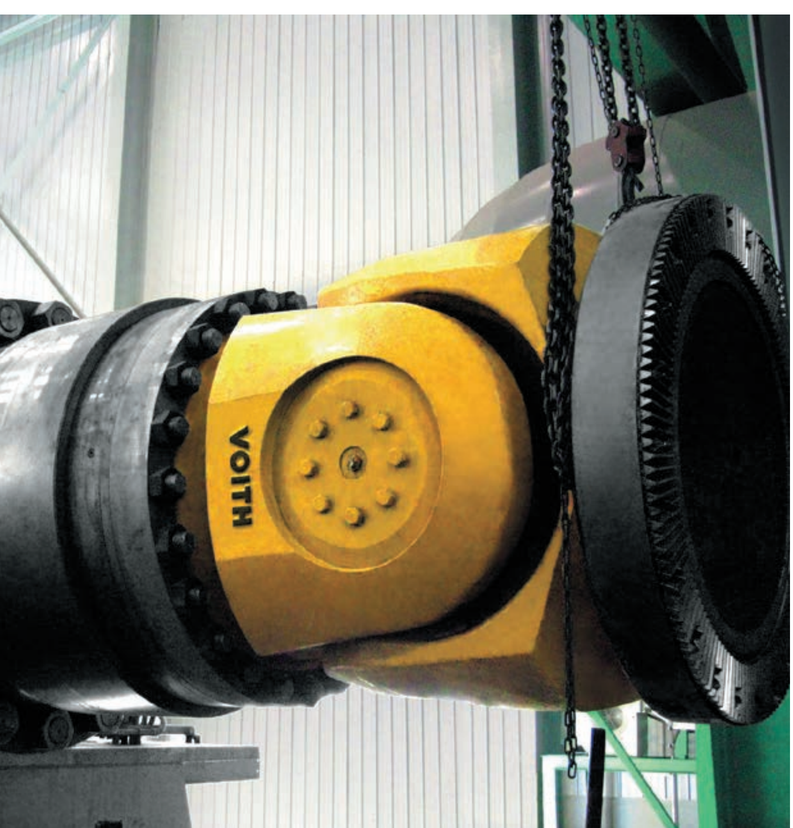
Technology is continually advancing, which means that the original requirements on which the design of a system was based could change over time.
Voith can help you realize significant improvements in efficiency and reliability through a tailored upgrade or retrofit of your old drive elements, e.g., slipper spindles. We analyze, advise, and upgrade universal joint shafts – including connection components – in order to keep you equipped with the latest and most economical technology.

What we offer

- Modification or redesign of your universal joint shafts and connection components
- Competent consultation regarding modernization opportunities, including the design of the driveline

Your benefits

+ Improved reliability, availability and affordability of your drive system
+ Reduced operating costs
+ A universal joint shaft that features the latest technology



9.7 Health check

In order to be able to assess the condition of your plant and your foundations as accurately as possible, the Health Check should be carried out at regular intervals and under com-parable conditions.
With our Health Check, you increase the availability and life-time of your system.

What we offer

- Visual inspection
- Middle part: Visual crack test of critical areas, if necessary
- Check condition of joints – Visual crack test at the flange
  - – Check condition of the bearings.
  - – Check condition of grease.
- Check the condition of roll end sleeve, dimensional test and visual crack test
- Check the tightening torques of flange connection bolts
- Check the Hirth coupling seal
- Regreasing the joints and the sliding area (if shaft has length compensation)
- Check condition of spare shafts in stock
- Recommendations

Example: Visual crack test at the flange yokes

Visual crack test areas in red – high loaded areas.
If necessary additional dye-penetration test.

Your benefits

+ The above inspection procedures will provide you with a clear assessment as to the condition of your installed universal joint shafts. Risk of failures is minimized.
+ Expert advice directly from the manufacturer
+ Visual assessment on the basis of manufacturer know-how
+ Competence and experience in diagnosing
+ Close cooperation between operator and manufacturer
+ Continuous information about the latest technical state of our products
+ Regular Health Checks minimize the risk of costly production downtimes.

10 Services and accessories

10.1 Engineering

We deliver not just products but ideas, too! Reap the benefit of our many years of engineering know-how in all matters related to projects involving complete drivelines, from design calculations, installation and commissioning, to questions about cost-optimized operation and maintenance concepts.

Engineering services

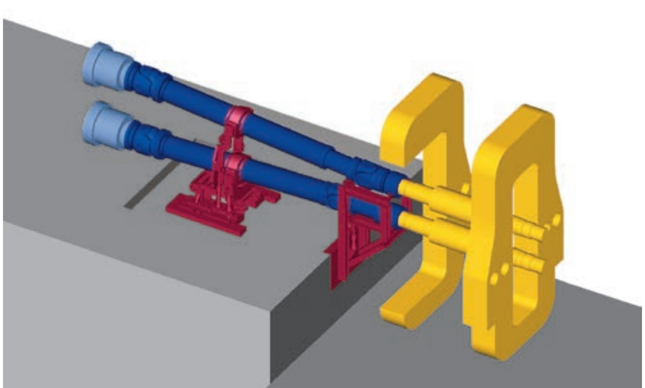
- Preparation of specifications
- Preparation of project-specific drawings
- Torsional and bending vibration calculations
- Design and sizing of universal joint shafts and connecting components
- Clarification of special requirements from the operator
- Preparation of installation and maintenance instructions
- Documentation and certifications
- Special acceptance tests conducted by classifying and certifying agencies

Special universal joint shafts

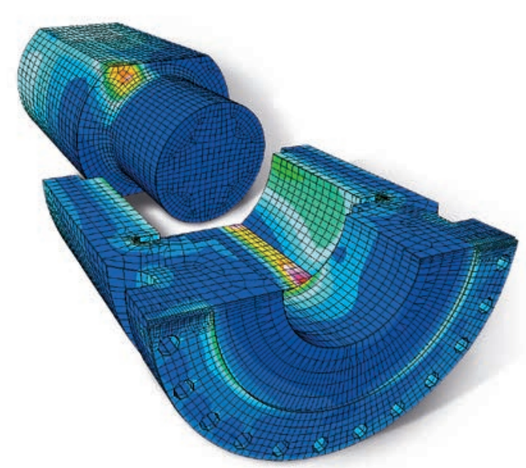
Designing special universal joint shafts to match your drive and your operating conditions is just one of the regular engineering services we offer. This includes:

- Any necessary design work
- Strength tests and optimization of the designs using FEM analysis
- Dynamic testing to ensure maximum reliability

Designing a driveline using CAD



FEM analysis of a work roll, with a split wobbler (illustration: roll journal and wobbler)



10.2 Connection components for universal joint shafts

Drive systems require reliable transmission of torque by the input and output connection component on the universal joint shaft, e.g.:

- Wobbler
- Connection flanges
- Adapter flanges
- Adapters

Applications

- Rolling mills
- Paper machines
- Pumps
- General mechanical engineering
- Test rigs
- Construction machinery and cranes

Features

- **Individual adaptation to all adjoining components**
- **Precision manufacturing through the use of state-of-the-art machining centers**
- **Transmission of maximum torque through the use of high-quality materials**
- **High level of wear resistance through hardened contact surfaces**

Rolling mill connection components for connecting universal joint shafts with work rolls ('wobbler')

10.3 FlexPad

The Voith FlexPad Roll End Hub (REH) design greatly increases hub body operational life through a significant reduction in wear.

Unlike to conventional steel wear plates the FlexPad generates an area contact to the roll neck by slight flexibility of the roll neck contact partner, the FlexPad. Already on a low load level the line contact is transferred into area contact what decreases stress on local hot spots. Thus wear for all components of the connection is reduced considerably. Furthermore the wear pads are fully embedded into a non-metallic layer and the REH-body is best protected from abrasion.

FlexPad Roll End Hubs are designed to provide a reliable roll neck connection which guarantees a safe operation between scheduled maintenance stops. The overall lifetime of the cost intensive REH body is multiplied and frequent and expensive disassembly and rework of the REH are avoided.

Considering all expenses of a roll neck – driveshaft connection (total cost of ownership) FlexPad is reducing cost in average by 20 %.

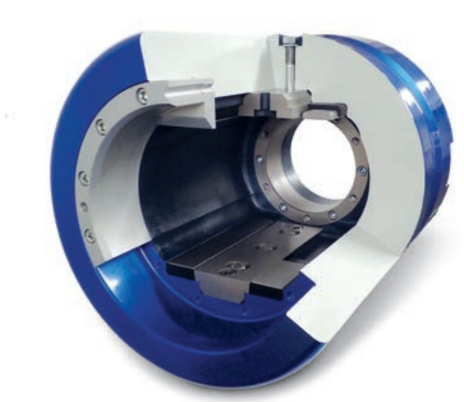
Features

- **100 % compatible to existing mechanical interface**
- **Customized for any roll neck geometry**
- **Quick and easy exchange of FlexPads**
- **Pad replacement in the mill (no need to dismantle the REH)**

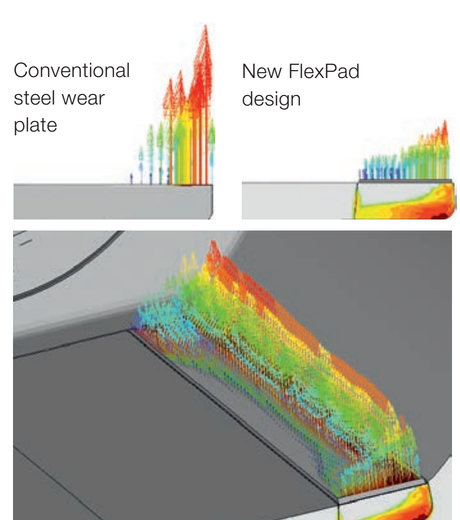
Benefits

- \+ **Lifetime of REH several times higher compared to conventional design**
- \+ **No highly stressed screw connection → No risk of cracked bolts**
- \+ **No expensive rework on REH-body**
- \+ **Reduction of dynamic effects in the whole driveline due to damping character of Flex–layer**
- \+ **No increase of clearance between roll neck and REH**
- \+ **Reduction of operation cost**

Voith FlexPad



Contact pressure distribution



10.4 Quick-release GT coupling

The quick-release GT coupling is designed to be a very effective connection component. The GT coupling allows you to rapidly assemble and disassemble a wide range of shaft connections in your machine, which in turn significantly reduces the amount of required downtime associated with maintenance and repair.

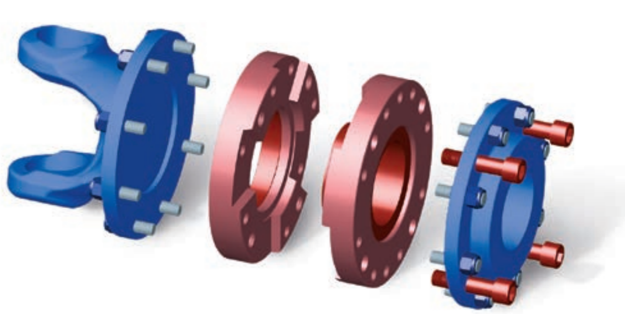
Applications

- Drives that require quick and precisely centered replacement of coupling connections, e.g., universal joint shafts and disk couplings
- Roll and cylinder connections, e.g., in paper machines

Features

- **Positive transmission of torque through claw serrations**
- **Quick and easy assembly/disassembly**
- **Compact design**
- **Only two major components**
- **Stainless steel version available**

Schematic diagram of the GT quick-release coupling



Universal joint shaft with ring of the GT quick-release coupling

10.5 Voith Hirth coupling

The Voith Hirth coupling transmits maximum torque at the specified diameter.

Applications

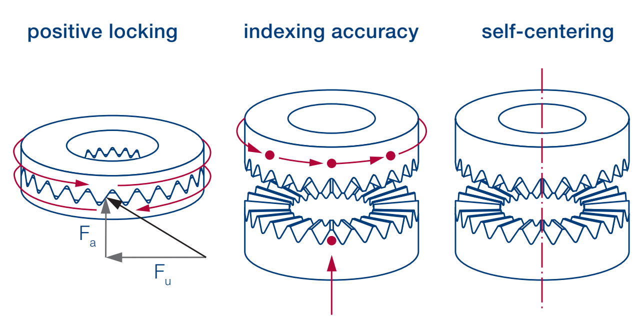
- Universal joint shafts with high torque requirements
- Connecting flange for universal joint shafts (also can be provided by customer)
- Machine tools
- Turbo compressors
- Metrology
- Robotic equipment
- Nuclear technology
- Medical equipment
- General mechanical engineering

Features

- **High level of torque transmission, as angular surfaces provide positive locking transmission of most of the peripheral forces. Only a small axial force needs to be absorbed by the bolts**
- **Self-centering through use of optimized tooth geometry**
- **High wear resistance due to the high load-bearing percentage of the tooth profile**
- **Excellent repeatable accuracy as a result of the multiple wedge design**

Universal joint shaft with Hirth coupling on the end flange faces

Primary functions of the Hirth coupling



10.6 Universal joint shaft support systems

Positioning and supporting a universal joint shaft and its wobbler and connection flanges requires a support mechanism.

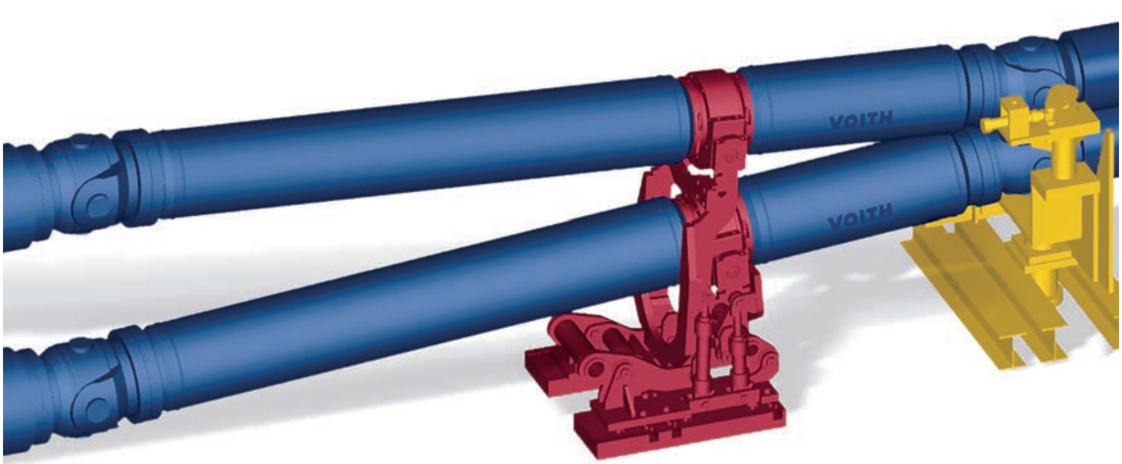
Applications

- Rolling mills
- Customer-specific drives

Features

- **Increased productivity and system availability as a result of significantly reduced maintenance downtime**
- **Reduced energy and lubricant costs as well as higher transmission efficiency through the use of roller bearings**
- **Reduced wear thanks to uniform power transmission**

Universal joint shaft support (red) and coupling support (yellow)



10.7 Universal joint shafts with carbon fiber-reinforced polymer (CFRP)

Universal joint shafts that use CFRP components increase the efficiency and performance of machines and systems. The use of CFRP in universal joint shaft design reduces masses, vibrations, deformations and energy consumption. We offer not only the drive engineering know-how, but also the production know-how for CFRP components – all from a single source.

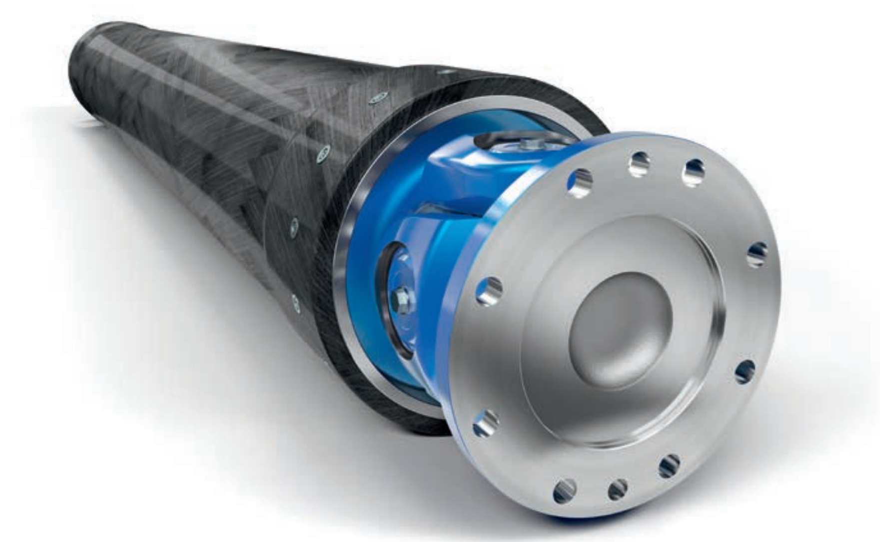
Applications

- Long drivelines with no intermediate bearings
- Drives with low mass
- Drives with optimized vibration behavior
- Pumps
- Ships and boats
- Rail vehicles
- General mechanical engineering

Features

- **Depending on the requirements, universal joint shafts with carbon tube or solid-carbon center section**
- **Lower loads thanks to low masses**
- **Extremely smooth operation and low vibration wear due to high rigidity**
- **Low acceleration and deceleration torques due to low moment of inertia**

Universal joint shaft with carbon-fiber tube



Voith WearCare 500 in 45 kg and 180 kg drums

10.8 High-performance lubricant for universal joint shafts

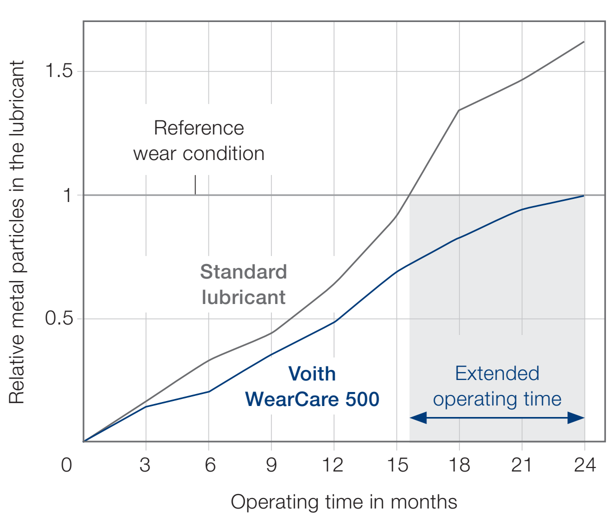
Voith development engineers have combined their universal joint shaft know-how with the tribology know-how of renowned bearing and lubricant manufacturers. The result of this cooperation is an innovative and exclusive lubricant with properties that far exceed those of conventional lubricants.

This lubricant gives bearings in universal joint shafts operating at low speeds and under high loads an even longer service life. In addition, lubrication intervals can be extended and emergency dry-running characteristics are improved significantly.

Characteristics of Voith's WearCare 500 high-performance lubricant	Advantages
Optimum adhesion and surface wetting	+ Lubricating film even in the event of underlubrication + Formulated for oscillating bearing motion
Exceptional corrosion protection	+ Ideal for rolling mills
Maximum ability to withstand pressure	+ Hydrodynamic lubricating film even under maximum torque conditions
Optimum and long-lasting lubricating action	+ Minimal abrasive wear in the bearing + Extended lubrication intervals + Lower maintenance costs
Can be mixed with lithium-based greases	+ Simple conversion to Voith's high-performance lubricant
High resistance to aging	+ Long shelf life
Excellent compatibility with all bearing components	+ No softening of bearing seals + Does not corrode nonferrous metals
Contains no silicone and copper-based ingredients	+ Suitable for aluminum rolling mills

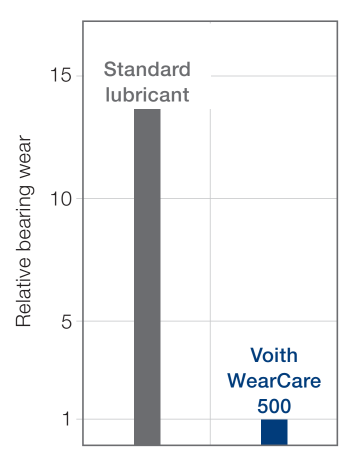
Field trial

Metal particles in the bearing lubricant of a high-performance universal joint shaft used in a rolling mill drive



FE8 test rig trial

Bearing wear in an axial cylindrical roller bearing



10.9 SafeSet torque limiting safety couplings

The SafeSet coupling is a torque limiting safety coupling that instantaneously disengages the force flow of the driveline in the event of a potentially catastrophic torque overload event, thus protecting all of the drive components in the driveline (motors, gearboxes, universal joint shafts, etc.) against damage.
By integrating the SafeSet safety coupling into the universal joint shaft, Voith's proprietary 'integral design' reduces the deflection angle of the universal joints, thus increasing the bearing life.

Applications

- Protects the driveline from potentially damaging overload torques
- Rolling mills
- Shredders
- Cement mills
- Sugar mills
- Rail vehicle drives

Features

- **Adjustable release torque**
- **Release torque does not change over time**
- **Backlash-free power transmission**
- **Compact, lightweight design**
- **Low mass moment of inertia**
- **Minimal maintenance required**

Three-dimensional view through a SafeSet safety coupling (type SR-C)

Torque-limiting SafeSet safety coupling (blue) integrated into a Voith high-performance universal joint shaft

10.10 ACIDA torque monitoring systems

ACIDA torque monitoring systems have proven their worth in accurately measuring dynamics in universal joint shafts. Being able to directly measure the actual, mechanical drive load provides important information for process monitoring and plant optimization. Analysis modules, for instance load spectra or service life monitoring, have been specially developed for extremely heavy-duty drives and unusually severe load conditions. Additional options include online vibration diagnosis for gearboxes and roller bearings.

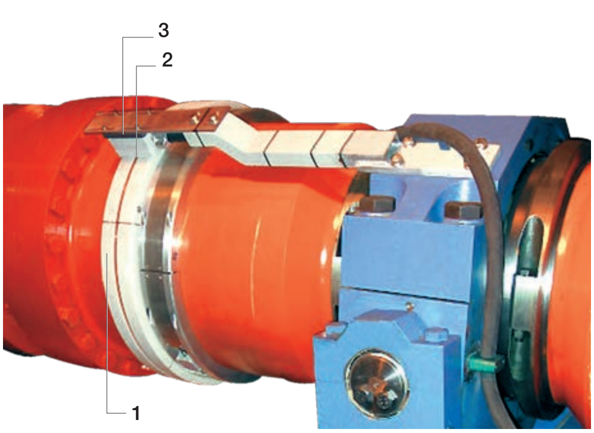
Applications

- Torque monitoring
- Vibration monitoring
- Process optimization
- Condition-based maintenance
- Reference systems: Rolling mills, cement mills, briquetting plants, agitators, conveying equipment, ship propulsion systems, locomotives, paper machines, mining, etc.

Features

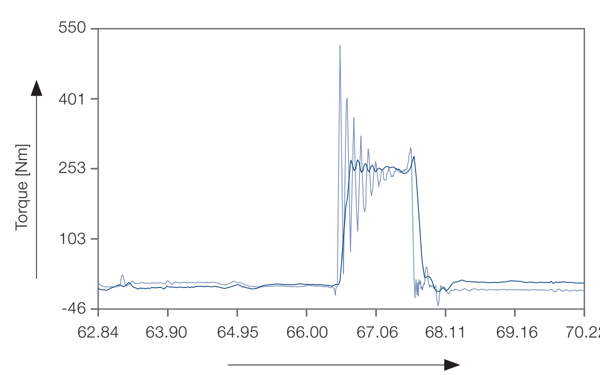
- **Permanent or temporary torque sensors**
- **Complete monitoring systems, including hardware and software**
- **Report generator with automatic analysis, alarm signaling and reporting**
- **Remote service with expert support**

Non-contact torque monitoring system



1 Rotor: Strain gauges and telemetry (requires no drive modifications)
2 Air gap: No contact between rotor and stator
3 Stator: Signal reception and inductive power supply

The ACIDA monitoring system in comparison



Bright blue: The ACIDA monitoring system measures torques and dynamics with extreme accuracy and high dynamic response.
Dark blue: Conventional systems measure motor current or hydraulic pressure, for example, with insufficient signal dynamics.

1

11 Integrated Management System

At Voith, ensuring the affordability, reliability, environmental compatibility and safety of our products and services is our top priority. In order to maintain these principles now and in the future, Voith has implemented a solid, integrated management system focused on quality, the environment, and occupational health and safety.

Our customers know that this means they are acquiring high-quality capital goods that are being manufactured and used under safe working and environmental conditions.

2

1 ISO 9001 certificates for management systems: 2000 (quality), ISO 14001: 2000 (environment) and OHSAS 18001: 1999 (occupational health and safety)

2 Flange yoke for a high-performance universal joint shaft on a 3-D coordinate measuring machine

11.1 Quality

- We employ state-of-the-art 3-D coordinate measuring machines for quality assurance.
- To ensure perfectly welded joints, we conduct x-ray inspections in-house.
- We offer our customers a variety of product-specific and application-specific certifications and classifications.
- Production and assembly fixtures are inspected on a regular basis.
- Quality-relevant measuring and testing instruments are subject to systematic monitoring.
- Process qualifications per ISO 3834-2 are available for the welding methods employed. Welding technicians are EN 287-qualified and our welding equipment is continuously monitored.
- Employees that perform nondestructive testing are ASNT-C-1A and / or EN 473-qualified.

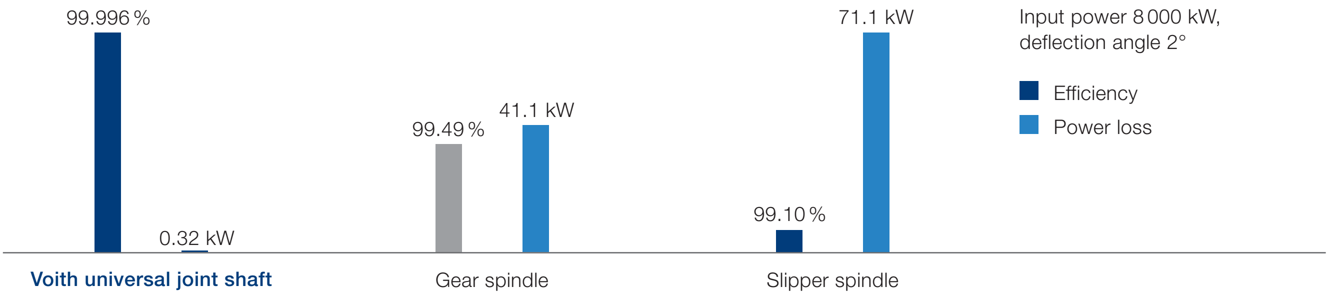
1

11.2 Environment

- Voith universal joint shafts are fitted with sealed roller bearings. These offer two major benefits over slipper and gear type spindles:

1. Lubricant consumption is considerably lower because of the seals.
2. Efficiency is enhanced, as rolling friction is significantly lower than sliding friction. This translates into reduced CO_2 emissions and protects the environment.

Efficiency and power loss in the main drive of a rolling mill



1 An employee coats the roller bearing of a universal joint shaft with Voith WearCare 500 high-performance lubricant

2 Voith universal joint shafts receive their final finish in a modern paint booth

11.3 Occupational health and safety

- Voith painting technicians use a modern painting system when painting the universal joint shafts that meets all of the requirements for health and safety for occupational and environmental protection.
- Electrostatic application of the paint reduces overspray.
- An exhaust system extracts any residual mist.
- An exhaust air treatment system with combined heat recovery reduces the impact on employees and the environment.

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