STAR – Precision Steel Shafts
Technical Data

7055377

Minimum hardness

Solid and tubular shafts → HRC 60

Corrosion-resistant
steel shafts → HRC 53
to DIN 17230 / EN 10 088

The figure opposite shows the microstructure in the surface zone of a shaft cross section (magnification approx. 10x). The hardened outer layer of martensite and the smooth transition to the tough inner core structure are clearly visible.

Induction-hardened surface zone
Structure: martensite
hardness ≥ HRC 60 (Rockwell C)

Transitional structure:
martensite
troostite
pearlite

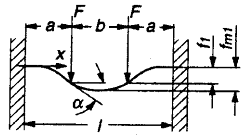
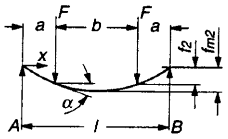
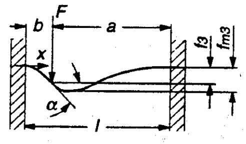
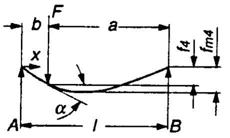
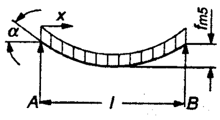
Core structure:
pearlite and ferrite

Shaft deflection

When steel shafts are used as linear motion guideways for Linear Bushings it is important that the shaft deflection occurring under load is kept within certain limits, as otherwise the proper functioning and the service life of the assembly could be impaired[1].

To facilitate the determination of shaft deflection by calculation, we have compiled the most common load cases together with the associated deflection equations in the table below.

The equations for calculation of the inclination of the shaft in the linear bushing (tan α) can also be taken from this table.

Case No.	Loading conditions	Deflection equation	Shaft inclination in linear bushings
1		$f_1 = \frac{F \cdot a^3}{6 \cdot E \cdot J} \cdot \left(2 - \frac{3 \cdot a}{l}\right)$ $f_{m1} = \frac{F \cdot a^2}{24 \cdot E \cdot J} \cdot (3l - 4a)$	$\tan\alpha_{(x=a)} =$ $= \frac{F \cdot a^2 \cdot b}{2 \cdot E \cdot J \cdot l}$
2		$f_2 = \frac{F \cdot l^3}{2 \cdot E \cdot J} \cdot \frac{a^2}{l^2} \cdot \left(1 - \frac{4}{3} \cdot \frac{a}{l}\right)$ $f_{m2} = \frac{F \cdot l^3}{8 \cdot E \cdot J} \cdot \frac{a}{l} \cdot \left(1 - \frac{4}{3} \cdot \frac{a^2}{l^2}\right)$	$\tan\alpha_{(x=a)} =$ $= \frac{F \cdot a \cdot b}{2 \cdot E \cdot J}$
3		$f_3 = \frac{F \cdot l^3}{3 \cdot E \cdot J} \cdot \frac{a^3 \cdot b^3}{l^3 \cdot l^3}$ $f_{m3} = \frac{2 \cdot F \cdot l^3}{3 \cdot E \cdot J} \cdot \frac{a^3}{l^3} \cdot \frac{b^2}{l^2} \cdot \left(\frac{l}{l + 2a}\right)^2$	$\tan\alpha_{(x=b)} =$ $= \frac{F \cdot a^2 \cdot b^2}{2 \cdot E \cdot J \cdot l^2}\left(1 - \frac{2 \cdot b}{l}\right)$
4		$f_4 = \frac{F \cdot l^3}{3 \cdot E \cdot J} \cdot \frac{a^2 \cdot b^2}{l^2 \cdot l^2}$ $f_{m4} = f_4 \cdot \frac{l + b}{3 \cdot b} \cdot \sqrt{\frac{l + b}{3 \cdot a}}$	$\tan\alpha_{(x=b)} =$ $= \frac{F \cdot a}{6 \cdot E \cdot J \cdot l}\left(3b^2 - l^2 + a^2\right)$
5		$f_{m5} = \frac{5 \cdot F \cdot l^3}{384 \cdot E \cdot J}$	$\tan\alpha_{(x=0)} =$ $= \frac{F \cdot l^2}{24 \cdot E \cdot J}$

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[1] There will be no loss of load-carrying capacity or service life in Super Linear Bushings A, H and SH provided the shaft deflection does not exceed 30' (tan 30' = 0.0087).

The table gives the values for the maximum permissible shaft inclination (tan α_{max}) for each size of Standard Linear Bushing.
At tan α = tan α_{max} the permissible static load capacity is approx. 0.4 C_O.

Shaft Ø d (mm)	tan α_{max}	**Shaft** Ø d (mm)	tan α_{max}
5	$12.3 \cdot 10^{-4}$	30	$6.4 \cdot 10^{-4}$
8	$10.0 \cdot 10^{-4}$	40	$7.3 \cdot 10^{-4}$
12	$10.1 \cdot 10^{-4}$	50	$6.3 \cdot 10^{-4}$
16	$8.5 \cdot 10^{-4}$	60	$5.7 \cdot 10^{-4}$
20	$8.5 \cdot 10^{-4}$	80	$5.7 \cdot 10^{-4}$
25	$7.2 \cdot 10^{-4}$		

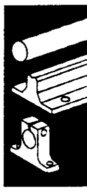
Values for E x J and mass for steel shafts

Solid Shafts

Ø d (mm)	E x J (N x mm^2)	Mass (kg/m)	Ø d (inches)	Ø d (mm)	E x J (N x mm^2)	Mass (kg/m)
5	$6.44 \cdot 10^{6}$	0.15	1/4	6.35	$1.68 \cdot 10^{7}$	0.25
8	$4.22 \cdot 10^{7}$	0.39	3/8	9.525	$8.48 \cdot 10^{7}$	0.56
10	$1.03 \cdot 10^{8}$	0.61	1/2	12.7	$2.68 \cdot 10^{8}$	0.99
12	$2.14 \cdot 10^{8}$	0.88	5/8	15.875	$6.55 \cdot 10^{8}$	1.54
16	$6.76 \cdot 10^{8}$	1.57	3/4	19.05	$1.36 \cdot 10^{9}$	2.22
20	$1.65 \cdot 10^{9}$	2.45	1	25.4	$4.29 \cdot 10^{9}$	3.95
25	$4.03 \cdot 10^{9}$	3.83	1 1/4	31.75	$1.05 \cdot 10^{10}$	6.18
30	$8.35 \cdot 10^{9}$	5.51	1 1/2	38.1	$2.17 \cdot 10^{10}$	8.89
40	$2.64 \cdot 10^{10}$	9.80	2	50.8	$6.87 \cdot 10^{10}$	15.81
50	$6.44 \cdot 10^{10}$	15.32	2 1/2	63.5	$1.68 \cdot 10^{11}$	24.70
60	$1.34 \cdot 10^{11}$	22.05	3	76.2	$3.48 \cdot 10^{11}$	35.57
80	$4.22 \cdot 10^{11}$	39.21	4	101.6	$1.10 \cdot 10^{12}$	63.24

Tubular shafts

Ø d outer Ø (mm)	inner Ø (mm)	E x J (N x mm^2)	Mass (kg/m)
25	14	$3.63 \cdot 10^{9}$	2.63
30	19	$7.01 \cdot 10^{9}$	3.30
40	26.5	$2.13 \cdot 10^{10}$	5.50
50	29.6	$5.65 \cdot 10^{10}$	9.95
60	36.5	$1.15 \cdot 10^{11}$	13.89
80	57.4	$3.10 \cdot 10^{11}$	19.02



STAR – Precision Steel Shafts
Diameters and Lengths

Shaft diameters

Solid shafts

Standard sizes for Linear Bushings	(mm)	5	8	10	12	16	20	25	30	40	50	60	80		
Special sizes	(mm)	6	14	15	18	22	24	32	35	38	45	55	70	100	110
Inch sizes	(inches)	1/4	3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4		

Tubular shafts

Outer diameter	(mm)	25	30	40	50	60	80	100
Inner diameter	(appr. mm)	14	19	26.5	29.6	36.5	57.4	65
Weight saving compared with solid shaft	(appr. %)	31	40	45	35	35	50	42
Reduction of resistance to bending stress against solid shafts	(appr. %)	10	16	20	12	12	25	20

Corrosion-resistant steel shafts

Shaft diameters	(mm)	5	8	10	12	16	20	25	30	40	50	60	80

Mill-cut lengths

Longer shafts than those quoted can also be supplied on request. These shafts are made up of shaft sections of precisely measured length joined end-to-end (see section on "Composite shafts" below).

Type of shaft	Diameter (mm)	Mill-cut length[1] (m)
Solid shafts[2]	< 20 (except 12 and 16) 12, 16 and ≥ 20	3.5 up to 4.0 5.7 up to 5.9
Tubular shafts	25 up to 100	4 up to 5.9[3]
Corrosion-resistant steel shafts	5 up to 20 > 20 up to 80	3.5 up to 4.0 5.7 up to 5.9

[1] The first 50 mm at each end of mill-cut lengths may deviate slightly from the nominal diameter.

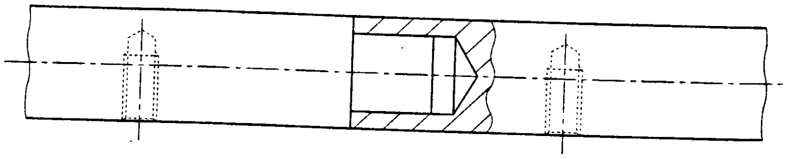
[2] Solid shafts of lengths up to 8 m and diameter 20 and over are available on request.

[3] Depending on size.

Composite shafts

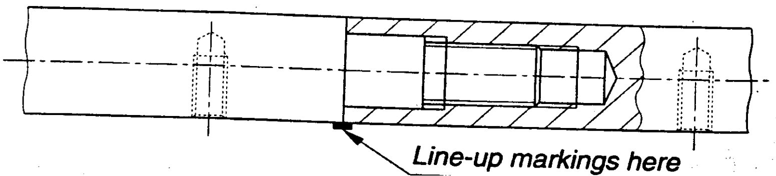
Shafts with plug-type joints

We can supply composite shafts for applications requiring a shaft longer than the mill-cut lengths available. The shaft sections are joined together by a spigot-and-recess arrangement, one section having a locating plug and the other a mating hole (see figure below). The joined shaft must rest on a full-length, continuous support rail or must at least be supported at regular intervals with one of the supports located at the joint between the shaft sections (see "Shaft Support Rails"). The shafts must be axially tensioned against each other at the time the shaft assembly is screwed to the shaft support rail. This is to prevent a gap opening at the joint when the shaft assembly is loaded in service.



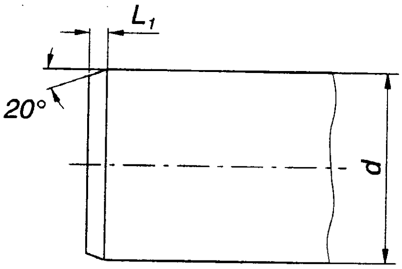
Shafts with threaded joints (does not apply to corrosion-resistant steel shafts)

At the customer's request, the plug can be threaded and the mating hole tapped (see figure below). Line-up markings are then provided at the ends of the mating shaft sections to facilitate vertical alignment of the radial holes for attachment of the coupled shaft assembly to the shaft support rail. All machining and marking operations are carried out on the shaft sections after they have been hardened and ground. Since it will not be possible to re-grind the finished joint, extreme care is taken in the machining of the centering arrangement to ensure precision mating of the shaft sections.



Shaft Machining

Steel shafts intended for use as linear motion guideways for Linear Bushings must be chamfered at the ends to prevent damage to the ball retainers or wipers when the linear bushing is being pushed onto the shaft.
The figure and the table give the dimensions of the chamfers required.
Linear bushings with seals must not be pushed over sharp edges in the shaft (e.g. retaining ring grooves), as this would damage the seal lips.



Shaft	Ø d	(mm)	5	8	10	12	16	20	25	30	40	50	60	80
Length of chamfer	L_1	(mm)	1.5	1.5	1.5	2	2	2	2	2	3	3	3	3

Hardened and ground steel shafts in mill-cut lengths are always in stock. These can be cut to any desired length and machined to give them any of the following:

- reduced-diameter ends
- radial or axial holes
- male or female threads
- recesses
- countersinks
- or other specially-machined features.

Length tolerances for cut-to-size shafts

Dimensions in mm

Length	Tolerance
up to 400	±0.5
over 400 up to 1000	±0.8
over 1000 up to 2000	±1.2
over 2000 up to 4000	±2.0
over 4000 up to 6000	±3.0
over 6000 up to 8000	±3.5

Steel shafts with closer length tolerances can also be supplied against a surcharge.