

Precision steel shafts

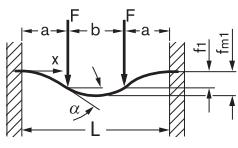
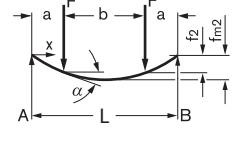
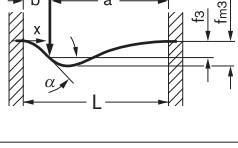
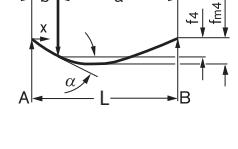
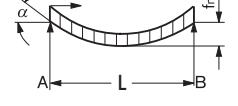
# Technical data

## Shaft deflection

When steel shafts are used as guides for linear bushings, any shaft deflection that occurs due to load must remain within certain tolerances. Otherwise function and service life will be impacted.<sup>1)</sup>

In order to make it easier to calculate warping, we have listed the most frequent load conditions with their corresponding deflection equations.

The equations for calculating any shaft inclination in the linear bushing ( $\tan \alpha$ ) can also be found in this table.

Case no.	Load condition	Deflection equation	Shaft inclination in linear bushing
1		$f_1 = \frac{F \times a^3}{6 \times E \times I} \times \left(2 - \frac{3 \times a}{L}\right)$ $f_{m1} = \frac{F \times a^2}{24 \times E \times I} \times (3 \times L - 4a)$	$\tan \alpha_{(x=a)} = \frac{F \times a^2 \times b}{2 \times E \times I \times L}$
2		$f_2 = \frac{F \times L \times a^2}{2 \times E \times I} \times \left(1 - \frac{4}{3} \times \frac{a}{L}\right)$ $f_{m2} = \frac{F \times L^2 \times a}{8 \times E \times I} \times \left(1 - \frac{4}{3} \times \frac{a^2}{L^2}\right)$	$\tan \alpha_{(x=a)} = \frac{F \times a \times b}{2 \times E \times I}$
3		$f_3 = \frac{F \times a^3 \times b^3}{3 \times E \times I \times L^3}$ $f_{m3} = \frac{2 \times F \times a^3 \times b^2}{3 \times E \times I \times L^2} \times \left(\frac{L}{L + 2 \times a}\right)^2$	$\tan \alpha_{(x=b)} = \frac{F \times a^2 \times b^2}{2 \times E \times I \times L^2} \times \left(1 - \frac{2 \times b}{L}\right)$
4		$f_4 = \frac{F \times a^2 \times b^2}{3 \times E \times I \times L}$ $f_{m4} = f_4 \times \frac{L + b}{3 \times b} \times \sqrt{\frac{L + b}{3 \times a}}$	$\tan \alpha_{(x=b)} = \frac{F \times a}{6 \times E \times I \times L} \times (3 \times b^2 - L^2 + a^2)$
5		$f_{m5} = \frac{5 \times F \times L^3}{384 \times E \times I}$	$\tan \alpha_{(x=0)} = \frac{F \times L^2}{24 \times E \times I}$

1) Super linear bushings and experience no reduction in load rating or service life at a shaft inclination of up to 30° ( $\tan 30^\circ = 0.0087$ ).

F	= Load	(N)	I	= Planar moment of inertia	(mm <sup>4</sup> )
a	= Distance	(mm)	$f_1$ to $f_4$	= Deflection at point of force application	(mm)
b	= Distance	(mm)	$f_{m1}$ to $f_{m5}$	= Max. deflection	(mm)
L	= Shaft length	(mm)	$\alpha$	= Shaft inclination in the linear bushing	(°)
E	= Young's modulus	(N/mm <sup>2</sup> )			

The table includes the values for the maximum acceptable shaft inclination ( $\tan \alpha_{\max}$ ) when using standard linear bushings.

When  $\tan \alpha = \tan \alpha_{\max}$ , the acceptable static load is about 0.4  $C_0$ .

Shaft $\varnothing d$ (mm)	$\tan \alpha$	$\alpha$ ( $10^{-3}^\circ$ )	$\alpha$ ( $^\circ$ )	$\alpha$ (min.)	$\alpha$ (sec)
5	12.3	70.5	0.0705	4	14
8	10.0	57.3	0.0573	3	26
12	10.1	57.9	0.0579	3	28
16	8.5	48.7	0.0487	2	55
20	8.5	48.7	0.0487	2	55
25	7.2	41.3	0.0413	2	29
30	6.4	36.7	0.0367	2	12
40	7.3	41.8	0.0418	2	30
50	6.3	36.1	0.0361	2	10
60	5.7	32.7	0.0327	1	58
80	5.7	32.7	0.0327	1	58

#### E x I values and weights for steel shafts

Solid shafts		
$\varnothing d$ (mm)	E x I (N x mm <sup>2</sup> )	Weight (kg/m)
3	$8.35 \times 10^5$	0.06
4	$2.64 \times 10^6$	0.10
5	$6.44 \times 10^6$	0.15
8	$4.22 \times 10^7$	0.39
10	$1.03 \times 10^8$	0.61
12	$2.14 \times 10^8$	0.88
14	$3.96 \times 10^8$	1.20
16	$6.76 \times 10^8$	1.57
20	$1.65 \times 10^9$	2.45
25	$4.03 \times 10^9$	3.83
30	$8.35 \times 10^9$	5.51
40	$2.64 \times 10^{10}$	9.80
50	$6.44 \times 10^{10}$	15.32
60	$1.34 \times 10^{11}$	22.05
80	$4.22 \times 10^{11}$	39.21

Hollow shafts			
Shaft diameter	E x I		Weight
Outer (mm)	Inner (mm)	(N x mm <sup>2</sup> )	(kg/m)
8	3.0	$4.14 \times 10^7$	0.34
10	4.0	$1.00 \times 10^8$	0.51
12	4.0	$2.11 \times 10^8$	0.79
16	8.0	$6.33 \times 10^8$	1.18
20	14.0	$1.25 \times 10^9$	1.25
25	14.0	$3.63 \times 10^9$	2.63
30	19.0	$7.01 \times 10^9$	3.30
40	26.5	$2.13 \times 10^{10}$	5.50
50	29.6	$5.65 \times 10^{10}$	9.95
60	36.5	$1.15 \times 10^{11}$	13.89
80	57.4	$3.10 \times 10^{11}$	19.02

Calculation values:

Young's modulus =  $2.1 \times 10^5$  N/mm<sup>2</sup>

Density = 7.8 g/cm<sup>3</sup>