Trapezoidal Lead Screws

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Technical Description

Due to their geometric shape, trapezoidal lead screws are especially well suited for transmitting movements and forces. The wide thread flanks can absorb high axial forces, while the large pitch transmits movements with relatively few revolutions.

The trapezoidal lead screws GN 103 have rolled threads. Thread rolling involves applying the geometry of the thread to the raw material by means of two rotating dies. Due to the strain hardening, the continuous chamfer and the press-polished surface, rolled spindles have higher strength, better wear properties and superior corrosion resistance compared to machined spindles.

Thread Dimensions
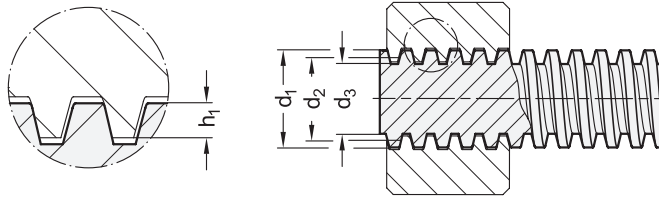
d x P Single-start	d_1 Nominal diameter	d_2 Flank diameter		d_3 Minor diameter		h_1 Thread bearing depth
		min.	max.	min.	max.	
8 x 1.5	8	7.013	7.183	5.921	6.2	0.75
10 x 2	10	8.739	8.929	7.191	7.5	1
10 x 3	10	8.191	8.415	6.15	6.5	1.5
12 x 3	12	10.191	10.415	8.135	8.5	1.5
14 x 4	14	11.64	11.905	9.074	9.5	2
16 x 4	16	13.64	13.905	11.074	11.5	2
18 x 4	18	15.64	15.905	13.074	13.5	2
20 x 4	20	17.64	17.905	15.074	15.5	2
24 x 5	24	21.094	21.394	18.019	18.5	2.5
30 x 6	30	26.547	26.882	22.463	23	3
36 x 6	36	32.547	32.882	28.463	29	3
40 x 7	40	36.02	36.375	31.431	32	3.5
50 x 8	50	45.468	45.868	40.368	41	4

d x Ph Multi-start	P_T Pitch	d_1 Nominal diameter	d_2 Flank diameter		d_3 Minor diameter		h_1 Thread bearing depth
			min.	max.	min.	max.	
12 x 6	P3	12	10.191	10.415	8.135	8.5	1.5
16 x 8	P4	16	13.640	13.905	11.074	11.5	2
20 x 8	P4	20	17.640	17.905	15.074	15.5	2
24 x 10	P5	24	21.094	21.394	18.019	18.5	2.5
30 x 12	P6	30	26.547	26.882	22.463	23.0	3
40 x 14	P7	40	36.020	36.375	31.431	32	3.5

Lead Accuracy

The lead accuracy describes the max. permissible deviation between the theoretical and actual movement distance. For trapezoidal lead screws, the max. permissible lead deviation is 0.1 mm / 300 mm movement distance.

Straightness

The straightness of trapezoidal lead screws depends largely on the manufacturing method, the material and the dimensions. For spindles with rolled thread, the straightness is typically 0.3 mm / 300 mm length.
If higher requirements apply with regard to straightness, the spindle can be straightened after manufacturing.

Multi-Start Thread

Single-start spindle

Multi-start spindle
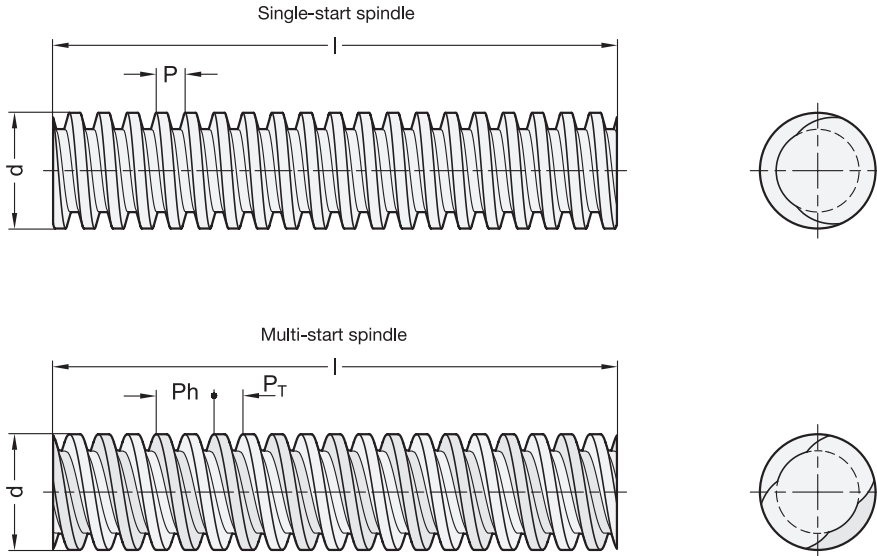
Multi-start spindles have several independent threads with the same thread profile as single-start spindles. The individual threads run parallel to each other and have the same lead. The lead is indicated with **Ph** and is a multiple of the pitch **P**, which describes the distance between two neighboring threads.

Lead Ph / pitch P = Number of thread starts

Multi-start threads are used when greater adjustment travel per revolution is to be achieved or no self-locking is required. With specified values for feed rate and speed, multi-start threads allow the spindle diameter to be reduced.

Backlash on Reversal

The play between the thread flanks of the spindle and the spindle nut results in backlash when the direction of the drive rotation changes. This backlash must be overcome before the spindle nut moves in the opposite direction.

This backlash on reversal prevents the spindle nut and spindle from jamming up. As the diameter increases, the backlash on reversal also increases, as described in DIN 103.

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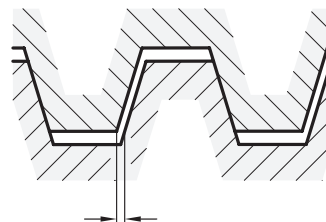
Theoretical Critical Buckling Force

Due to the unfavorable ratio of length to diameter, threaded spindles are subject to a risk of lateral buckling under axial compressive stress.
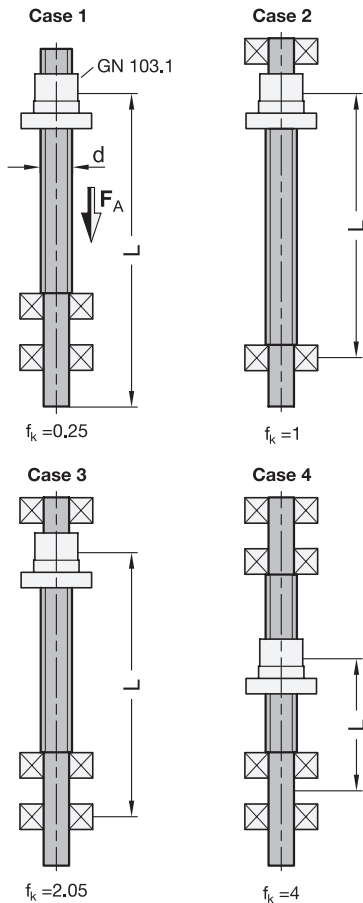
The following load cases (as per Euler) and the diagram for determining the theoretical critical buckling force can be used to determine the max. permissible axial force for the respective spindle bearing. Safety factors must be taken into account in accordance with the application.
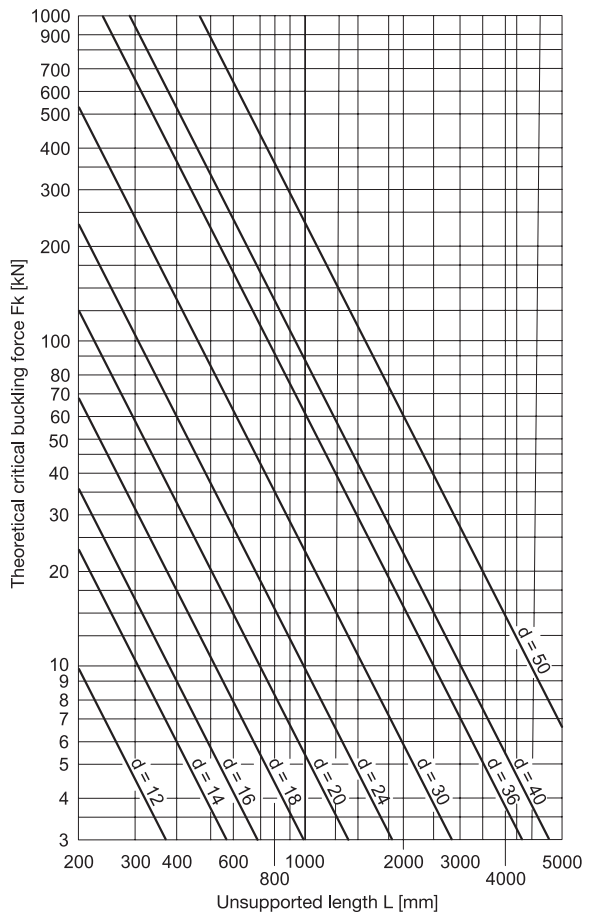
Maximum permissible axial force

$$F_{A\,max} = F_k \times f_k \times v$$

$F_{A\,max}$	Max. permissible axial force [kN]
F_k	Theoretical critical buckling force [kN]
f_k	Correction factor for the load case
v	Safety factor

Load cases (as per Euler)

Theoretical critical buckling force diagram

Case 1

GN 103.1

d

F_A

L

$f_k = 0.25$

Case 2

L

$f_k = 1$

Case 3

L

$f_k = 2.05$

Case 4

L

$f_k = 4$

Theoretical critical buckling force Fk [kN]

Unsupported length L [mm]

d = 12, d = 14, d = 16, d = 18, d = 20, d = 24, d = 30, d = 36, d = 40, d = 50

Theoretical Critical Rotational Speed

Due to their geometry, threaded spindles tend to experience not only buckling but also resonant bending vibration. The resonant bending vibration also significantly increases the risk of buckling. The theoretical critical rotational speed must therefore be considered alongside the critical buckling force.
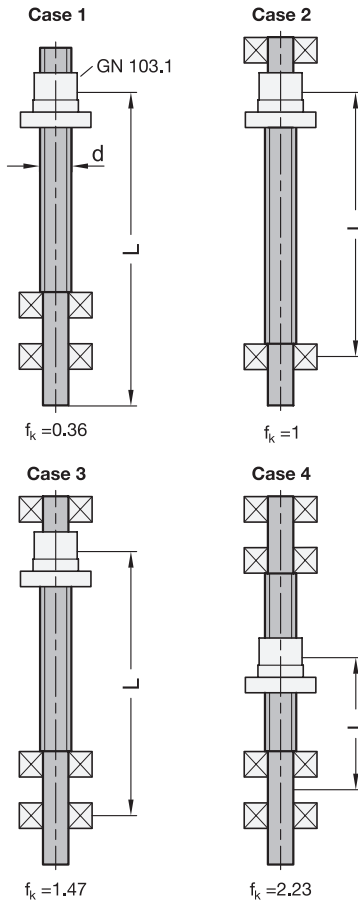
The formula and diagram below can be used to estimate the critical rotational speed indepently of the critical buckling force and in consideration of the respective spindle bearing. Safety factors must be taken into account in accordance with the application.
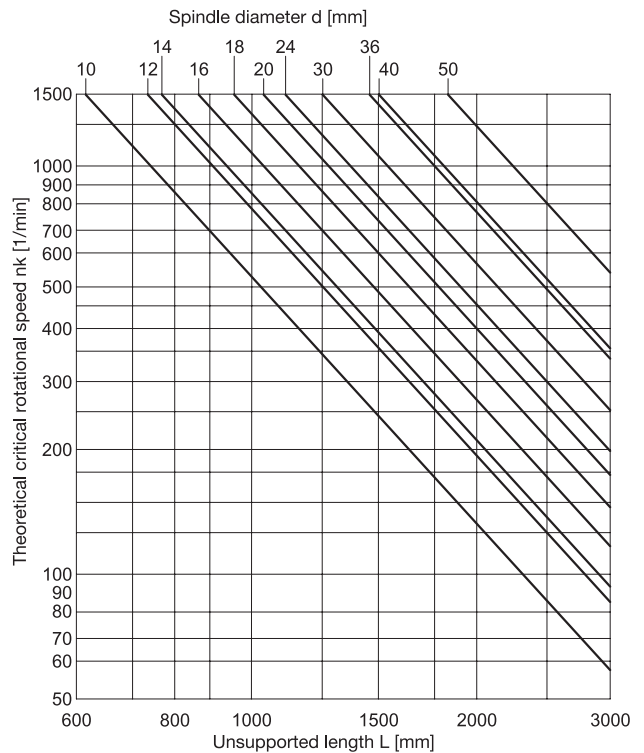
Maximum permissible rotational speed

$$n_{max} = n_k \times f_k \times v$$

n_{max}	Max. permissible rotational speed [rpm]
n_k	Theoretical critical spindle rotational speed [rpm]
f_k	Correction factor for the load case
v	Safety factor

Load cases

Theoretical critical rotational speed diagram

Case 1 — GN 103.1 — d — L — $f_k = 0.36$

Case 2 — L — $f_k = 1$

Case 3 — L — $f_k = 1.47$

Case 4 — L — $f_k = 2.23$

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Flank Pressure

The axial load of the spindle drive creates flank pressure, i.e. surface pressure, between the thread flanks of the spindle and the nut. As the thread flanks slide against each other during operation, the thread flanks experience wear with increasing operating time. As a measure to minimize the wear as far as possible, in addition to sufficient lubrication, the flank pressure should not exceed certain limit values.

The flank pressure between the thread flanks can be calculated as below.

$$p = \frac{F_a \times P}{m \times d_2 \times \pi \times h_1 \times k}$$

p	Flank pressure [N/mm²]
F_a	Axial force [N]
P	Lead / pitch
m	Load-bearing nut length [mm]
d_2	Thread flank diameter [mm]
h_1	Thread bearing depth [mm]
k	Thread factor (in general = 0.75)

Frictional Heat

All losses that occur during the conversion of the rotational movement to translational movement heat the spindle drive. The frictional heat is directly influenced by the flank pressure of the thread flanks, the speed and the operating time. To prevent over-heating, all external influences should be taken into account. In addition to correct lubrication, this also includes the ambient temperature, for example.

Lifespan

The lifespan of trapezoidal lead drives in a given application depends on the expected ambient conditions. Factors such as installation position, the load moved, the adjustment speed, the movement frequency and the ambient temperature have influence on the service life.

Self-locking

If the friction angle of the trapezoidal lead screw is larger than the lead angle, the trapezoidal lead drive is self-locking. The friction angle is influenced by the material pairing, the lubrication and the surface roughness.

A distinction is also made between static and dynamic self-locking. With static self-locking, the nut only begins to move as a result of external influences. With dynamic self-locking, a moving nut comes to a stop once the drive is removed.

Theoretically, all single-start lead screws have static self-locking, with the exception of the plastic nut. In practice, the self-locking often cannot be guaranteed due to the surface roughness, lubrication and vibration. As a safety measure, locking option should therefore always be provided.

Multi-start screw drives are never self-locking due to the large lead.