A.MANNESMANN
A member of
SCHNEEBERGER linear technology

AM Ball Screws

TÜV CERT
EN ISO 9001
QA 041005506

We have the
know-how for machining and
treatment of super refined
alloy, tool or special steels...

Mechanical engineering with special machinery of highest efficiency and equipment for high precision internal and external machining, special coatings to increase wear resistance and to achieve special individual requirements.
Hardening and annealing shops for any heat treatment,
vertical furnaces up to 14 m deep,
nitriding equipment,
salt bath hardening.

Straightening equipment.

Quality assurance with inspection of materials and continual production checks according to most modern methods, certified according to EN/ ISO 9001.

Certified quality,
inspection certificates according to DIN-EN – in cooperation with Classification Companies or authorized experts.

Continously integrated data processing system granting most economic execution of orders and reliable delivery schedules.

Manufacturing partners of internationally successful Companies producing machinery of high demand.

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AM Ball Screws

Precision components for transmission of motion and power at maximum efficiency.

Quality advantages

- **Free and easy motion with the greatest axial rigidity, i.e. also minimum loss of friction under load.**
- **Smooth running nuts without jerk, minimum torque variation – also for the advantage of long-time application without wear.**
- **Rolling resistance of the ball tracks as well as wear and shock resistance are the results of using a special nitriding steel, heat treated with high core strength and deep-nitrided.**
  These are the reasons for the long-time operation security of screw flanks and nut preload.
- **Highest speed rate, lowest heat generation and quiet running.**

  This is a measurable profit by intelligent precision.

AM Quality –
An additional value for
performance and life rating

Deep-nitrided AM ball screws have been giving excellent service for decades.

As one of the first manufacturers, we have continued development through advancing technology by a continual interchange of experience with leading users of these machine components.

This publication introduces you to the outstanding quality of the AM system. It contains useful technical data and information on design and calculations for the engineering department.

Our individual consultancy service is ready to provide advice to make your work easier, since primary features vary from application to application.

To enable us to submit a quotation tailored to your needs we have listed the most important questions in the enclosed questionnaire.

Previous catalogues are no more valid.

Contents	**page**

Nominal diameters

from 25 up to 200 mm

Lengths

continuous thread lengths up to 10,000 mm and above this length as a coupled design

Nominal diameter/lead combinations as specified in German standards DIN 69051, part 2

d_0 \ P	5	10	15	20	25	30	40
25	●	●					
32	●	●	●	●			
40	●	●	●	●	●	●	
50	●	●	●	●	●	●	
63	●	●	●	●	●	●	●
80		●		●		●	●
100		●		●		●	●
125		●		●			●
160				●			●

other leads upon request

AM system with deep-nitrided screws

From experience gained over many years we can confidently recommend our deep-nitrided screws.
The greater hardness of the thread flanks $\geqq$ 900 HV $\triangleq$ 67 Rockwell and high core strength of the material (850 - 1,000 N/mm^2) have the following benefits:

- increased wear resistance
- increased fatigue strength
- consistent long-term accuracy
- longer, real service life
- corrosion inertness
- deep-nitrided screw ends and bearing seats

Ground ball tracks of screws and nuts

enable us to grant even dimensional accuracy of flank diameter and profile over the entire length, high surface quality and optimum running properties.
Lead accuracy: corresponding to ISO-tolerance IT1, 3, 5, depending on the needs of each application.

Special designs

- Telescopic screws (multistage) made of steel or aluminium
- up to diameter 400 mm hollow bored
- designs of stainless steel
- designs without lubrication

Please explain your special case of application.

AM Ball Screws

perfect in

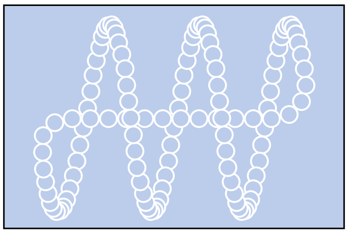
- high speed application
- positioning accuracy of highest resolution
- highest dynamic, also in
- long-time application

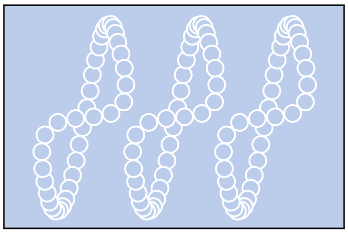
AM Nut design

$n_{perm.} \times d_0 = 200{,}000$

$n_{perm.}$ = max. permissible speed of rotation

d_0 = nominal ∅





Our system of ball recirculation proved over many years has been continuously developed to the utmost perfection.

In certain cases of application characteristic values up to $n_{perm.} \times d_0 = 200{,}000$ are achievable, speed rates up to 150 m/min and accelerations up to 20 m/sec². Please inform us about your special case of application.

Optimised geometry and manufacturing precision ensure ease and smoothness of ball transfer within the walls of the nut. This produces uniform and quiet running at all speeds and high axial rigidity with the least friction.

The threads in the nut are fully ground using the complete length of the nut. This means that there are no inactive threads and best concentricity is achieved.

The external shape of the nut is closed and smooth and provides complete protection for the ball-return track against dirt and damage.

Preload

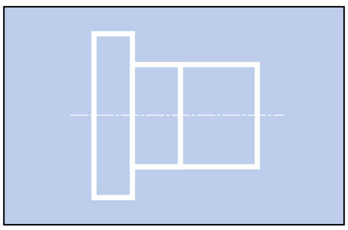
The proven AM fixed preload is brought about form-fit by feather key. We set the preload and it remains constant for the complete service life of the unit.

Wiper seals

The internal brush type wiper seals can flex in the circumferential direction to adapt on the threads, but are stiffened by back plates in the axial direction to prevent dirt contaminating the lubricating film. Friction is so low, that heat generation is avoided, and wiping is improved by the thread profile ground on the base.

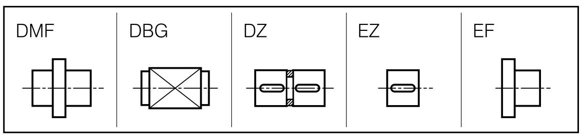
For critical application (e.g. machining of casting, aluminium, magnesium, etc.) we give you our advice for offering special designs.

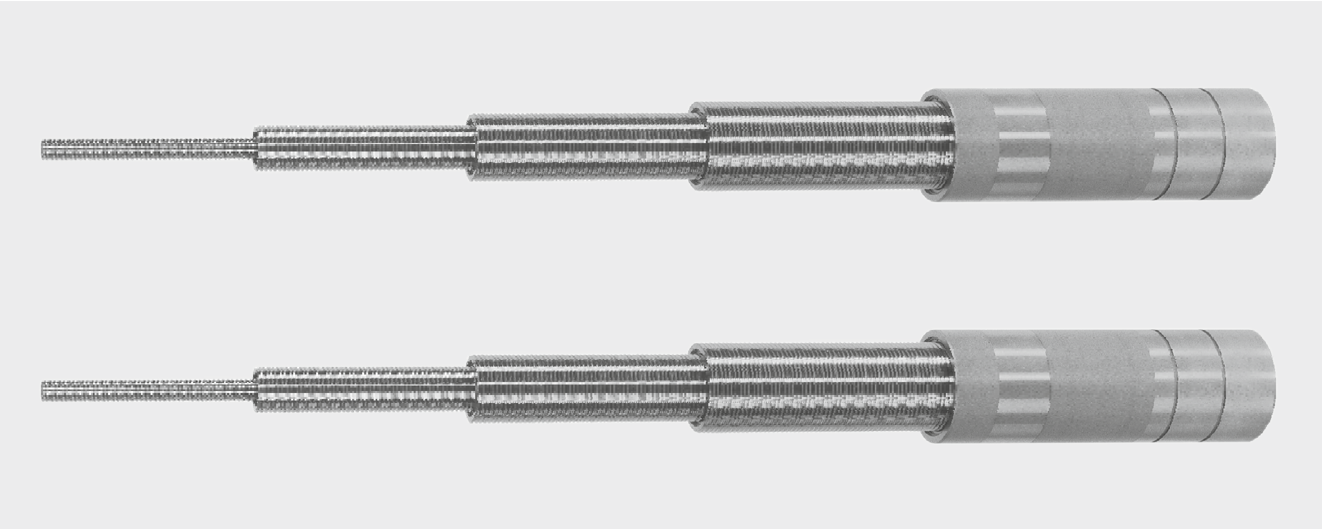
Nut designs



AM-standard:
Double nut with end flange, preloaded, with wipers
for **driven screws**
see data sheet AM 2.51
for **driven nuts**
see data sheet AM 2.52

Other types of nut upon request





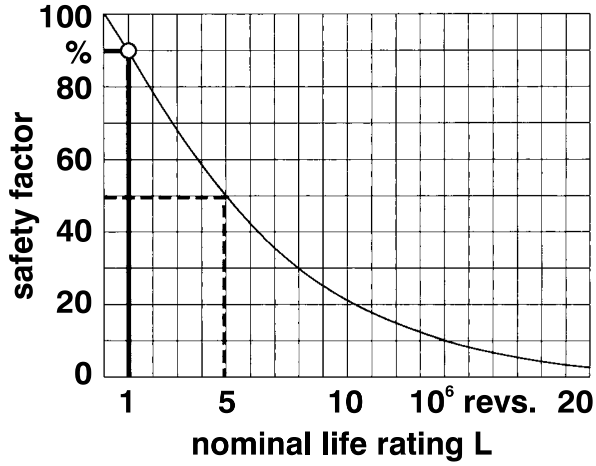
Telescopic Ball Screws	= 4 stage
draw ratio i	= 3.64
max. height h_{max}	= 1,375 mm
largest Ø	= 130 mm
dynamic load rate C_{dyn}	= 26 kN
max. number of rotation n_{max}	= 600 min^{-1}

hollow-bored ball screws
e.g. 370 x 20 mm

Design calculations

Life rating L

This is a nominal period of operation, computed for a given load and speed of rotation, at the end of which 90% of seemingly identical ball screws are not expected to exhibit any signs of fatigue (pitting).
For example in case of 50% security (instead of 90%) the calculation results in a quintuple life-rating.
The real life time is significantly affected by **design, material and production** of the ball screw.
This is the reason for our long-time success.
The manufacturer or the user of the machine has to take care for keeping the ball screw protected against probable contaminants which may cause wear and loss of preload.



Dynamic load rating **C_{am}**	standard AM design as shown in data sheet	calculated in accordance with German Standard DIN 69051 part 4

The mean load F_m, n_m, (F_w)

According to the calculation as per DIN 69051 part 4 the axial force $\mathbf{F_{ai}}$ of different operation intervals (rough-working, finish-machining, rapid motion, standstill) have to be determined under consideration of the corresponding numbers of rotation n_i and the portion of time in per cent $\mathbf{q_i}$ and to convert the representative mean value by the given formula: $\mathbf{F_m}$, $\mathbf{n_m}$.

$$\sqrt[3]{\frac{1}{100\, n_m}\left(F_{w1}^{3} \cdot q_1 \cdot n_1 \cdot + F_{w2}^{3} \cdot q_2 \cdot n_2 + \ldots\right)} = F_m$$

$$\frac{1}{100} \cdot (n_1 \cdot q_1 + n_2 \cdot q_2 + \ldots) = n_m$$

However, ball screws for high dynamic application (high-speed) need a high preload of nuts $\mathbf{F_{pr}}$ and therefore this preload has to be taken into consideration for calculation of life rating $\mathbf{L_h}$.
For taking account of $\mathbf{F_{pr}}$ please consider the effective force $\mathbf{F_{wi}}$ as a result of the axial force $\mathbf{F_{ai}}$ of one operating interval (see page 9+12).

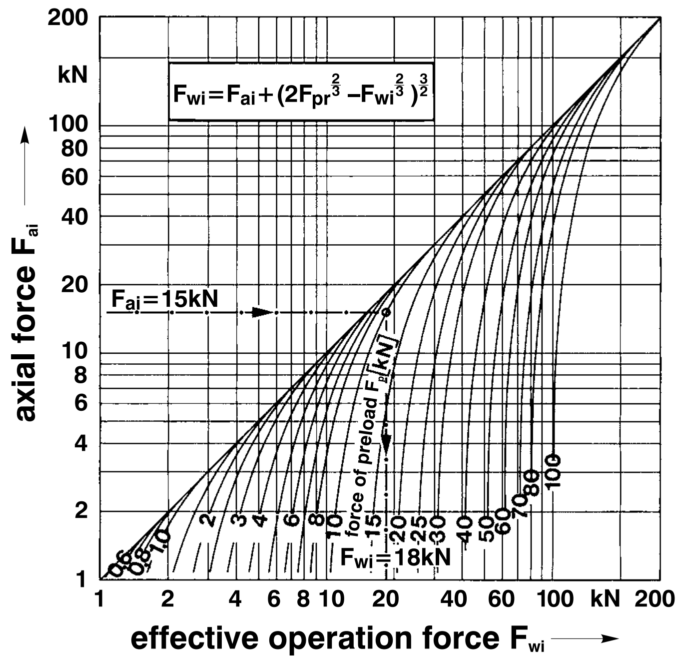
load spectrum

	q_1	F_{ai}	F_{wi}	n_i
1				
2				
⋮				
	100%	-	F_{mw}	n_m

The mean load calculated by the load spectrum is the effective mean load $\mathbf{F_{mw}}$.

Influence of the nut preload on the life rating

The relevant operation force $\mathbf{F_{ai}}$ gets a further force by the preload $\mathbf{F_{pr}}$. The operation force becoming effective by this result can be taken from the diagram beside. You have to take $\mathbf{F_{wi}}$ (instead of $\mathbf{F_{ai}}$) for the load spectrum of the life rating calculation.



Calculation of the nominal life rating (fatigue)

After the multiple of 10^6 load revolutions the fatigue $\mathbf{L_{10^6}}$ begins statistically.

$$L_{10^6} = \left(\frac{C_{am}}{F_{mw}} \right)^3$$

The number of revolutions n_m determines the duration of fatigue = screw's running time $\mathbf{L_{h1}}$ in hours.

$$L_{h1} = \frac{16666}{n_m} \left(\frac{C_{am}}{F_{mw}} \right)^3$$

The hours of the machine utilization time $\mathbf{L_{hm}}$ determine the utilization time of the machine by the operating factor ED of the axis.

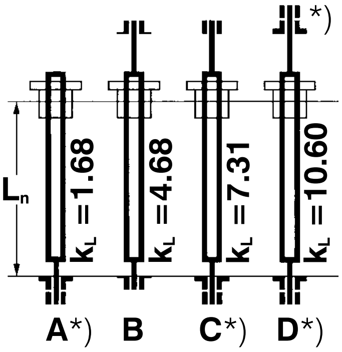
$$L_{hm} = \frac{\lambda}{ED} \cdot L_{h1}$$

$$\left(ED = \frac{\text{total running time of screw } \mathbf{L_{h1}}}{\text{total machine utilization time } \mathbf{L_{hm}}} \right)$$

$\lambda = 1$ for uni-directional loading
$\lambda = 2$ for load directions with equal distribution -
(load directions with unequal distribution
for each part of nut to be calculated individually)

Permissible speed of rotation $n_{perm.}$

The calculated values are to be understood as an approximation. For an exact calculation we ask you to contact us.



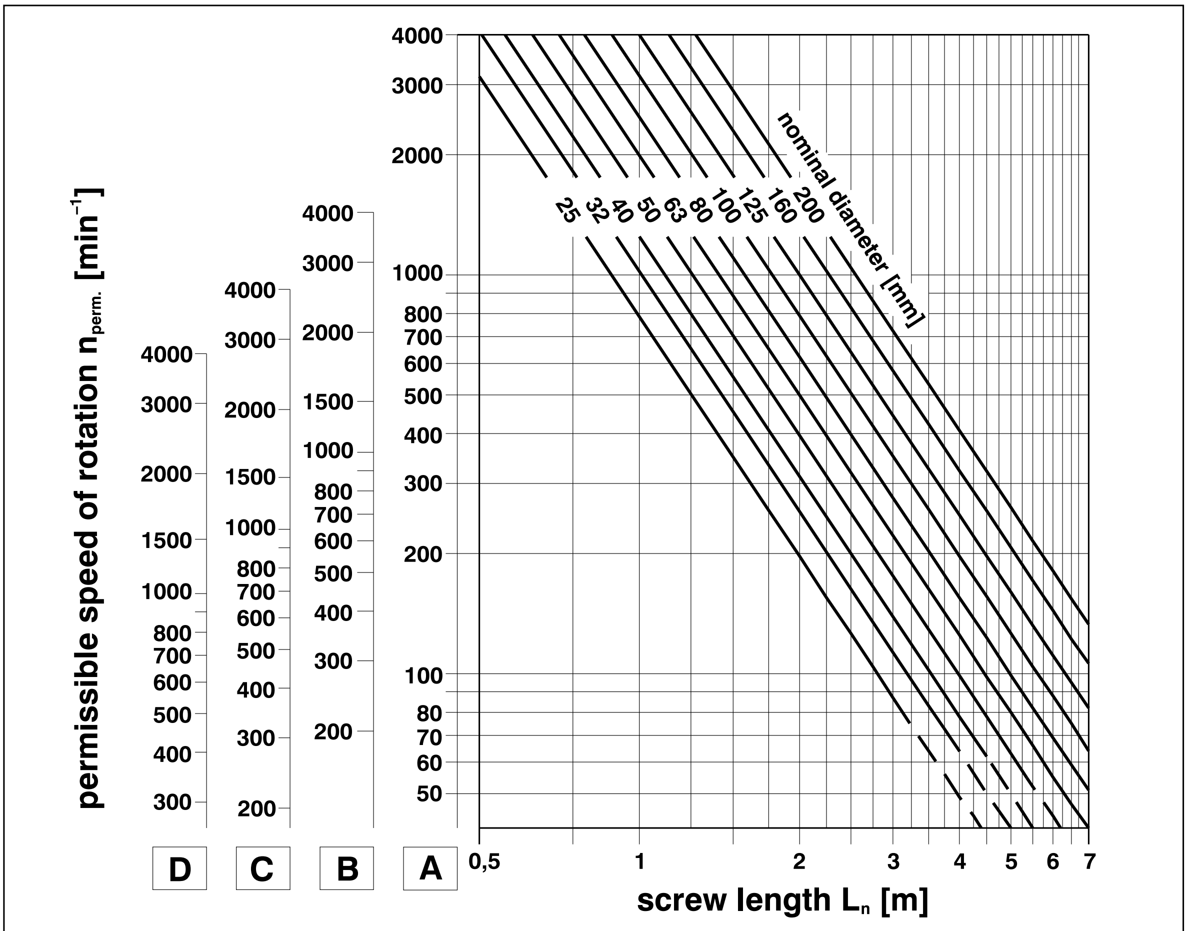
*) directionally stable mounting

Transverse resonant vibration is excited in any shaft which exceeds its permissible speed of rotation. On ball screws this results in excessive radial loading of the nut system.
The maximum permissible speed of rotation is 20% below the critical speed.This safety factor has been taken into account in the diagram below.

The concrete execution of screw bearing is of great importance for the permissible speed of rotation.

$$n_{perm.} = \frac{d_0 + d_k}{L_n^2} \cdot k_L \cdot 10^7 \ [min^{-1}]$$

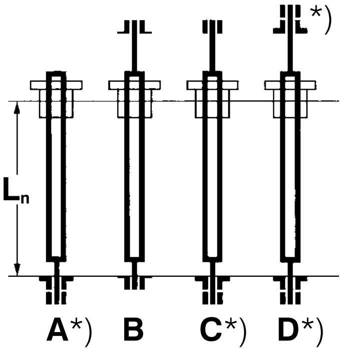
d_0 = nominal diameter	[mm]
d_k = core diameter	[mm]
L_n = screw length	[mm]
K_L = bearing factor	
d_0, d_k see data sheet	



Inadmissible sagging of screw

Ball screws with high slenderness **L_n/d_0 >50,** need to have an additional supporting in the free area of threaded length to prevent it from sagging. Otherwise the ball screw is subject to inadmissible operating conditions. This is also important for driven nut systems!
In limiting cases of application **L_n/d_0 >40,** please contact us.

Permissible compressive axial load $F_{perm.}$



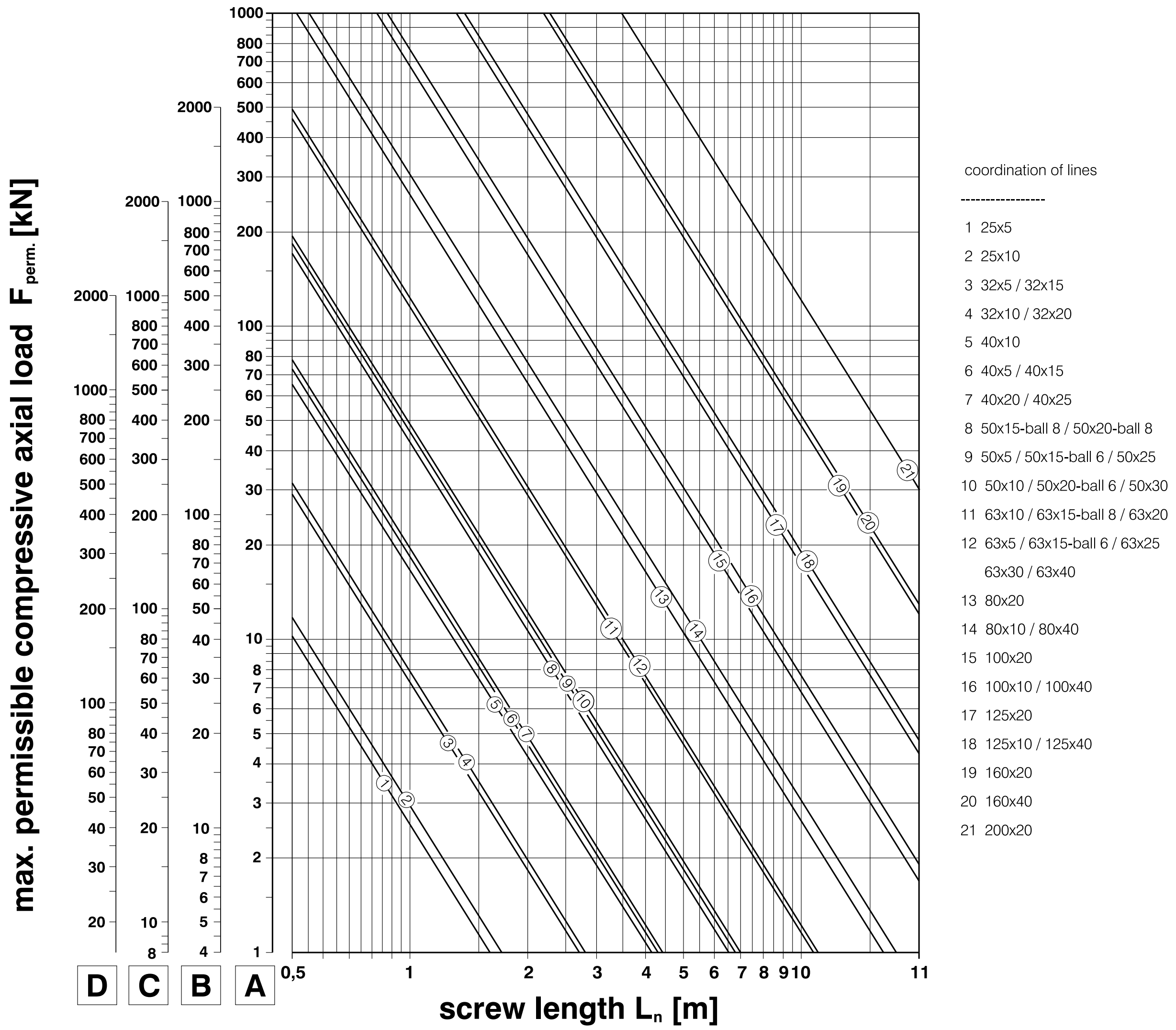
*) directionally stable mounting

The permissible axial load can be determined from the following diagram as a function of the screw bearing, the nominal diameter $\mathbf{d_0}$ x lead **P** and the screw length $\mathbf{L_n}$. Concerning the compressive axial load $\mathbf{F_k}$ the diagram includes a threefold safety factor (ν **= 3**).

$$F_{perm.} = \frac{F_k}{\nu} \leqq C_{0am}$$

The static load rate $\mathbf{C_{0am}}$ is the load limit which causes a plastic deformation of 10^{-4} x ball-∅ under standstill condition.

C_{0am} see data sheet



Steps for increasing the permissible compressive axial load

- Adoption of bearing arrangement **D**
- Application of a tensile load to the screw in cases **A** or **C**
- Increase nominal diameter
- Relieve compressive load (by means of hydraulic or counter-weight)

Axial rigidity R_{ax}

$$\frac{1}{R_{ax}} = \frac{1}{R_{nu}} + \frac{L_s}{R_s \cdot k}$$

k =1 in case of fixed bearing one side
=4 in case of fixed bearing both sides

R_{nu} =nut rigidity on nut flange

R_s = Spindle rod rigidity per m (see following table)

L_s = loaded length of spindle in m

Approx. values for rigidity of nuts and spindle rod rigidity per m											
	[mm]	d_0	=	25	32	40	50	63	80	100	125
	[kN/µm]	R_{nu}*)	=	0.5	0.7	1.0	1.5	2.1	2.5	2.8	3.1
	[kN/µm]	R_s	=	0.09	0.15	0.22	0.36	0.6	0.9	1.5	2.4

*) Values for preloaded double nuts with P =10 mm, other leads see data sheet.

AM offers you
the ideal combination of
– high axial rigidity with
– low no-load torque

The result: high grade of efficiency and low operating temperature (see picture page 13)

Preload F_{pr}

Ball screws for high-dynamic machine axis with changing load directions need a nut preload F_{pr}.

Particulary in case of acceleration and braking the balls have to remain in contact with the thread profile of screw and nut. The value of preload is mainly dependant on the acceleration and braking force F_{ai}.

$$\mathbf{F_{ai\,(perm.)} \leqq F_{pr} \cdot 2.83}$$

For standard cases the force of preload F_{pr} amounts to approx. 0.07 · C_{am}, but may be increased up to max. 0.15 · C_{am}.
If required the optimum force of preload F_{pr} id determined and just adjusted under consideration with the customer's requirement concerning axial rigidity R_{nu} and no-load torque T_{pro}.

The natural rolling power in the contact area of the rolling bodies is an unavoidable loss. Therefore, the real value of efficiency η_a is always some percent under 100%.

$$\eta_a = \frac{\tan\varphi}{\tan(\varphi+\rho)}$$ transformation of a torque into an axial force

$$\eta'_a = \frac{\tan(\varphi-\rho)}{\tan\varphi}$$ transformation of an axial force into a back torque

The angle of friction ρ is determined by **manufacturer's specific features:**

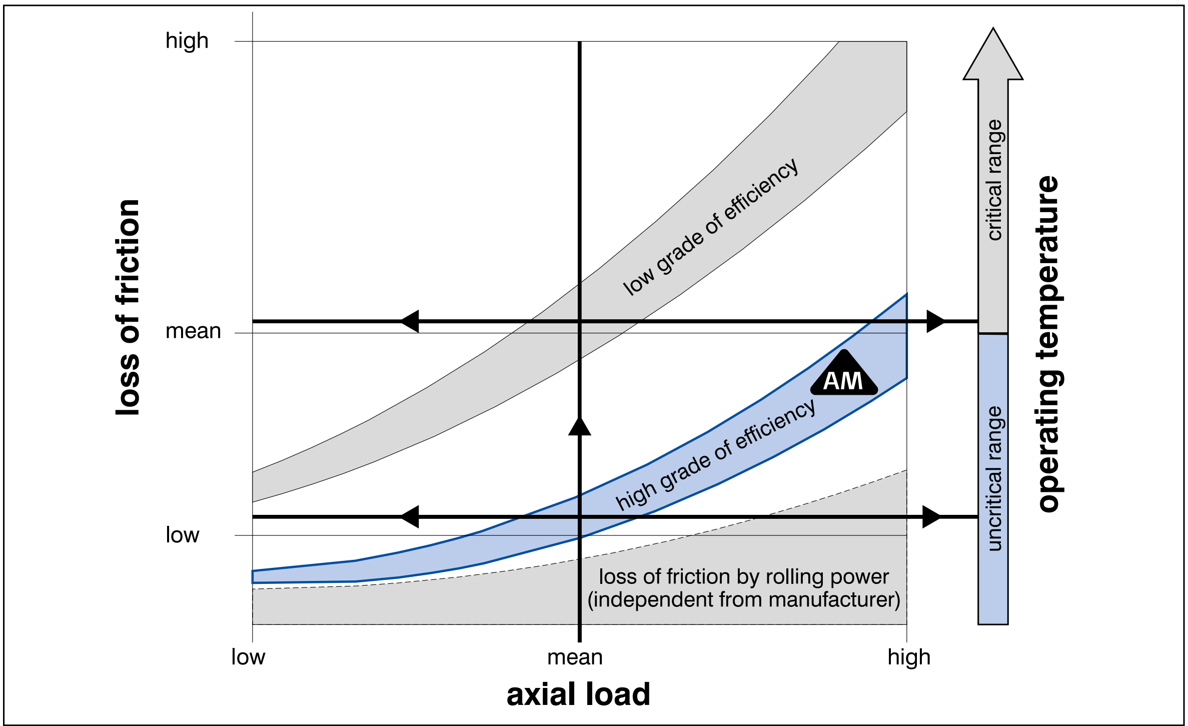
- form of ball tracks of screw and nut
- manufacturing accuracy
- surface hardness of screw and nut
- surface quality of the ball tracks
- recirculating system

Users' operation data:

- axial load and acceleration
- lubrication
- number of rotation
- mounting accuracy of screw and nut

Under operating conditions the axial load F_a can be a multiple of the nut preload F_{pr}. Therefore, the manufacturer's specific features have an important influence on the practical efficiency η_a.
The effect on the operation temperature is shown in the diagram.

After adjustment of the nut preload and the resulting axial rigidity the angle of friction ρ of AM ball screws is approx. 0.2°.



Driving torque

Transformation of a torque M_a into an axial force F_a

$$Ma = \frac{F_a \cdot P}{2000 \cdot \pi \cdot \eta_a}$$

Transformation of an axial force F_a into a back torque M_e

$$Me = \frac{F_a \cdot P \cdot \eta'_a}{2000 \cdot \pi}$$

F_a	= axial load	[N]
P	= lead (pitch)	[mm]
φ	= angle of lead	[degree]
ρ	= angle of friction	[degree]
ηa	= real value of efficiency	
$\eta' a$	= real value of efficiency	
Ma	= driving torque	[Nm]
Me	= back torque	[Nm]

Lead accuracy

Concepts, designations and tolerances according to ISO/DP 3408/3 differentiate between: Nominal, specified and actual lead.

A straight line is determined from the actual lead gradient.
The tolerance lines of the variation run parallel to the straight lines.

To compensate for changes in length of the screw due to thermal expansion and / or preload, the user has to state the specified lead or the value

c = (compensation), giving the difference between the specified and the nominal lead over the usable length l_u.

All deviations **e** are then related to the specified lead.

Subscript a:
actual values, the most important:

$\mathbf{e}_{oa}$ = mean actual lead deviation related to usable length of thread l_u.

$\mathbf{v}_{300a}$ = actual variation over 300 mm

$\mathbf{v}_{ua}$ = actual variation over l_u

Subscript p:
permissible values, the most important:

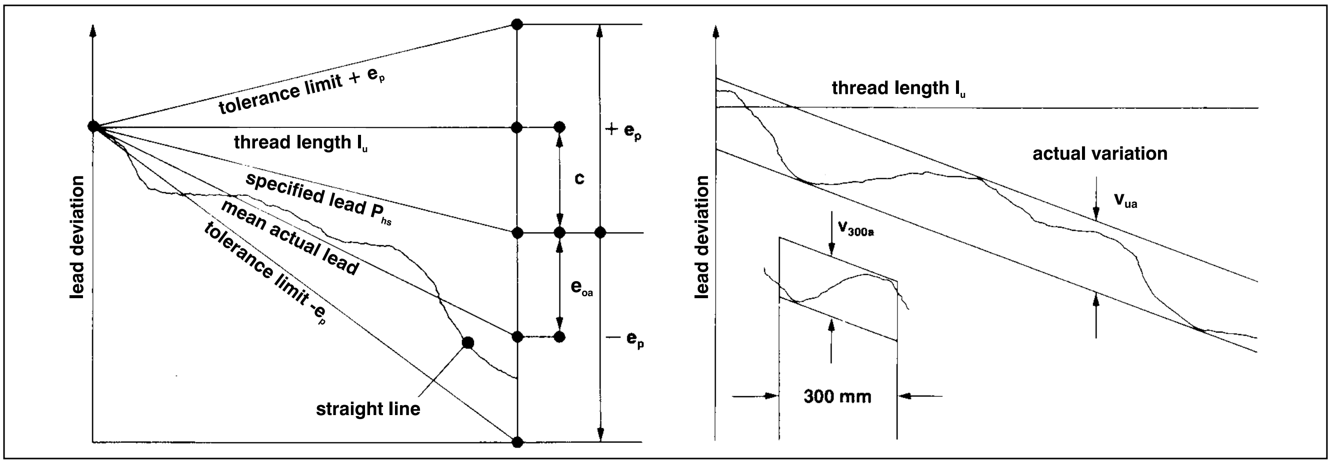
$\pm\mathbf{e}_p$ = permissible mean lead deviation related to l_u

$\pm\mathbf{e}_{1000p}$ = permissible mean lead deviation over 1000 mm

$\mathbf{v}_{300p}$ = permissible variation over 300 mm

$\mathbf{v}_{up}$ = permissible variation over l_u

These tolerance limits are specified in the classes for accuracy in relation to length.



Type T

In case of existing parallel measuring systems such as linear scales or position transmitters the ball screw's function is restricted to feed motion. Then, the lead of the screw is not used as distance measuring scale. This is type T (T=transport). Although the ball screw may operate with µm-accurate feed motion in a closed loop position control (attitude control) with direct measuring system the ball screw only gives the uniform transport without jerk.

V_{300p} (µm)			$\pm e_{1000p}$ (µm)		
IT 1	IT 3	IT 5	IT 1	IT 3	IT 5
6	12	23	80		

Type P

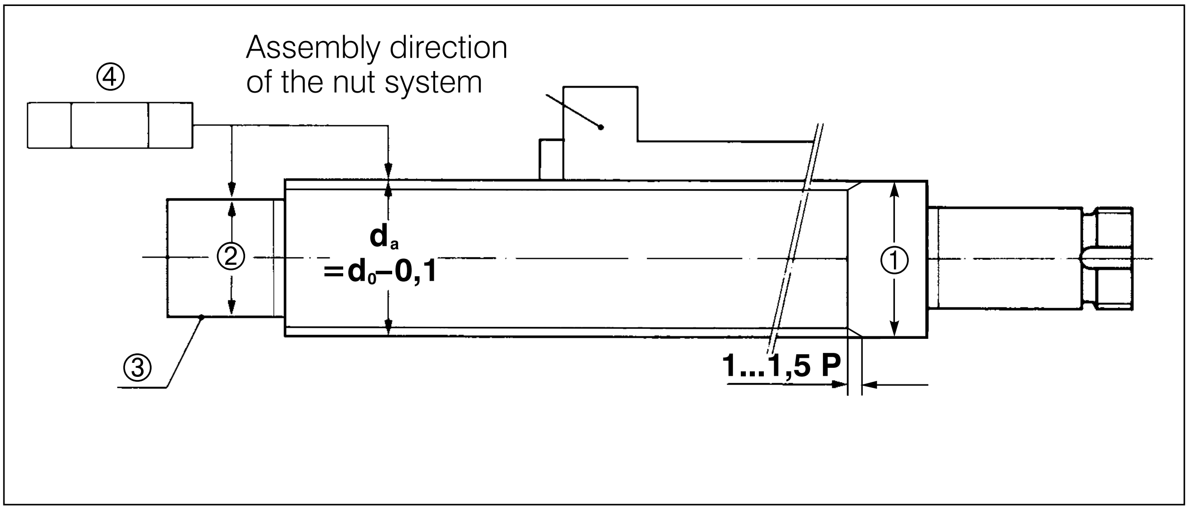
When a shaft encoder indicates angular steps as position (distance) increments on the center line of the screw or the motor the ball screw lead has to be of highest precision, because it has become a measuring unit.

This is the same for application of incremental motors. This application with "indirect" measuring system requires type P (P=positi-oning), because the screw with its travel length represents the absolute measuring system.

Thread length		V_{up} (µm)			$\pm e_p$ (µm)		
from	to	IT 1	IT 3	IT 5	IT 1	IT 3	IT 5
≦315		6	12	23			
316	400	6	12	25	7	13	25
401	500	7	13	26	8	15	27
501	630	7	14	29	9	16	30
631	800	8	16	31	10	18	35
801	1000	9	17	35	11	21	40
1001	1250	10	19	39	13	24	46
1251	1600	11	22	44	15	29	54
1601	2000	13	25	51	18	35	65
2001	2500	15	29	59	22	41	77
2501	3150	17	34	69	26	50	93
3151	4000	21	41	82	32	62	115
4001	5000	25	50	99	39	76	140

Manufacturing drawing

Recommendations for cost-effective design



① Collar dia. ≦ screw outside dia. $\mathbf{d_a}$
Avoid as far as possible collar dia. larger than $\mathbf{d_a}$.

② Shaft diameter on at least one side of the thread for the nut assembly either $\mathbf{d = d_k = d_0}$**-ball dia. – 0,5** (also applies for undercuts).

③ AM-ball screws have deep-nitrided bearing seats. Please identify all surfaces which have to remain unhardened. Fine threads always remain unhardened.

④ Form and position tolerances in accordance with DIN 69051.

⑤ Provide spindles of different lengths – with equality of nominal dia. and lead – with identical screw ends and nuts ("Parts family").

⑥ Consider nuts in accordance with German standards DIN, preferably AM standard 2.51 or 2.52.

Please include these performance characteristics in your drawing:

Characteristics			
nominal dia.	d_0		mm
nominal lead	P		mm
direction of lead		L.H. ○ R.H. ○	
ISO precision class – type T / type P		IT○ type ○	
tolerance of specified lead	$\pm e_p$		$\mu m/l_u$
variation	V_{300p}		µm
type of nut system (abbr.)	type No.		
nut rigidity	R_{nu}		kN/µm
- no-load torque without wipers	T_{pr0}		Nm
- preload	F_{pr}		kN
mean load	F_m		kN
mean speed of rotation	n_m		min^{-1}
max. speed of rotation	n_{max}		min^{-1}
acceleration	a		m/sec^2
moved mass	m		kg
lubrication			
mounting position		horizontal ○	vertical ○
driven element		nut ○	screw ○

Lubrication

Oil or grease lubrication conforming to the roller bearing lubrication specifications is absolutely essential for ball screws.

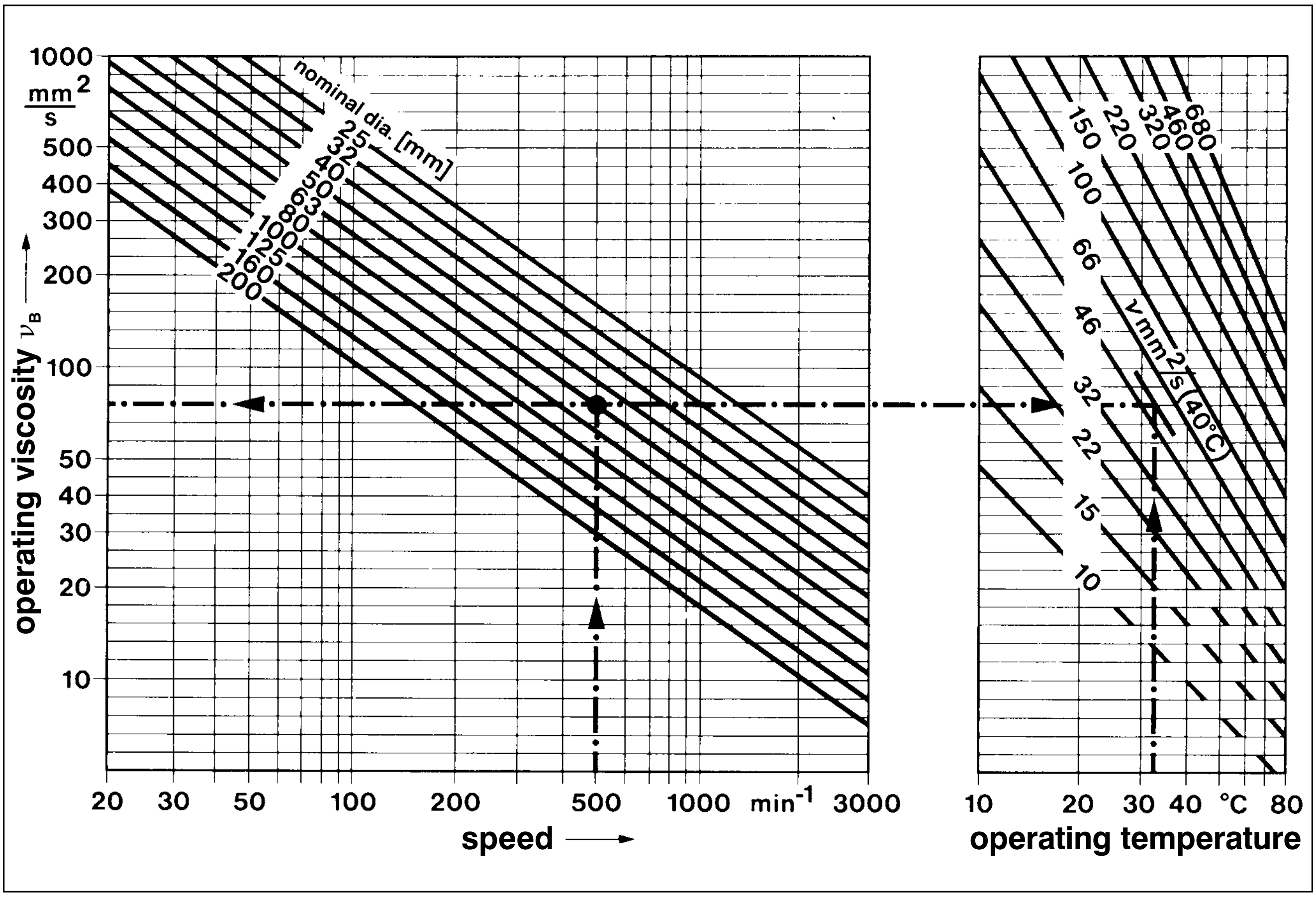
The life rating calculation presupposes an elasto-hydrodynamic lubrication film. Basically the commercially available mineral oils and greases for roller bearings and transmissions are suitable.

For high speed application synthetical oils have been proved.

Solid grease lubrication additives such as graphite, molybdenum disulphide (as dry lubrication or dispersed in oil) are prohibited.

The diagrams contain the characteristics and selection criteria important for the usual operating conditions.

When the customer does not require any special lubrication instructions the performance test and delivery will be effected with lubrication oil DIN 51517/3 CLP ISO VG 100.



Oil lubrication

The most suitable oil viscosity can be determined from the diagram, depending on speed, nominal diameter and operating temperature. The minimum viscosity is 21 cSt. at operating temperature.

Apart from viscosity, which is to be determined according to the speed range, load is decisive for the chemical additives to increase the carrying capacity:

For load of $\mathbf{F_a > 0,15\ C_{am}}$, it is necessary to use lubricating oil CLP with EP additives in accordance with German standards DIN 51517, part 3. (Maximum limiting stress to the failure load step at least 12, test in accordance with German standards DIN 51354, part 2).

The quantity of lubrication oil is dependant on the operating and screw data.

Example: a ball screw d_0=50, P=20, n_{max}=3,000 min^{-1} should be operated with a minimum lubrication oil quantity of 0.5 cm³/h.

Increasing the lubrication oil quantity improves the washout of any contaminants.

Grease lubrication

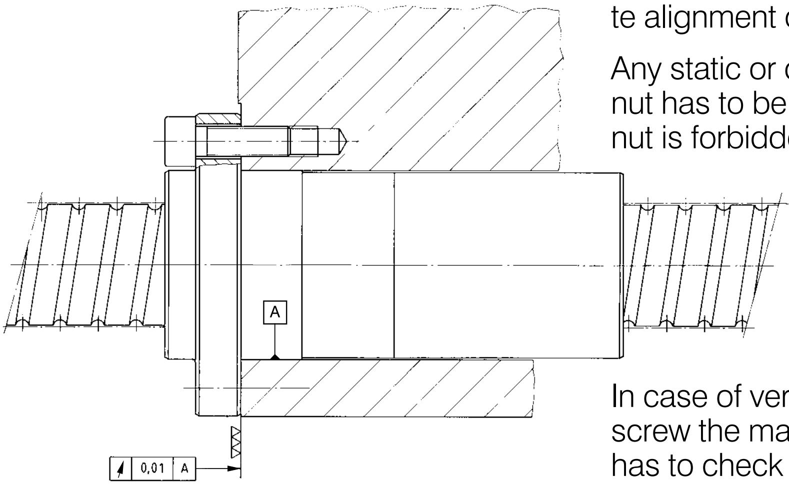
For grease lubrication
it is necessary to use
AM wiper seals

NL GI-class DIN 51878	fulling penetration acc. DIN 51804	lithium soap grease		synthetical special grease
		($F_a \leq 0{,}15\ C_{am}$) without EP-additives	**($F_a > 0{,}15\ C_{am}$)** with EP-additives	
0	355-385 (semi-liquid fluid grease)	–	high load up to **800 min^{-1}**	
1	310-340 (very soft)	interior load up to **800 min^{-1}**	–	**high speed-application** up to **4,000 min^{-1}**
2	265-295 (soft)	normal load up to **600 min^{-1}**	very high load up to **600 min^{-1}**	
3	220-250 (medium firm)	high load up to **400 min^{-1}**	–	–

In principle, re-lubrication is necessary. Due to the permanent travel of the nut there is a loss of lubricant. Maintenance or renewal of the quantity of grease is also necessary in view of ageing and contamination.
Re-lubrication intervals have to be established in practice for each case, because they depend on other influences such as load, speed of rotation, temperature, environmental conditions, mounting position and contaminants.

Installation notes

Spindle nut



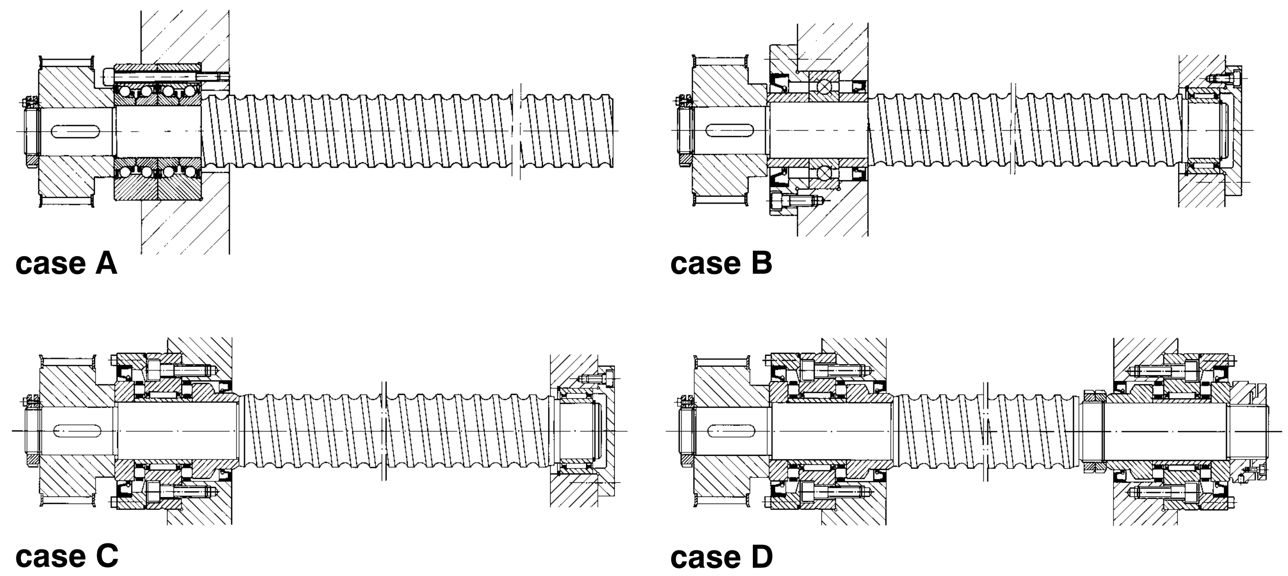
In order to ensure a proper function, we recommend the angularity of your flange locating surface to spindle axis be maintained, as indicated in the figure, i.e. also note alignment of bearing to guidance track.

Any static or dynamic radial force on the nut has to be avoided. Dismounting the nut is forbidden.

In case of vertical application of the ball screw the manufacturer of the machine has to check whether a safety catch device must be provided.

Installation notes

Bearing of spindles



Protective devices

Impurities, foreign substances:
The working space of a ball screw should be protected against the ingress of chips, abrasive grain or other foreign substances by a suitable covering.
Even deposits of soft particles, such as fibres, wood dust, etc. preventing the lubrication film, have to be avoided.

In principle, we recommend the use of wipers.

Overload by crash or collision:
Overload clutches and predetermined breaking points are recommended, since shock loads can occur in collisions, which exceed the value of the static load rating. When the spindle has a high moment of inertia, the predetermined breaking point on the nut locator or axial bearing is more effective than an overload coupling between drive an spindle.

Shock absorbing devices prevent damage if the limit switches have been overrun.

Never lay ball screws down on nuts, store them on V-blocks.

- production of one-off parts, series and units
- high precision and wear resistance
- ready-for-installation according to your drawings
- completely manufactured in our own works
- all dimensions, lengths 300 mm up to 12,000 mm in one piece, up to 15,000 mm on request
- machine components with high slenderness ratio

for machine tools and general mechanical engineering	main spindles and main spindle assemblies with rams, ball screws, racks, quills, spline shafts, threaded spindles, driving shafts, adjusting screws and nuts, knife shafts, guide columns, straightening rolls, twisting screws, filament winding mandrels…
plastics processing machinery	screws and barrels, grooved sleeves, crossheads and shafts...
compressors	piston rods, plungers, cylinder liners...
heavy diesel engines	control shafts, flange and intermediate shafts...
special solutions	units and aggregates, boring bars, lifting and telescopic spindle units

as well as similar machine components for many other applications in industry and technology.

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