NUT RIGIDITY

The calculations necessary to determine the rigidity of the ball zone are very involved. However the following approximation will give a value that is sufficiently accurate for most purposes.

For double ball nut assemblies, preloaded to one tenth of the Dynamic Capacity, the rigidity can be approximated by using the equation:

$$R_z \simeq 10 \cdot d_o \cdot i$$

where
R_z = rigidity of ballzone (N/µm)
d_o = nominal diameter of ballscrew (mm)
i = number of rows of balls in one nut
For single ball nuts the rigidity may be approximated by:
$R_z \simeq 5 \cdot d_o \cdot i$

OVERALL SYSTEM RIGIDITY

The overall rigidity is calculated by the following formula:

$$\frac{1}{R} = \frac{1}{Rs} + \frac{1}{Rn} + \frac{1}{Rb} + \frac{1}{Rh}$$

where
R = overall rigidity (N/µm)
Rs = rigidity of screw shaft (N/µm)
Rn = rigidity of nut (N/µm) which normally $\simeq 0.8 \cdot R_z$
Rb = rigidity of bearings (N/µm)
Rh = rigidity of nut mounting and bearing housings (N/µm)
Exact calculation to DIN 69051 (Part 6)

MATERIALS

JENA-TEC use high quality steels, specially processed to ensure high performance product.

Ballshafts: Inductively hardened tempered steel Cf 53 balltrack hardened to 60± 2 HRC. Core and spindle ends non-hardened.

Ballnuts: Case hardened steel 16MnCr5 or roller-bearing steel 100Cr6.

Note: Special materials and stainless steels can be supplied as required. Please discuss your requirements with JENA-TEC Engineers.

STATIC LOAD RATING

Static load rating Co: is the centred axial load under which the permanent combined deformation of balls and tracks at the most heavily loaded point on the ballscrew drive is 1/10000 of the ball diameter.

Note: The figure for maximum static load, beyond which brinelling of the balltrack will occur, is given in the ballscrew data sheets.

DRIVING TORQUE REQUIREMENTS

The torque which must be applied to a ballscrew in order to produce an axial thrust is given by:

$$T = \frac{F \cdot Ph_o}{2 \cdot 10^3 \cdot \pi \cdot \eta}$$

which $= \frac{F \cdot Ph_o}{5655}$ when $\eta = 0.9$

where
T = torque (Nm)
F = axial thrust load (N)
Ph_o = lead (mm)
η = efficiency of the ballscrew

To this the torque due to drag from preloading, wiper seals, and inertia of the ballscrew shaft should be added.

The preload drag torque may be calculated from the following:

$$\max Tp = \frac{0.004 \cdot d_o \cdot Fp}{1000}$$

where
Tp = dynamic preload drag torque (Nm)
Fp = preload (N)
d_o = nominal diameter of ballscrew (mm)

The preload drag torque will decrease as the external load is applied and can be ignored if the applied load is three times that of the preload.

The torque required to overcome the inertia of the ballscrew shaft, assuming constant acceleration, is given by the following formula:

$$T_1 = \frac{0.08 \cdot 10^{-12} \cdot d^4 \cdot L \cdot n}{t}$$

where
T_1 = torque to overcome inertia (Nm)
d = average dia. of ballscrew shaft (mm)
(shaft outside dia + root dia) · 0.5
L = length of ballscrew (mm)
n = maximum rotational speed (min^{-1})
t = time taken to start or stop (sec)

Note: When a mass is being moved, it is important that acceleration and deceleration forces are taken into account in calculating the axial load on the ballscrew.

SERVICE LIFE / LIFE EXPECTANCY

The use of correctly treated high grade steels and attention to detail mean that long life and trouble free operation can be expected from JENA-TEC ballscrews. It is important that the design, application, installation and maintenance procedures are correctly followed to achieve maximum service life. Assuming the above criteria are met the calculations are as follows:

The estimated service life of a ballscrew can be calculated as follows:

$$L = \left(\frac{Ca}{Fm}\right)^3 \cdot 10^6$$

where

L = the estimated life in revolutions achieved or exceeded by 90% of an appropriately large number of identical ballscrew drives before the first signs of material fatigue.

Ca = the dynamic load rating (N)

Fm = the equivalent applied load (N). Loads can act on a ballscrew drive in two directions. Fm should be determined for each of the load directions; the larger value should then be used in the calculation of L. It is useful to draw a schematic diagram as (Fig 11), it should be noted that any preloading represents a continuous load.

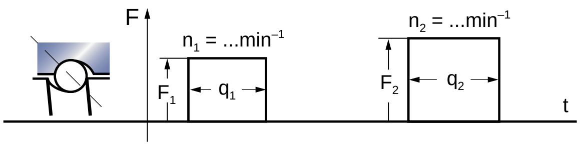


FIG. 11

From Fig 11

n_m = Mean speed

$$n_m = \frac{n_1 \cdot q_1 + n_2 \cdot q_2 + n_n \cdot q_n}{100}$$

$$Fm = \left(\frac{F_1^3 \; n_1 \cdot q_1}{n_m \cdot 100} + \frac{F_2^3 \cdot n_2 \cdot q_2}{n_m \cdot 100} + \ldots\ldots\right)^{1/3} \cdot f_a$$

where

q1, q2 = the components of the duration of a load in one direction in %. ($q_1+q_2+q_n$ = 100%)

n_1, n_2 = the speeds during q_1, q_2 (rpm)

F_1, F_2 = the axial load in N in one load direction during q_1, q_2

fa = the machine specific allowance.

fa = 1 for low acceleration values and no vibration

fa = 1.5 for higher acceleration and with vibration and medium impact loads

Please consult JENA-TEC in the case of impact loads exceeding 0.5 · Ca.

Ballscrew drive with preloaded nut system:

In cases where preloaded nut systems are used, the above calculations are used to determine the service life of each individual nut in both load directions. The overall service life is then calculated as follows:

$$L = (Fm1^{10/3} + Fm2^{10/3})^{-0.9} \cdot Ca^3 \cdot 10^6$$

where

L = the overall service life (as above)

Fm1 or Fm2 = the load of the nut 1 or 2 in the relevant load direction

Ca = the dynamic load rating (N)

Important Note: The calculations above are valid only with correct lubrication. The presence of dirt, or lubrication starvation may reduce service life to a fraction of the calculated value. Reduced service life must also be expected with very short strokes.

Ballscrew nuts cannot absorb radial forces or tilting moments.

LEAD ACCURACY

JENA-TEC precision ballscrews are manufactured to an international grading system as shown below or to customers' own specific requirements.

	Permissible deviation Grade (IT)					
	1	3	4	5	7	10
Lead Accuracy						
per 300 mm	0.006	0.012	0.016	0.023	0.052	0.210
per foot	0.0002	0.0005	0.0006	0.0009	0.002	0.008
Total travel deviation						
length ≤ 1000	0.011	0.021	0.029	0.040	0.090	-
›1000 ≤ 2000	0.018	0.035	0.048	0.065	0.150	-
›2000 ≤ 3000	0.026	0.050	0.069	0.093	0.210	-

Note: Grade 1 is offered only by special arrangement. Grade 3-5 are normally acceptable for machine tool applications.
Transport screws are generally not preloaded.

Specified Lead: Nominal leads may be modified to accommodate specific requirements. A minus compensation will, for example, accommodate for temperature or pre-tensioning in the shaft.

Ground screws: are available in Grade 1 to Grade 7
Rolled screws: are available in Grade 5 to Grade 10
Cut screws: are available in Grade 7 to Grade 10

FEATURES OF JENA-TEC PRECISION LEADSCREWS

ACCURACY, QUALITY & RELIABILITY: JENA-TEC continue to service customers who prefer to use traditional leadscrews. The JTPL and JTRL range of leadscrews are manufactured with the same precision, experience and standards of release applied to ballscrew products.

AVAILABILITY: A range of precision leadscrews in metric and inch sizes in single and multi-start, standard leads, with nuts in various materials, to suit application, are available either directly from inventory or on a short delivery from our manufacturing base.

LEADSCREW DRIVE OPTIONS:

- Single start threads
- Steel, Grey Iron & Phosphor bronze nuts
- Multi start threads
- Gunmetal & plastic nuts for high speed low noise operation
- Trapezoidal & acme threads
- Special threadforms by request

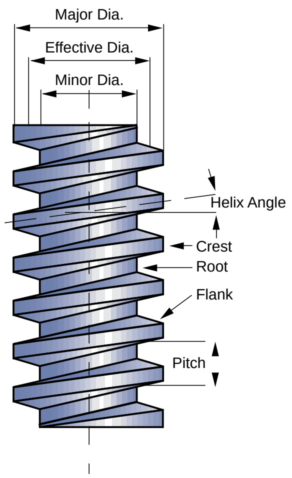
Note: Trapezoidal thread spindles with pitch angles of less than 2.5˚ can be considered self locking.

JENA-TEC LEADSCREW RANGE DETAILS:

JTpL Range: A range of high precision ground and whirled leadscrews and nuts manufactured in a range of threadforms to customer requirements.

JTrL Range: A range of precision rolled trapezoidal screws in single and multi-start configurations with optional nut materials.

A selection of some of the many thread forms available in rolled, milled, whirled and ground formats in both metric and inch sizes.



END FEATURES AND NUTS

End features and nuts are produced to meet customer requirements. Splines, keyways, fine threads, trunnions, gear forms and ground diameters are a few of the features regularly supplied.

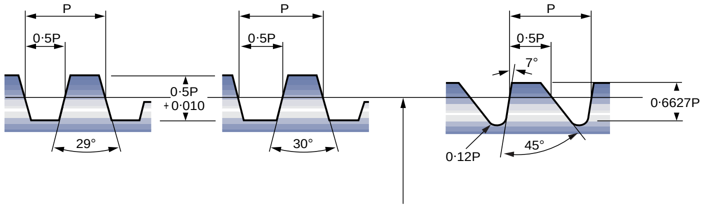


FIG. 12

DESIGN CONSIDERATIONS LEADSCREWS:

LOAD RATING: The load rating of leadscrews is dependent, as a general principle, on the material used, surface quality, state of wear, surface pressure, lubrication conditions, running speed and temperature, and thus on the duty cycle and provision for heat dissipation.

The permissible surface pressure is dependent on the running speed of the screw drive.

With motion drives the surface pressure should not exceed 10 - 15N/mm².

The pv values specified for the nut material and the bearing surface provide a simple method of calculating the permissible running speed.

Example:

Load = 10000N

Required bearing surface $= \dfrac{10000\text{N}}{10\text{N/mm}^2} = 1000\ \text{mm}^2$

pv value of Gunmetal $= 300\text{N/mm}^2 \cdot \text{m/min}$

Permissible surface running speed $= \dfrac{300\text{N/mm}^2 \cdot \text{m/min}}{10\text{N/mm}^2} = 30\text{m/min}$

If this speed is too low, a larger spindle must be selected to obtain a larger bearing surface.
The permissible running speed can now be used to calculate the spindle speed; which in turn can be used together with the spindle pitch to calculate the feed speed.

Feed speed = Speed x lead

CRITICAL SPEED OF LEADSCREW SPINDLES:
The comments and calculations for establishing the maximum permissible spindle speed are the same as for ballscrews (see page 28/29). The theoretical critical speed can be taken from Fig 8 page 28/29.

BUCKLING FORCE LEADSCREW SPINDLES:
The comments and method of calculation for establishing the buckling force are the same as those used for ballscrews (see page 31). The theoretical critical buckling force can be taken from Fig 9 page 30.

DRIVING TORQUE REQUIREMENTS/ INSTALLATION AND MAINTENANCE:

The required torque for a leadscrew drive (T) is governed by the load, the spindle pitch and the efficiency of the screw drive and bearings. With short run up times and high speeds, the acceleration torque should be checked and additionally, in the case of leadscrew drives, the breakaway torque
The same calculation (page 33) as for ballscrew drives can be made to establish drive torque. In the case of leadscrew drives the efficiency (η) is much lower than for ballscrew drives.

Calculations:

$$T = \frac{F \cdot Pho}{2 \cdot 10^3 \cdot \pi \cdot \eta}$$

$$\eta = \frac{\tan \alpha}{\tan (\alpha + \beta)}$$

$$\eta^1 = \frac{\tan (\alpha - \beta)}{\tan \alpha}$$

where
η = the efficiency of conversion of rotary motion into linear motion.
η^1 = the efficiency of conversion of linear motion into rotary motion.
α = lead angle of the thread.
β = coefficient of friction
$\tan \beta = \mu$ = coefficient of friction.

In general terms the efficiency of leadscrew (η) are based on a coefficient of friction of $\mu = 0.1$

	μ during start up		μ in motion	
	dry	lubricated	dry	lubricated
Metal nuts	~0.3	~0.1	~0.1	~0.04
Plastic nuts	~0.1	~0.04	~0.1	~0.03

Note: For efficiency values of Leadscrews please contact JENA-TEC Engineers.

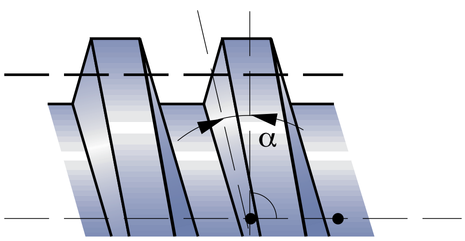


Fig 13

LEADSCREW INSTALLATION AND MAINTENANCE

INSTALLATION:
JENA-TEC leadscrew drives must be aligned carefully during installation. In the absence of suitable measuring equipment the drive should be turned through its entire length by hand before the drive unit is attached.
Variations in the force required and/or marks on the spindle indicate alignment errors between the spindle and guide.
In the case of mis-alignment the relevant mounting bolts should be loosened and the drive rotated through its entire length by hand. When a constant force is produced over the entire screwed length, alignment has been achieved.

PROTECTION:
Covers: by virtue of their design JENA-TEC leadscrew drives are less sensitive to dirt than ballscrew drives, particularly at low speeds (manual operation).
Leadscrew drives, especially with plastic nuts nonetheless, for long service life, require protection against dirt in the same way as ballscrew drives.

LUBRICATION:
Oil lubrication: this is used only in special cases for leadscrew drives.
Grease lubrication: This is the normal method of lubrication for leadscrew drives. Lubrication intervals are governed by operating condition; it is always advisable to thoroughly clean the spindle before greasing. The use of a high quality spindle spray, particularly before greasing, will increase service life.

OPERATING TEMPERATURES:
Depends primarily on the type of nut used, the condition of lubrication, and the environment. Please consult JENA-TEC Engineers in the case of temperatures above 100°C (70°C plastic nuts).

WEAR:
Can be checked manually; if the axial backlash with a single start leadscrew drive is more than 1/8 of the pitch, the nut should be replaced.