Trapezoidal screw drives
Sizing and selection

Load rating of trapezoidal screw drives
As a general principle, the load rating of trapezoidal screw drives is
dependent on their material, surface quality, state of wear, surface
pressure, lubrication conditions, running speed and temperature,
and thus on the duty cycle and the provision for the heat dissipation.

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

With motion drives the surface pressure should not exceed 5 N
per mm².

The permissible speed can be calculated from the supporting surface
of the respective nut (see tables pp. 37 – 40) and the pv-factor of the
respective nut materials (see p. 40).

### pv-factors

<table>
<thead>
<tr>
<th>Material</th>
<th>pv-factors [N/mm² · m/min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-CuSn 7 ZnPb (Rg 7)</td>
<td>300</td>
</tr>
<tr>
<td>G-CuSn 12 (G Bz 12)</td>
<td>400</td>
</tr>
<tr>
<td>Plastic (PETG)</td>
<td>100</td>
</tr>
<tr>
<td>Cast iron GG 22 / GG25</td>
<td>200</td>
</tr>
</tbody>
</table>

### Required bearing surface

\[
A_{\text{eff}} = \frac{F_{\text{ax}}}{P_{\text{ul}}} \quad \text{(VII)}
\]

- \(A_{\text{eff}}\): Required bearing surface \([\text{mm}^2]\)
- \(F_{\text{ax}}\): Total axial load \([\text{N}]\)
- \(P_{\text{ul}}\): Maximum permissible surface pressure = 5 N/mm²

### Maximum linear running speed

\[
v_{\text{Gzul}} = \frac{pv - \text{factor}}{P_{\text{ul}}} \quad \text{(IX)}
\]

- \(v_{\text{Gzul}}\): Maximum linear running speed \([\text{m/min}]\)
- \(pv\)-factor: see table

### Maximum permissible speed of rotation

\[
n_{\text{zul}} = \frac{v_{\text{Gzul}} \cdot 1000}{D \cdot \pi} \quad \text{(X)}
\]

- \(n_{\text{zul}}\): Maximum permissible speed of rotation \([\text{rpm}]\)
- \(D\): Flank diameter \([\text{mm}]\)

### Permissible feed speed

\[
s_{\text{zul}} = \frac{n_{\text{zul}} \cdot P}{1000} \quad \text{(XI)}
\]

- \(s_{\text{zul}}\): Permissible feed speed \([\text{m/min}]\)
- \(P\): Thread lead \([\text{mm}]\)
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Example load rating calculation

Given:
- Screw drive,
  - Trapezoidal screw drive with bronze nut $P_{zul} = 5 \text{ N/mm}^2$,
  - Total axial load $F_{ax} = 10\,000 \text{ N}$

Required: What travel speed is still permissible at this load?

$A_{erf}$ Required bearing surface (mm$^2$)

from (VIII) $A_{erf} = \frac{F_{ax}}{P_{zul}} = \frac{10\,000 \text{ N}}{5 \text{ N/mm}^2} = 2000 \text{ mm}^2$

Selection of bronze nut EFM of technical data page 39

36x6 with bearing surface $A = 2140 \text{ mm}^2$

$P$ Thread lead $= 6 \text{ mm}$

$D$ Flank diameter $= \frac{d - P - 2}{2} = 33 \text{ mm}$

$V_{Czul}$ Maximum linear running speed (m/min)

from (IX) $V_{Czul} = \frac{p \cdot v \text{-factor}}{P_{zul}} = \frac{300 \text{ N/mm}^2 \cdot \text{m/min}}{5 \text{ N/mm}^2} = 60 \text{ m/min}$ With $p \cdot v$-factor for RG 7 = 300 m/min (see table)

$n_{zul}$ Maximum permissible speed (rpm)

from (X) $n_{zul} = \frac{V_{Czul} \cdot 1000}{D \cdot \pi} = \frac{60 \text{ m/min} \cdot 1000 \text{ mm/m}}{33 \text{ mm} \cdot \pi} = 579 \text{ rpm}$

$s_{zul}$ Permissible feed speed

from (XI) $s_{zul} = \frac{n_{zul} \cdot P}{1000} = \frac{579 \text{ 1/min} \cdot 6 \text{ mm}}{1000 \text{ mm/m}} = 3.474 \text{ m/min}$

Result:

At a load of 10\,000 N, the trapezoidal screw drive can be operated at a speed of 3.474 metres per min.
Critical speed of trapezoidal screws

With thin, fast-rotating screws, there is the danger of "whipping". The method described below allows the resonant frequency to be estimated assuming a sufficiently rigid assembly. Furthermore, speeds in the vicinity of the critical speed considerably increase the risk of lateral buckling. The critical speed is therefore included in the calculation of the critical buckling force.

Maximum permissible speed

\[ n_{zul} = 0.8 \cdot n_{kr} \cdot f_{kr} \]  (XII)

- \( n_{zul} \): Maximum permissible speed [rpm]
- \( n_{kr} \): Theoretical critical speed [rpm], that can lead to resonance effects (see diagram)
- \( f_{kr} \): Correction factor considering the bearing support of the screw (see table)

The operating speed must not exceed 80% of the maximum speed.

Theoretical critical speed \( n_{kr} \)

Bearing support

Typical values of correction factor \( f_{kr} \), corresponding to the usual cases of installation for standard screw bearings.

![Diagram showing various cases of bearing support with correction factors and unsupported lengths.](image-url)
**Trapezoidal screw drives**

**Sizing and selection**

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**Critical buckling force of trapezoidal screws**

With thin, fast-rotating screws under compressive load, there is the danger of lateral buckling. The procedure described below can be used to calculate the permissible axial force according to Euler.

Before the permissible compressive force is defined, allowance must be made for safety factors appropriate to the installation.

---

**Maximum permissible axial force**

\[ F_{\text{zul}} = 0.8 \cdot F_k \cdot f_k \]  

- \( F_{\text{zul}} \) Maximum permissible axial force [kN]
- \( F_k \) Theoretical critical buckling force [kN]  
  - see diagram
- \( f_k \) Correction factor considering the bearing support of the screw.  
  - see table

The operating force must not exceed 80% of the maximum permissible axial force.

---

**Bearing support**

Typical values of correction factor \( f_k \) corresponding to the usual cases of installation for standard screw bearings.

---

**Theoretical critical buckling force \( F_k \)**

- Case 1: \( f_k = 0.25 \)
- Case 2: \( f_k = 1 \)
- Case 3: \( f_k = 2.05 \)
- Case 4: \( f_k = 4 \)
Deflection of the screw under its own weight

Even in the case of correctly installed screw drives where the resulting radial forces are absorbed by external guides, the weight of the unsupported screw itself may lead to deflection. The formula below allows you to calculate the maximum deflection of the screw.

**Maximum deflection of screw**

\[
f_{\text{max}} = f_B \cdot 0.06 \cdot \frac{m'_{\text{TGS}} \cdot L_{\text{TGS}}}{I_Y} \tag{XIV} \]

- \(f_{\text{max}}\): Maximum deflection of the screw [mm]
- \(f_B\): Correction factor considering the bearing support of the screw. See table
- \(I_Y\): Planar moment of inertia \([10^4 \text{ mm}^4]\) 
  - See table page 35
- \(L_{\text{TGS}}\): Unsupported screw length [mm]
- \(m'_{\text{TGS}}\): Weight \([\text{kg/m}]\)

**Theoretical maximum deflection of screw**

**Bearing support**

Typical values of correction factor \(f_B\) corresponding to the usual cases of installation for standard screw bearings.
Example calculation for a trapezoidal screw drive

**Given:**
- Trapezoidal screw drive, Screw RPTS Tr 24x5
- Length \( L = 1500 \text{ mm} \)
- Installation case 2
- Maximum operating speed: \( n_{\text{max}} = 500 \text{ rpm} \)

**Required:**
- Is the operating speed uncritical?
- What is the permissible axial force?
- What is the maximum deflection?

**Maximum permissible speed \( n_{\text{zul}} \)**

From (XIII)

\[
n_{\text{zul}} = 0.8 \cdot n_{\alpha} \cdot f_{\varphi} = 0.8 \cdot 830 \text{ rpm} \cdot 1 = 664 \text{ rpm}
\]

From (XIII)

\[
F_{\text{zul}} = 0.8 \cdot F_{\varphi} \cdot f_{\varphi} = 0.8 \cdot 4.2 \text{ kN-m} \cdot 1 = 3.36 \text{ kN}
\]

From (XIV)

\[
f_{\text{\varphimax}} = f_{\varphi} \cdot 0.061 \cdot \frac{m_{\text{TGS}} \cdot L_{\text{TGS}}}{l_{y}} = 1 \cdot 0.061 \cdot \frac{2.85 \text{ kg/m} \cdot 1.5 \text{ m}}{0.460 \text{ cm}^4}
\]

\[
f_{\text{\varphimax}} = 0.57 \text{ mm}
\]

**Result:**

The selected screw drive is uncritical at \( n_{\text{max}} = 500 \text{ rpm} \).
It can be loaded with a maximum axial force of 3.36 kN,
and when installed horizontally has a maximum deflection of 0.57 mm.

*(Note surface pressure and pv-factor)*
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Required drive torque and drive power
The required drive torque of a screw drive results from the axial load, the screw lead and the efficiency of the screw drive and bearings. With short run-up times and high speeds, the acceleration moment should be checked.

Required drive torque

\[ M_d = \frac{F_x \cdot P}{2000 \cdot \pi \cdot \eta \cdot \eta} + M_{rot} \quad (XV) \]

- \( F_x \): Total axial load [N]
- \( P \): Thread lead [mm]
- \( \eta \): Efficiency of the overall drive
- \( \eta \text{fixed} \) and \( \eta \text{movable} \): see table page 35
- \( M_d \): Required drive torque [Nm]
- \( M_{rot} \): Rotational acceleration torque [Nm]

\[ M_{rot} = \frac{J_{rot} \cdot \alpha_0}{7.7 \cdot d_4 \cdot L \cdot 10^{-13}} \]

- \( J_{rot} \): Rotational mass moment of inertia [kgm²]
- \( d_4 \): Nominal screw diameter [mm]
- \( L \): Screw length [mm]
- \( \alpha_0 \): Angular acceleration [1/s²]

Efficiency \( \eta \) for coefficients of friction other than \( \mu = 0.1 \)

\[ \eta = \frac{\tan \alpha}{\tan (\alpha + \rho')} \quad (XVI) \]

- \( \eta \): Efficiency for converting a rotary motion into a linear motion
- \( \alpha \): Helical angle of the thread [°]
- \( \rho' \): Thread friction angle [°]

\[ \tan \alpha = \frac{P}{d_2 \cdot \pi} \]

- \( P \): screw lead [mm]
- \( d_2 \): flank diameter [mm]

\[ \tan \rho' = \mu \cdot 1.07 \] for ISO-trapezoidal thread

<table>
<thead>
<tr>
<th>( \mu ) during start-up (= ( \mu_{0} ))</th>
<th>( \mu ) in motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>dry lubricated</td>
<td>dry lubricated</td>
</tr>
<tr>
<td>Metal nuts</td>
<td>0.3</td>
</tr>
<tr>
<td>Plastic nuts</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Required drive power

\[ P_a = \frac{M_d \cdot \eta}{9550} \quad (XVII) \]

- \( M_d \): Required drive torque [Nm] (from XV)
- \( \eta \): Screw speed [rpm]
- \( P_a \): Required drive power [kW]
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Torque resulting from an axial load
Trapezoidal screw drives with a helical angle \( \alpha \) greater than the friction angle \( \rho' \), are not self-locking, i.e. the application of an axial load produces a screw torque.

Efficiency \( \eta' \) for converting a linear motion into a rotary motion is lower than the conversion of a rotary motion into a linear motion.

Required holding moment

\[
M_{d'} = \frac{F_{ax} \cdot P \cdot \eta'}{2000 \cdot \pi} + M_{rot}
\]

(XVIII)

- \( F_{ax} \): Total axial load [N]
- \( P \): Thread lead [mm]
- \( \eta' \): Efficiency for converting a linear motion into a rotary motion.

\[
\eta' = \frac{\tan(\alpha - \rho')}{\tan(\alpha)} = 0.7 \cdot \eta
\]

The effect of the efficiency of the bearing is negligible.

- \( M_{d'} \): Required holding moment [Nm]
- \( M_{rot} \): Rotational acceleration torque [Nm]
- \( J_{rot} \): Rotational mass moment of inertia [kgm²]
- \( d \): Nominal screw diameter [mm]
- \( L \): Screw length [mm]
- \( \alpha_0 \): Angular acceleration [1/s²]