Key(s) for shaft-hub connection

The feather key are used to transfer the torque between the shaft and the hub. The feather key are inserted into shaft and hub grooves. The torque is transmitted only by the flanks of the feather key. Therefore, the grooves of the grooves and the feather key must be parallel. The feather key are standardized most commonly used, which are listed in DIN 6885A. The material is usually C45+C steel. For alternating or impact torque loads, the feather key is not suitable because changing the load direction and the impact of the wall, which can lead to loosening of the connection.

![Diagram of key(s) for shaft-hub connection]

Fig. 1 Key(s) for shaft-hub connection

Torsion stress in the shaft:

$$\tau_s = \frac{16M_T}{\pi \left(\sqrt{(D-2t)^2 + b^2}\right)^3} \leq \tau_{all}$$

- $\tau_s$: torsion stress in the shaft [MPa]
- $M_T$: torque [Nm]
- $D$: diameter of the shaft [mm]
- $t$: depth in the shaft [mm]
- $b$: key width [mm]
- $\tau_{all}$: allowable shear stress [MPa]

Allowable shear stress:

$$\tau_{all} = \frac{0.4R_{p0.2T}}{S_F} \times C_c$$

- $\tau_{all}$: allowable shear stress [MPa]
- $R_{p0.2T}$: the minimum yield strength or 0.2% proof strength at calculation temperature [MPa]
- $S_F$: safety factor []
- $C_c$: coefficient of use of joints according to load []
Coefficient of use of joints according to load:

<table>
<thead>
<tr>
<th>load</th>
<th>[]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unidirectional load, non-impact load</td>
<td>0,8</td>
</tr>
<tr>
<td>Unidirectional load, with a small impact load</td>
<td>0,7</td>
</tr>
<tr>
<td>Unidirectional load, with a big impact load</td>
<td>0,6</td>
</tr>
<tr>
<td>Alternating load, with a small impact load</td>
<td>0,45</td>
</tr>
<tr>
<td>Alternating load, with a big impact load</td>
<td>0,25</td>
</tr>
</tbody>
</table>

**key under shear stress:**

\[
\tau_p = \frac{2M_T}{D \ast i \ast \left( (l - b - l_t) \ast b + \frac{\pi b^2}{4} \right)} \leq \tau_{all}
\]

- \(\tau_p\): key under shear stress [MPa]
- \(M_T\): torque [Nm]
- \(D\): diameter of the shaft [mm]
- \(i\): number of key []
- \(l\): key length [mm]
- \(b\): key width [mm]
- \(l_t\): tolerance of key length [mm]
- \(\tau_{all}\): allowable shear stress [MPa]

**Key/shaft under bearing stress:**

\[
p_s = \frac{2M_T}{D \ast i \ast \left( (l - b - l_t) \ast (h_s - t_{1t} - (t + t_1 - h) - r_1) \right)} \leq \sigma_{all}
\]

- \(p_s\): key/shaft under bearing stress [MPa]
- \(M_T\): torque [Nm]
- \(D\): diameter of the shaft [mm]
- \(i\): number of key []
- \(l\): key length [mm]
- \(b\): key width [mm]
- \(l_t\): tolerance of key length [mm]
- \(h_s\): the height of the key in the shaft [mm]
- \(t_{1t}\): tolerance of the groove height in the hub [mm]
- \(t\): depth in the shaft [mm]
- \(t_1\): depth in the hub [mm]
- \(h\): key height [mm]
- \(r_1\): max. rounding the key [mm]
- \(\sigma_{all}\): allowable bearing stress [MPa]

**The height of the key in the shaft:**

\[
h_s = t - \frac{D}{2} + \frac{D}{2} \cos \left( \sin^{-1} \frac{b}{D} \right)
\]

- \(h_s\): the height of the key in the shaft [mm]
\( t \) depth in the shaft \([\text{mm}]\)  
\( D \) diameter of the shaft \([\text{mm}]\)  
\( b \) key width \([\text{mm}]\)  

**Allowable bearing stress:**  
\[
\sigma_{\text{all}} = \frac{0.9 R_{p0.2T}}{S_F} * C_c
\]

\( \sigma_{\text{all}} \) allowable bearing stress \([\text{MPa}]\)  
\( R_{p0.2T} \) the minimum yield strength or 0.2\% proof strength at calculation temperature \([\text{MPa}]\)  
\( S_F \) safety factor \([]\)  
\( C_c \) coefficient of use of joints according to load \([]\)  

**Key/hub under bearing stress:**  
\[
\rho_h = \frac{2 M_T}{D * i * ((l - b - l_t) * (h_h - t_t - (t + t_1 - h) - r_1))} \leq \sigma_{\text{all}}
\]

\( \rho_h \) key/hub under bearing stress \([\text{MPa}]\)  
\( M_T \) torque \([\text{Nm}]\)  
\( D \) diameter of the shaft \([\text{mm}]\)  
\( i \) number of key \([]\)  
\( l \) key length \([\text{mm}]\)  
\( b \) key width \([\text{mm}]\)  
\( l_t \) tolerance of key length \([\text{mm}]\)  
\( h_h \) the height of the key in the hub \([\text{mm}]\)  
\( t_t \) tolerance of the groove height in the shaft \([\text{mm}]\)  
\( t \) depth in the shaft \([\text{mm}]\)  
\( t_1 \) depth in the hub \([\text{mm}]\)  
\( h \) key height \([\text{mm}]\)  
\( r_1 \) max. rounding the key \([\text{mm}]\)  
\( \sigma_{\text{all}} \) allowable bearing stress \([\text{MPa}]\)  

**The height of the key in the hub:**  
\( h_h = t + t_1 + h_s \)

\( h_h \) the height of the key in the hub \([\text{mm}]\)  
\( t \) depth in the shaft \([\text{mm}]\)  
\( t_1 \) depth in the hub \([\text{mm}]\)  
\( h_s \) the height of the key in the shaft \([\text{mm}]\)  

**Torsion stress in the hub:**  
\[
\tau_h = K_t \frac{16 M_T}{\pi \left( D_h^4 - \left( \sqrt{(D + 2 t_1)^2 + b^2} \right)^4 \right) / D_h} \leq \tau_{\text{all}}
\]

\( \tau_h \) torsion stress in the hub \([\text{MPa}]\)
Concentration factor:

\[
K_t = 1,953 + 0,1434 \left( \frac{0,1}{r_2/D} \right) - 0,0021 \left( \frac{0,1}{r_2/D} \right)^2
\]

If the shaft is loaded with the bending moment in the joint, the bending stress must be checked. If the shaft is loaded with a shear force in the joint, the shear stress must be checked. The shaft may be loaded in the joint by axial force. The shaft must be checked for axial stresses. When calculating the different load types, it is necessary to calculate the combined stress.

Bending stress in the shaft:

\[
\sigma_B = \frac{32M_B}{\pi \left( \sqrt{(D - 2t)^2 + b^2} \right)^3} \leq \sigma_{Bal}
\]

Allowable bending stress:

\[
\sigma_{Bal} = \frac{0,6R_{p0,2T}}{S_F} * C_c
\]
Shear stress in the shaft:
\[
\tau_{s(s)} = \frac{4F_R}{\pi \left( \sqrt{(D - 2t)^2 + b^2} \right)^2} \leq \tau_{all}
\]

- \( \tau_{s(s)} \): shear stress in the shaft [MPa]
- \( F_R \): shear forces [N]
- \( D \): diameter of the shaft [mm]
- \( t \): depth in the shaft [mm]
- \( b \): key width [mm]
- \( \tau_{all} \): allowable shear stress [MPa]

Axial stress in the shaft:
\[
\sigma_A = \frac{4F_A}{\pi \left( \sqrt{(D - 2t)^2 + b^2} \right)^2} \leq \sigma_{Aall}
\]

- \( \sigma_A \): axial stress in the shaft [MPa]
- \( F_A \): axial forces [N]
- \( D \): diameter of the shaft [mm]
- \( t \): depth in the shaft [mm]
- \( b \): key width [mm]
- \( \sigma_{Aall} \): allowable axial stress [MPa]

Allowable axial stress:
\[
\sigma_{Aall} = 0.45 R_{p0.2T} S_F * C_c
\]

- \( \sigma_{Aall} \): allowable axial stress [MPa]
- \( R_{p0.2T} \): the minimum yield strength or 0.2% proof strength at calculation temperature [MPa]
- \( S_F \): safety factor []
- \( C_c \): coefficient of use of joints according to load []

Combined stress in the shaft:
\[
\sigma_{tresca} = \sqrt{\sigma_B^2 + \sigma_A^2 + 4 \left( (K_t \cdot \tau_s)^2 + \tau_{s(s)}^2 \right)} \leq \sigma_{call}
\]

- \( \sigma_{tresca} \): combined stress in the shaft [MPa]
- \( \sigma_B \): bending stress in the shaft [MPa]
- \( \sigma_A \): axial stress in the shaft [MPa]
- \( K_t \): concentration factor []
- \( \tau_s \): torsion stress in the shaft [MPa]
- \( \tau_{s(s)} \): shear stress in the shaft [MPa]
- \( \sigma_{call} \): allowable combined stress [MPa]
Allowable combined stress:

\[ \sigma_{\text{Call}} = \frac{R_{p0.2T}}{S_F} \times C_c \]

- \(\sigma_{\text{Call}}\): allowable combined stress [MPa]
- \(R_{p0.2T}\): the minimum yield strength or 0.2% proof strength at calculation temperature [MPa]
- \(S_F\): safety factor []
- \(C_c\): coefficient of use of joints according to load []

Literature:
- MET-Calc: Allowable stress.