Calculation dimensions for drive by key(s) ISO 5211

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.

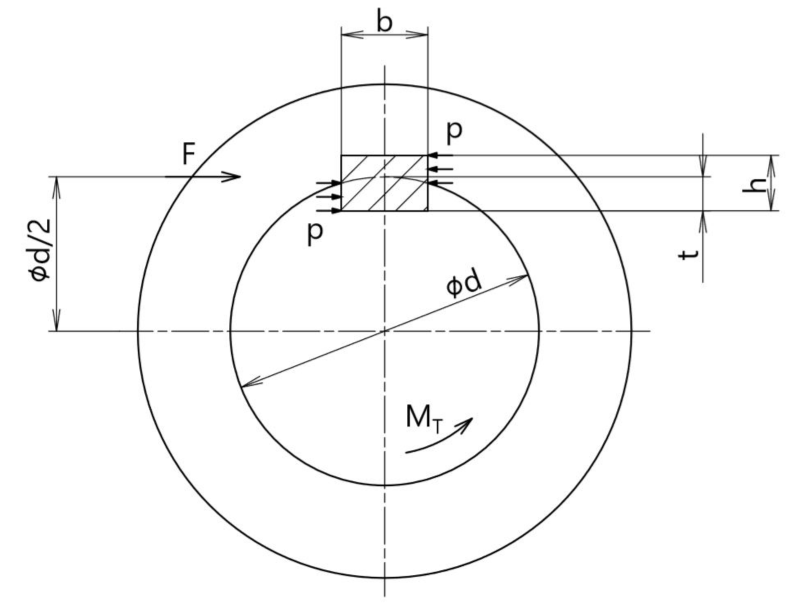

Fig. 1 Stress, keyway

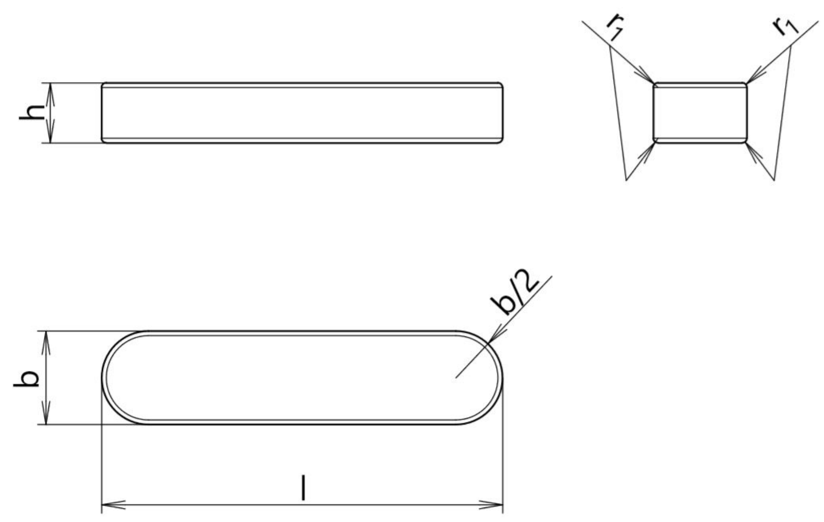

Fig. 2 Key DIN 6885

Perimeter force on the shaft surface:

$$F = \frac{2M_T}{d}$$

F	perimeter force on the shaft surface	[N]
M_T	torque	[Nm]
d	diameter of the shaft	[mm]

key under shear stress:

$$\tau = \frac{F}{i * \left((l - b - l_t) * b + \frac{\pi b^2}{4}\right)} \leq \tau_{all}$$

τ	key under shear stress	[MPa]
F	perimeter force on the shaft surface	[N]
i	number of key	[]
l	key length	[mm]
b	key width	[mm]
l_t	tolerance of key length	[mm]
τ_{all}	allowable shear stress	[MPa]

Allowable shear stress:

$$\tau_{all} = \frac{0{,}4R_{p0,2T}}{S_F} * C_c$$

τ_{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:

load	[]
Unidirectional load, non-impact load	0,8
Unidirectional load, with a small impact load	0,7
Unidirectional load, with a big impact load	0,6
Alternating load, with a small impact load	0,45
Alternating load, with a big impact load	0,25

Key/shaft under bearing stress:

$$p_s = \frac{F}{i * \left((l - b - l_t) * (h_s - t_{1t} - (t + t_1 - h) - r_1)\right)} \leq \sigma_{all}$$

p_s	key/shaft under bearing stress	[MPa]
F	perimeter force on the shaft surface	[N]
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]
σ_{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	[mm]
d	diameter of the shaft	[mm]
b	key width	[mm]

Allowable bearing stress:

$$\sigma_{all} = \frac{0{,}9R_{p0,2T}}{S_F} * C_c$$

σ_{all}	allowable bearing 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	[]

Key/hub under bearing stress:

$$p_h = \frac{F}{i * \left((l - b - l_t) * (h_h - t_t - (t + t_1 - h) - r_1)\right)} \leq \sigma_{all}$$

P_h	key/hub under bearing stress	[MPa]
F	perimeter force on the shaft surface	[N]
i	number of key	[]
l	key length	[mm]
b	key width	[mm]
l_t	tolerance of key length	[mm]
h_h	the height of the key in the hub	[mm]
t_t	tolerance of the groove height in the shaft	[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]
σ_{all}	allowable bearing stress	[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	[mm]
t	depth in the shaft	[mm]
t_1	depth in the hub	[mm]
h_s	the height of the key in the shaft	[mm]

Example:

We should determine safety factor the keys, for shear stress and bearing stress, material the keys is C45+C. Key size according to DIN6885.
Values for the calculation will be from the standard EN ISO 5211. M_T=8000Nm, d=72mm, $R_{p0,2T}$=305MPa, l=110mm, i=1, b=20mm, h=12mm, t=7,5mm, l_t=0,5mm, t_{1t}=0,2mm, t_1=4,9mm, t_t=0,2mm, r_1=0,8mm,

Perimeter force on the shaft surface:

$$F = \frac{2M_T}{d} = \frac{2 * 8000000}{72} = 222222{,}2N$$

Shear the key:

$$\tau = \frac{F}{i * \left((l - b - l_t) * b + \frac{\pi b^2}{4}\right)} = \frac{222222{,}2}{1 * \left((110 - 20 - 0{,}5) * 20 + \frac{\pi * 20^2}{4}\right)} = 105{,}6MPa$$

Shear safety factor:

$$S_F = \frac{0{,}4R_{p0{,}2T}}{\tau} * C_c = \frac{0{,}4 * 305}{105{,}6} * 0{,}8 = 0{,}92 \rightarrow does\ not\ suit$$

The height of the key in the shaft:

$$h_s = t - \frac{d}{2} + \frac{d}{2}\cos\left(\sin^{-1}\frac{b}{d}\right) = 7{,}5 - \frac{72}{2} + \frac{72}{2}\cos\left(\sin^{-1}\frac{20}{72}\right) = 6{,}08mm$$

Key/shaft under bearing stress:

$$p_s = \frac{F}{i * \left((l - b - l_t) * (h_s - t_{1t} - (t + t_1 - h) - r_1)\right)}$$

$$p_s = \frac{222222{,}2}{1 * \left((110 - 20 - 0{,}5) * (6{,}08 - 0{,}2 - (7{,}5 + 4{,}9 - 12) - 0{,}8)\right)} = 530{,}5MPa$$

Key/shaft safety factor under bearing stress:

$$S_F = \frac{0{,}9R_{p0{,}2T}}{p_s} * C_c = \frac{0{,}9 * 305}{530{,}5} * 0{,}8 = 0{,}41 \rightarrow does\ not\ suit$$

The height of the key in the hub:

$$h_h = t + t_1 - h_s = 7{,}5 + 4{,}9 - 6{,}08 = 6{,}32mm$$

Key/hub under bearing stress:

$$p_h = \frac{F}{i * \left((l - b - l_t) * (h_h - t_t - (t + t_1 - h) - r_1)\right)}$$

$$p_h = \frac{222222{,}2}{1 * \left((110 - 20 - 0{,}5) * (6{,}32 - 0{,}2 - (7{,}5 + 4{,}9 - 12) - 0{,}8)\right)} = 504{,}7MPa$$

Key/hub safety factor under bearing stress:

$$S_F = \frac{0{,}9R_{p0{,}2T}}{\sigma_{all}} * C_c = \frac{0{,}9 * 305}{504{,}7} * 0{,}8 = 0{,}44 \rightarrow does\ not\ suit$$

Value safety factor key for shear stress and bearing stress is lower than 1. The key does not meet any safety of the connection.

As an engineer, we always provide the reliability and integrity of the drive and its components. However as far as stem components are concerned we either give little attention to mechanical integrity of stem or sometimes we leave it to valve vendor and assume stem design is sufficient enough to withstand actuator torque, this is not always true.
No table in standard or catalog can in any way replace the expert opinion of the technician. The maximum torque allowed is calculated during the engineering stage with sufficient safety to operate load and it must be ensured that the torque delivered by the drive is always less than the maximum torque allowed.

Literature:

AISC: Specification for structural steel buildings: Allowable Stress design and plastic design 1989
František Boháček: Části a mechanismy strojů I. 1984.
Joseph E. Shigley, Charles R. Mischke, Richard G. Budynas: Konstruování strojních součástí 2010.
R. Kříž: Strojní součásti I pro SPŠ strojnické 1984.