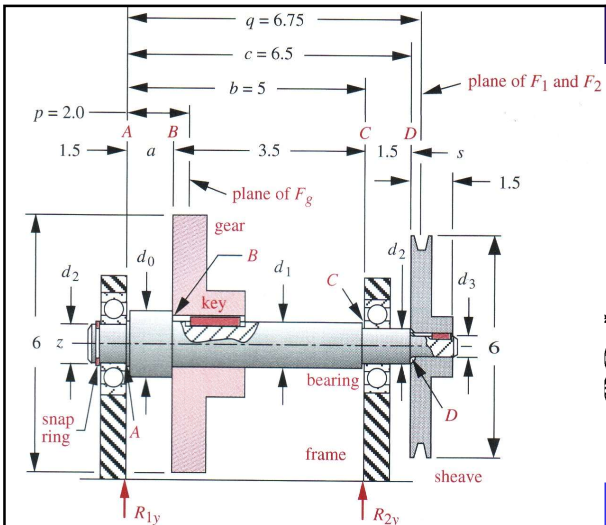
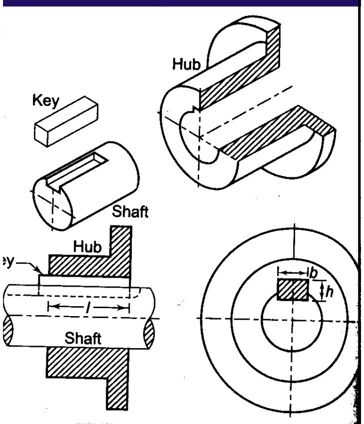
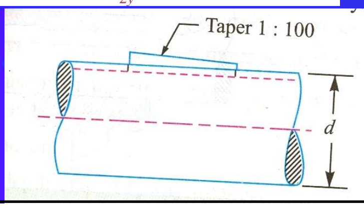
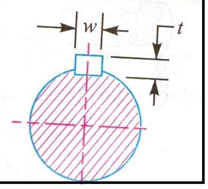
Keys


q = 6.75
c = 6.5
b = 5
plane of F1 and F2
p = 2.0
A B C D
1.5 a 3.5 1.5 s
1.5
plane of Fg
gear
d0 d1 d2 d3
B
C
key
6 z 6
bearing
snap ring
A
D
frame
sheave
R1y R2y


Hub
Key
Shaft
Hub
Shaft
l
b
h


Taper 1 : 100
d


w
t

Key

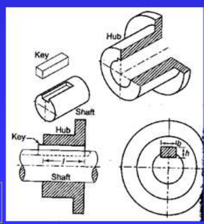
- A key is defined as a machine element that is used to connect the transmission shaft to rotating machine elements like pulley, gear, sprocket, flywheel etc. .

Keys are used as temporary fastening of shaft and hub

Functions of Keys

- The primary function of the key is to transmit the torque from the shaft to the hub of connecting element or vice-versa
- The another function of the key is to prevent relative rotational motion & axial movement (except in case of feather key or splines) between the shaft & the joined m/c elements like gear, pulley etc.

Keyed joint – Consisting of
- Shaft
- Hub
- Key



Keyway is a slot or recess on a shaft and or hub to accommodate a key

Key

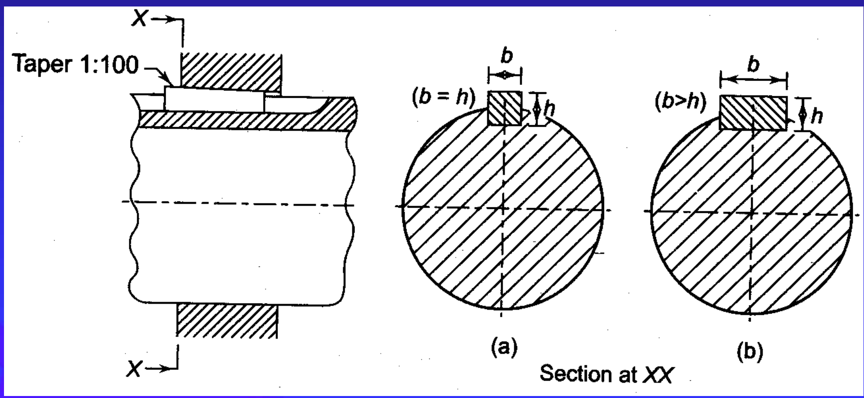
Types of Keys
- Sunk Keys
  - Rectangular sunk key or Flat key
  - Square sunk key
  - Gib- head key
  - (Parallel Key / Taper key)
- Saddle keys
  - Hollow Saddle Key
  - Flat Saddle Key
- Special Keys
  - Woodruff key
  - Feather or kennedy key
  - Round key
- Splines

Factors are considered for selecting of the type of key for a given application

- Power or torque to be transmitted
- Tightness of fit
- Cost

Sunk Key

- Half the thickness of the key fits into the keyway on the shaft & the remaining half in the keyway on the hub
- Power is transmitted due to shear resistance of the key. The relative motion between the shaft & the hub is also prevented by the shear resistance of key



Square Rectangular

Rectangular Sunk Key

- Sunk key with rectangular cross-section, is also called Flat Key

d=diameter of the shaft = diameter of the hole in the hub
b= width of key
h=height or thickness of key
l=length of key

Usual proportions of dimensions of key

$b = \frac{d}{4}$ $h = \frac{2}{3}b = \frac{d}{6}$ $l \geq 1.5d$

If data book or IS 2293 is not given

Square Sunk Key

- Width & thickness are equal

Usual proportions of dimensions of key

$b = h = \frac{d}{4}$ $l \geq 1.5d$

N.B: Flat key has more stability as compared with square key

Dimensions of Square & Rectangular Sunk Keys (in mm) *[IS : 2293]*

Shaft diameter		Key size	Keyway depth	
Above	Upto & including	Width × Height	*In shaft*	*In hub*
6	8	2 × 2	1.2	1
8	10	3 × 3	1.8	1.4
10	12	4 × 4	2.5	1.8
12	17	5 × 5	3	2.3
17	22	6 × 6	3.5	2.8
22	30	8 × 7	4	3.3
30	38	10 × 8	5	3.3
38	44	12 × 8	5	3.3
44	50	14 × 9	5.5	3.8
50	58	16 × 10	6	4.3
58	65	18 × 11	7	4.4
65	75	20 × 12	7.5	4.9
75	85	22 × 14	8.5	5.9

Parallel Sunk Key

IS: 2048

- is a sunk key (with rectangular or square cross-section) which is uniform in width as well as height throughout the length of key

Taper Key

IS: 2292

- is a sunk key which is uniform in width but tapered in height
- Bottom surface of the key is straight & the top surface is given a taper
- Standard taper is 1 in 100

Designation of Parallel Sunk Keys

Width × Height × Length

Example: A parallel key of width 10mm, height 8 mm & a length 50 mm shall be designated as : Parallel key 10×8 ×50 [IS: 2048]

Design of Sunk Keys

Step 1 - Function: Key is used in transmitting torque from a shaft to a hub.

Step 2 **Forces acting on a sunk key**

The following two types of forces act on the key:

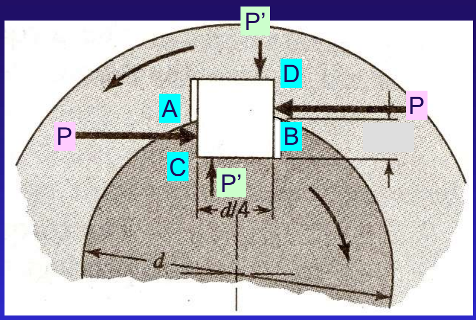
- Forces due to fit of the key in its keyway. These forces produce compressive stresses in the key which are difficult to determine its magnitude and distribution.
- Force (P) due to the torque transmitted by the shaft.

  - The distribution of the forces along the length of the key are not uniform because the forces are concentrated near the torque-input end. Therefore, the stresses are not uniform along the key in the axial direction.
  - The non-uniformity of distribution is caused by the twisting of the shaft within the hub.

Assumption

- Forces due to fit of the key are neglected.
- The distribution of forces along the length of key is uniform.

Forces acting on Key

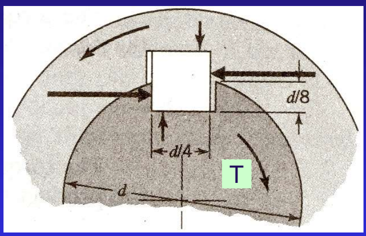


- The transmission of torque from the shaft to the hub results in two equal & opposite forces denoted by P.
- The torque (T) is transmitted by means of a force P acting on the left surface (AC) of the key.
- The equal & opposite force (P), acting on the right surface (DB) of the key is reaction of the hub on the key.

- It is observed that force (P) on left surface 'AC' and its equal & opposite reaction 'P' on right surface DB is not in same plane. Therefore, forces P' (=P) act as resisting couple preventing the key to roll in the keyway.
- The exact location of force (P) on surface (AC) is unknown.

Forces acting on Key

Engineers commonly assume that the entire torque is carried by a tangential force (P) located at the shaft surface.



T : Max.Torque transmitted by the shaft (N-mm).

P : Tangential force acting at the circumference of the shaft (N).

d : Diameter of the shaft (mm).

$$T = P \times \frac{d}{2}$$

$$P = \frac{2T}{d}$$

Designation of Parallel Sunk Keys

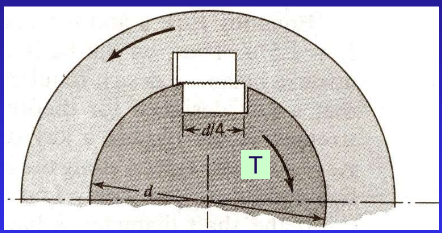
Width (b) × Height (h) × Length (l)

Design Analysis

Due to the power or torque transmitted by the shaft, the key may fail due to shearing or crushing.

Design of sunk key is based on two criteria:

- Failure due to shear.
- Failure due to crushing.



Design Analysis

Failure due to Shear

- Shear failure will occur in plane AB.

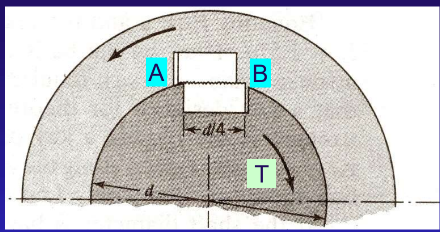
Area resisting shearing: $A_s = b \times L$

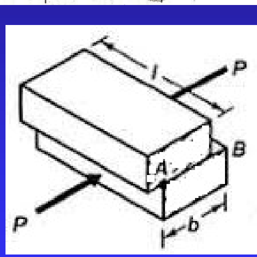
Shear stress induced in plane AB = τ

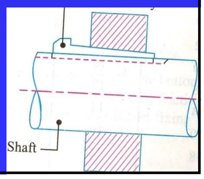
$$\tau = \frac{P}{A_s} = \frac{P}{b \times L}$$

$$\tau = \frac{2T}{d.b.L} \leq [\tau]_{key}$$

$$L \geq \frac{2T}{d.b.[\tau]_{key}}$$







L= Effective length of the Key

Design Analysis

Failure due to Crushing

- Crushing failure will occur on surface AC or DB.

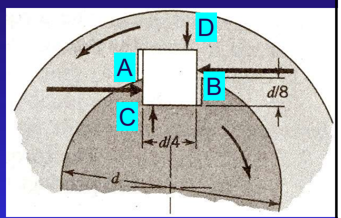
Area resisting crushing: $A_c = L \times h/2$

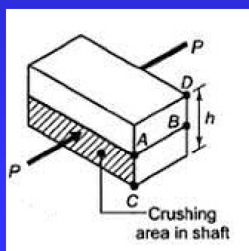
Crushing stress induced = σ_c

$$\sigma_c = \frac{P}{A_c} = \frac{P}{L \times \frac{h}{2}}$$

$$\sigma_c = \frac{4T}{d.h.L} \leq \text{min. of } ([\sigma_c]_{key}, [\sigma_c]_{shaft}, [\sigma_c]_{hub})$$

$$L \geq \frac{4T}{d.h.[\sigma_c]_{min}}$$





Design Analysis

Main Steps in Design Analysis of Key

Step 1 - Either shaft diameter (d) is given or estimate shaft diameter (d).

Step 2 - Select **width×height** of the key from IS 2293:1963 (Data Book)

Step 3 - Calculate force acting on key.

Step 4 - Calculate effective length of the key (L) based on two design criteria (shear failure & crushing failure) & recommend larger of the above two dimensions.

Prob#1: It is required to design a sunk key for fixing a gear on a shaft (made of plain C-steel 50C4) of 25 mm diameter. The shaft is transmitting 10 KW power at 720 RPM to the gear (made of same material of shaft). The drive is subjected to medium shocks for which a service factor of 1.5 is to be considered. The key is made of steel 45C8 and factor of safety is 3.

Solution

Diameter of the shaft (d)=25 mm

Power transmitted by the shaft (Pow)=10 KW.

N=720 RPM

$$\mathrm{Pow} = \frac{2\pi N T_0}{60};\quad T_0 = \frac{60\times 10000}{2\pi\times 720} = 132.63\ \mathrm{N-m} = 132630\ \mathrm{N-mm}$$

$$T = C_s T_0 = 1.5\times 132630\ \mathrm{N-mm} = 198943.6\ \mathrm{N-mm}$$

Material of the key Plain C-steel: 45C8, Yield stress S_{yt}=380 MPa, Factor of safety=3

Allowable tensile stress $[\sigma_t]_{key}=S_{yt}/FOS=127\ N/mm^2$,

Allowable shear stress $[\tau]_{key}=0.5\times[\sigma_t]_{key}=63\ N/mm^2$,

Allowable crushing stress $[\sigma_c]_{key}=1.25\times[\sigma_t]_{key}=158\ N/mm^2$,

Dimensions of Square & Rectangular Sunk Keys (in mm) [*IS : 2293*]

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50	58	16 × 10	6	4.3
58	65	18 × 11	7	4.4
65	75	20 × 12	7.5	4.9
75	85	22 × 14	8.5	5.9

Material of shaft & hub Plain C-steel: 50C4, Yield stress S_{yt}=460 MPa, Factor of safety=3

Allowable tensile stress $[\sigma_t]_s = S_{yt}/FOS = 153$ N/mm^2,

Allowable crushing stress $[\sigma_c]_s = 1.25\times[\sigma_t]_s = 191$ N/mm^2.

Selection of **width×height** of the key from IS 2293:1963 (Data Book)

For shaft diameter d=25 mm: width (b) × height (h)=8×7

Width of the key (b) =8 mm; Height of the key (h)=7 mm.

Failure due to Shear

Shear stress induced in plane AB = τ

$$\tau = \frac{P}{A_s} = \frac{P}{b \times L}; \quad \tau = \frac{2T}{d.b.L} \le [\tau]_{key}; \quad L \ge \frac{2T}{d.b.[\tau]_{key}} \quad \Rightarrow \quad L \ge 31.58 \text{ mm}$$

Failure due to Crushing

Crushing stress induced = σ_c

$$\sigma_c = \frac{P}{A_c} = \frac{P}{L \times \frac{h}{2}} \qquad \sigma_c = \frac{4T}{d.h.L} \le \text{min. of } ([\sigma_c]_{key}, [\sigma_c]_{shaft}, [\sigma_c]_{hub})$$

$$L \ge \frac{4T}{d.h.[\sigma_c]_{min}} \quad \Rightarrow \quad L \ge 28.78 \text{ mm}$$

Effective length of the key=32 mm