



SNS COLLEGE OF TECHNOLOGY

**Coimbatore-35
An Autonomous Institution**

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A+' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai



DEPARTMENT OF AGRICULTURE ENGINEERING

19AGT202 – MACHINE DESIGN

II YEAR IV SEM

UNIT 3 – DESIGN OF MACHINE ELEMENTS

TOPIC 1 – KEYS





Introduction

- A key is a device which is used for connecting two machine parts for preventing relative motion or rotation with respect to each other.
- Keys are used as temporary fastenings and are subjected to considerable crushing and shearing stresses
- It is always inserted parallel to the axis of the shaft.

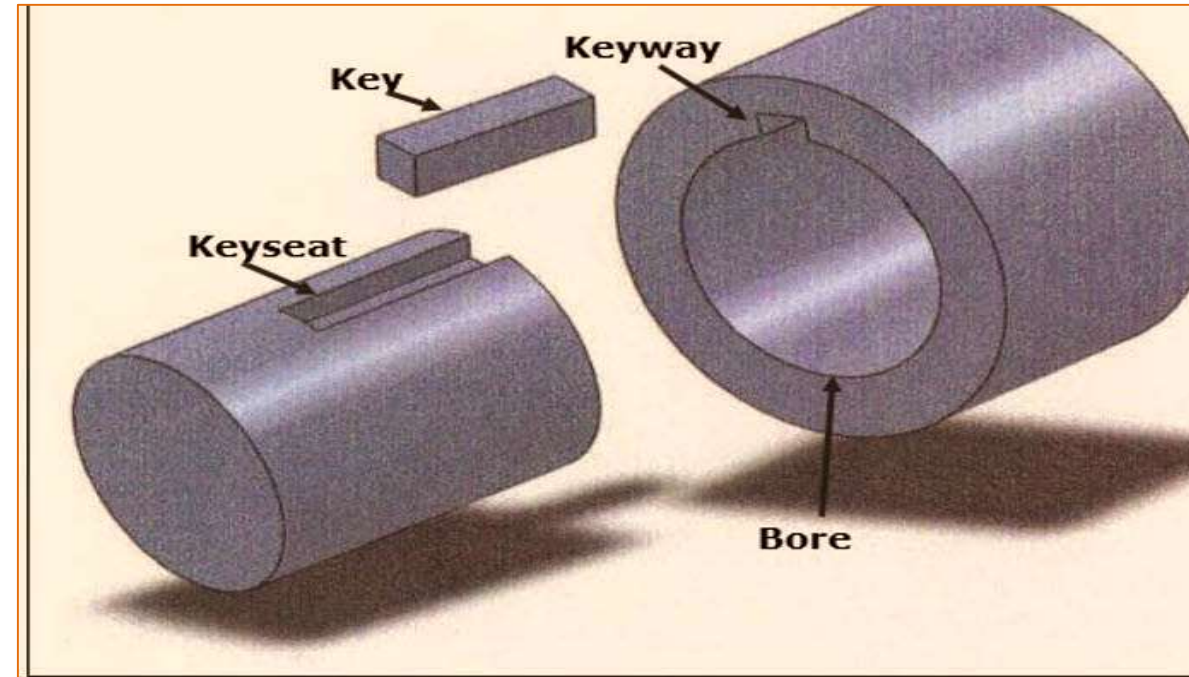


Keys



Types of Keys

- Sunk Keys
- Saddle Keys
- Tangent Keys
- Round Keys
- Splines



Key & Shaft with Hub

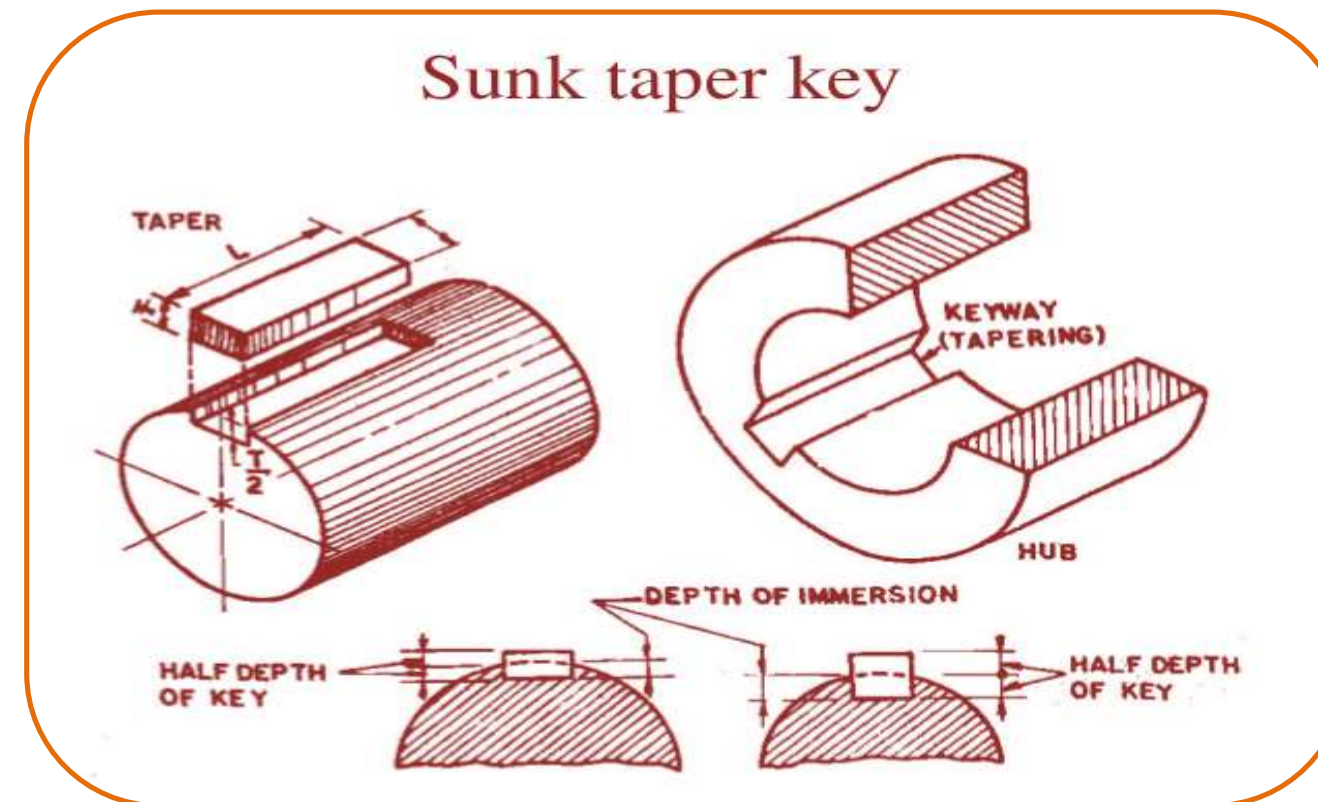
Key & Shaft





Sunk Key

Sunk keys are provided half in the keyway of the shaft and half in the keyway of the hub or boss of the pulley.

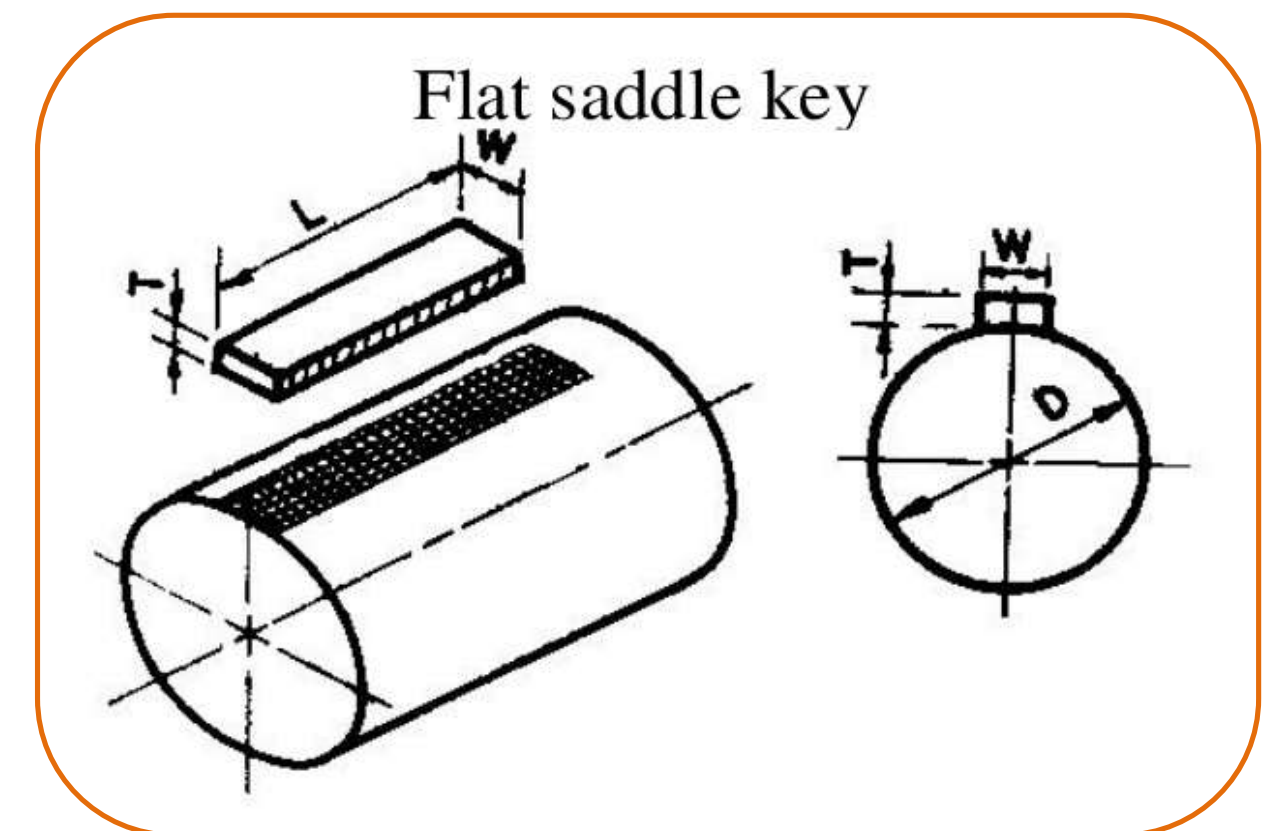




Saddle Key

A flat saddle key is a taper key which fits in a keyway in the hub and is flat on the shaft. It is used for comparatively light loads to slip round the shaft under load.

$$\text{Width of key, } w = d/4$$
$$t = w/3 = d/12$$

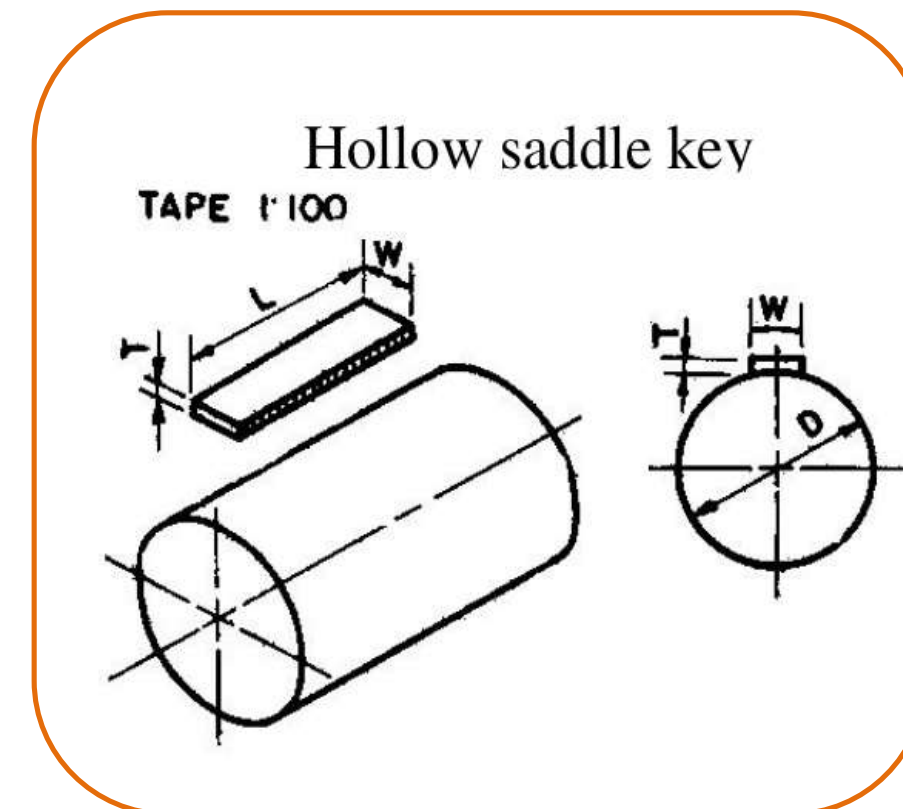
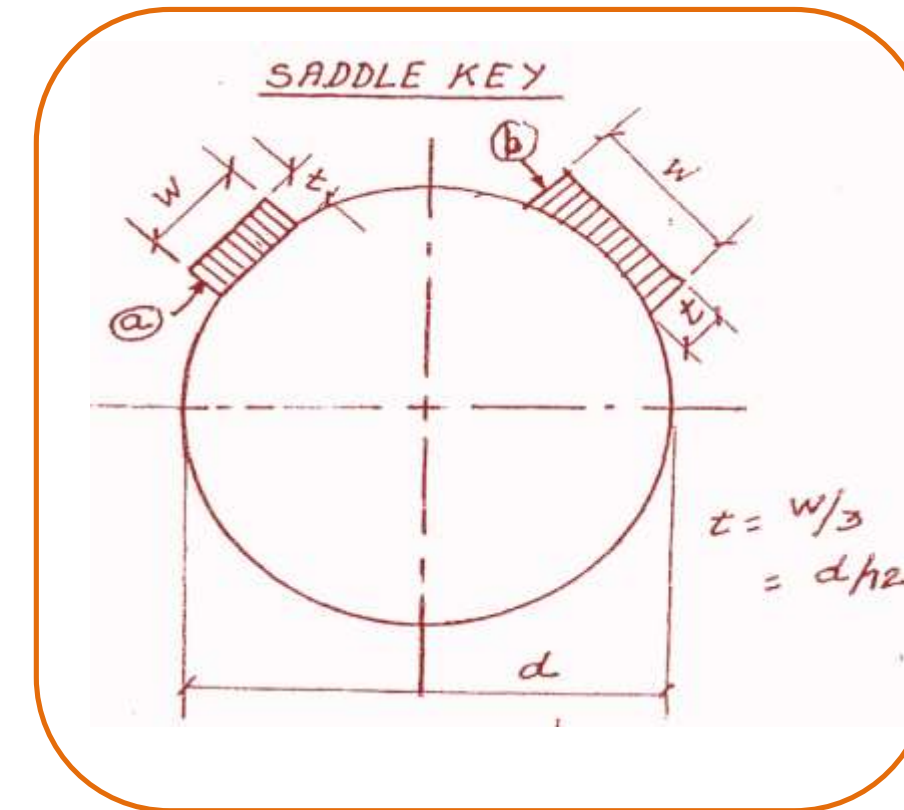




Saddle Key

A hollow saddle key is a taper key which fits in a keyway in the hub and the bottom of the key is shaped to fit the curved surface of the shaft. It holds on by friction, these are suitable for light loads. It is used for comparatively light loads.

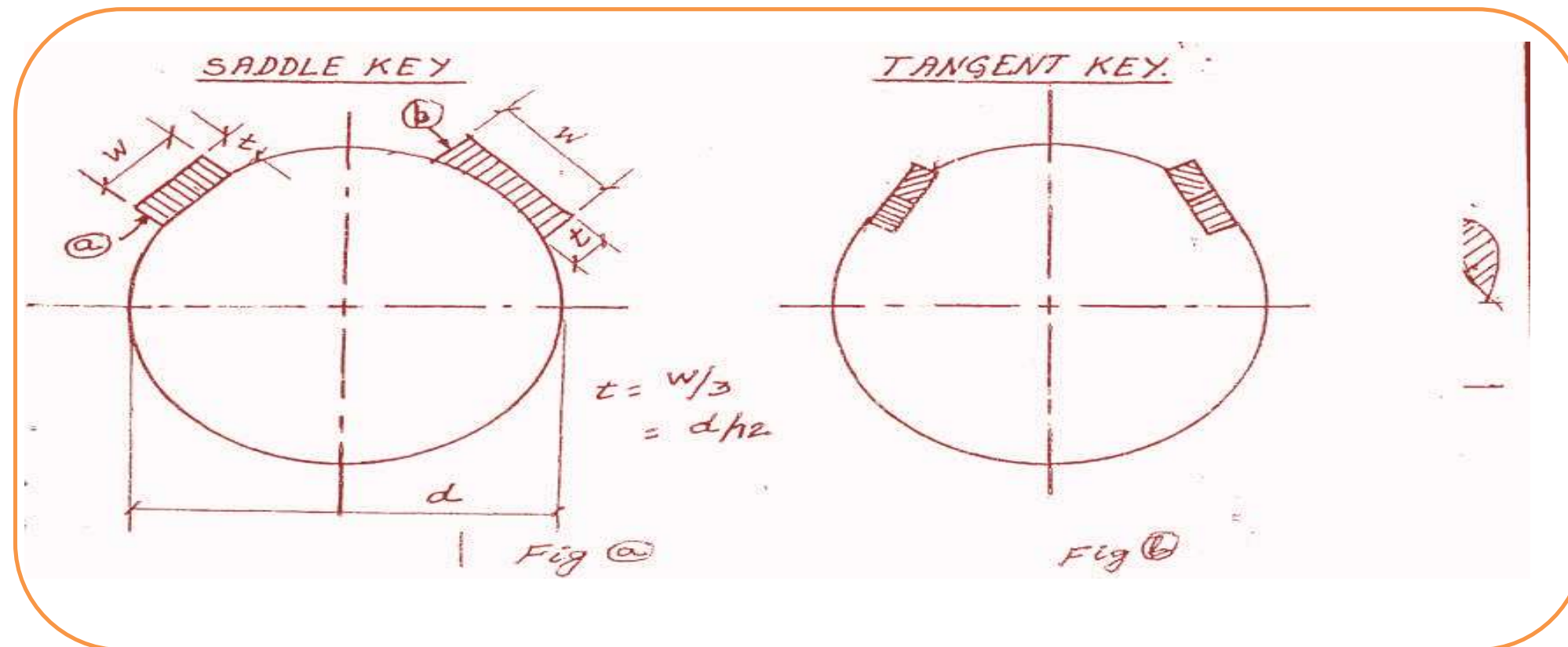
<p>Width of key, $w = d/4$ $t = w/3 = d/12$</p>





Tangent Key

The tangent keys are fitted in pair at right angles. Each key is to withstand torsion in one direction only. These are used in large heavy duty shafts.

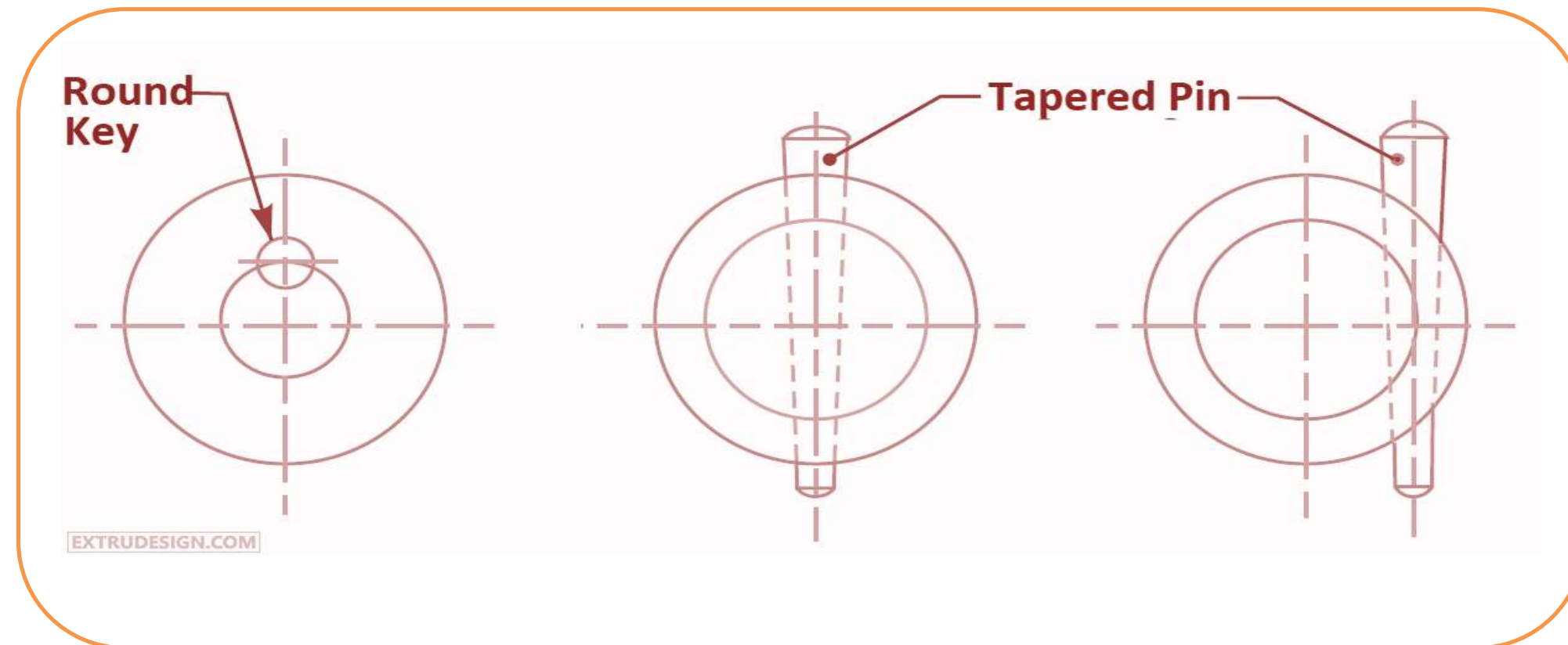




Round Key



- The round keys are circular in section and fit into holes drilled partly in the shaft and partly in the hub.
- Round keys are usually considered to be most appropriate for low power drive.





Spline Key



- Keys are made integral with the shaft which fits in the keyways broached in the hub.
- These shafts usually have four, six, ten or sixteen splines. The splined shafts are relatively stronger than shafts having a single keyway.

$$\text{Width of key, } w = d/4$$
$$t = w/3 = d/12$$

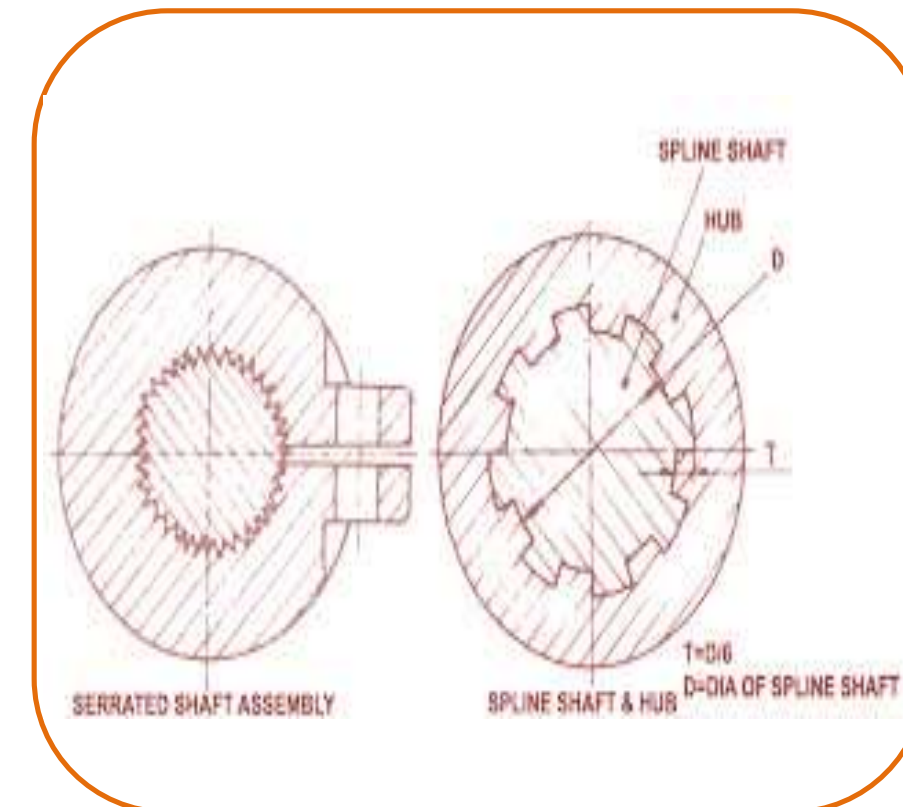




Table 13.1. Proportions of standard parallel, tapered and gib head keys.

Shaft diameter (mm) upto and including	Key cross-section		Shaft diameter (mm) upto and including	Key cross-section	
	Width (mm)	Thickness (mm)		Width (mm)	Thickness (mm)
6	2	2	85	25	14
8	3	3	95	28	16
10	4	4	110	32	18
12	5	5	130	36	20
17	6	6	150	40	22
22	8	7	170	45	25
30	10	8	200	50	28
38	12	8	230	56	32
44	14	9	260	63	32
50	16	10	290	70	36
58	18	11	330	80	40
65	20	12	380	90	45
75	22	14	440	100	50



13.9 Strength of a Sunk Key

A key connecting the shaft and hub is shown in Fig. 13.9.

Let T = Torque transmitted by the shaft,
 F = Tangential force acting at the circumference of the shaft,
 d = Diameter of shaft,
 l = Length of key,
 w = Width of key,
 t = Thickness of key, and

τ and σ_c = Shear and crushing stresses for the material of key.

A little consideration will show that due to the power transmitted by the shaft, the key may fail due to shearing or crushing.

Considering shearing of the key, the tangential shearing force acting at the circumference of the shaft,

$$F = \text{Area resisting shearing} \times \text{Shear stress} = l \times w \times \tau$$

\therefore Torque transmitted by the shaft,

$$T = F \times \frac{d}{2} = l \times w \times \tau \times \frac{d}{2} \quad \dots(i)$$

Considering crushing of the key, the tangential crushing force acting at the circumference of the shaft,

$$F = \text{Area resisting crushing} \times \text{Crushing stress} = l \times \frac{t}{2} \times \sigma_c$$

\therefore Torque transmitted by the shaft,

$$T = F \times \frac{d}{2} = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} \quad \dots(ii)$$

The key is equally strong in shearing and crushing, if

$$l \times w \times \tau \times \frac{d}{2} = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} \quad \dots[\text{Equating equations (i) and (ii)}]$$

or
$$\frac{w}{t} = \frac{\sigma_c}{2\tau} \quad \dots(iii)$$

The permissible crushing stress for the usual key material is atleast twice the permissible shearing stress. Therefore from equation (iii), we have $w = t$. In other words, a square key is equally strong in shearing and crushing.



In order to find the length of the key to transmit full power of the shaft, the shearing strength of the key is equal to the torsional shear strength of the shaft.

We know that the shearing strength of key,

$$T = l \times w \times \tau \times \frac{d}{2} \quad \dots(iv)$$

and torsional shear strength of the shaft,

$$T = \frac{\pi}{16} \times \tau_1 \times d^3 \quad \dots(v)$$

...(Taking τ_1 = Shear stress for the shaft material)

From equations (iv) and (v), we have

$$l \times w \times \tau \times \frac{d}{2} = \frac{\pi}{16} \times \tau_1 \times d^3$$

$$\therefore l = \frac{\pi}{8} \times \frac{\tau_1 d^2}{w \times \tau} = \frac{\pi d}{2} \times \frac{\tau_1}{\tau} = 1.571 d \times \frac{\tau_1}{\tau} \quad \dots \text{(Taking } w = d/4 \text{)} \quad \dots(vi)$$

When the key material is same as that of the shaft, then $\tau = \tau_1$.

$$\therefore l = 1.571 d \quad \dots \text{ [From equation (vi)]}$$



Example 13.1. Design the rectangular key for a shaft of 50 mm diameter. The shearing and crushing stresses for the key material are 42 MPa and 70 MPa.

Solution. Given : $d = 50$ mm ; $\tau = 42$ MPa = 42 N/mm² ; $\sigma_c = 70$ MPa = 70 N/mm²

The rectangular key is designed as discussed below:

From Table 13.1, we find that for a shaft of 50 mm diameter,

Width of key, $w = 16$ mm **Ans.**

and thickness of key, $t = 10$ mm **Ans.**

The length of key is obtained by considering the key in shearing and crushing.

Let $l =$ Length of key.

Considering shearing of the key. We know that shearing strength (or torque transmitted) of the key,

$$T = l \times w \times \tau \times \frac{d}{2} = l \times 16 \times 42 \times \frac{50}{2} = 16\,800\,l \text{ N-mm} \quad \dots(i)$$

and torsional shearing strength (or torque transmitted) of the shaft,

$$T = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 42 \times (50)^3 = 1.03 \times 10^6 \text{ N-mm} \quad \dots(ii)$$

From equations (i) and (ii), we have

$$l = 1.03 \times 10^6 / 16\,800 = 61.31 \text{ mm}$$

Now considering crushing of the key. We know that shearing strength (or torque transmitted) of the key,

$$T = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} = l \times \frac{10}{2} \times 70 \times \frac{50}{2} = 8750\,l \text{ N-mm} \quad \dots(iii)$$

From equations (ii) and (iii), we have

$$l = 1.03 \times 10^6 / 8750 = 117.7 \text{ mm}$$

Taking larger of the two values, we have length of key,

$$l = 117.7 \text{ say } 120 \text{ mm } \mathbf{Ans.}$$



Example 13.2. A 45 mm diameter shaft is made of steel with a yield strength of 400 MPa. A parallel key of size 14 mm wide and 9 mm thick made of steel with a yield strength of 340 MPa is to be used. Find the required length of key, if the shaft is loaded to transmit the maximum permissible torque. Use maximum shear stress theory and assume a factor of safety of 2.

Solution. Given : $d = 45$ mm ; σ_{yt} for shaft = 400 MPa = 400 N/mm² ; $w = 14$ mm ; $t = 9$ mm ; σ_{yt} for key = 340 MPa = 340 N/mm²; $F.S. = 2$

Let $l =$ Length of key.

According to maximum shear stress theory (See Art. 5.10), the maximum shear stress for the shaft,

$$\tau_{max} = \frac{\sigma_{yt}}{2 \times F.S.} = \frac{400}{2 \times 2} = 100 \text{ N/mm}^2$$

and maximum shear stress for the key,

$$\tau_k = \frac{\sigma_{yt}}{2 \times F.S.} = \frac{340}{2 \times 2} = 85 \text{ N/mm}^2$$

We know that the maximum torque transmitted by the shaft and key,

$$T = \frac{\pi}{16} \times \tau_{max} \times d^3 = \frac{\pi}{16} \times 100 (45)^3 = 1.8 \times 10^6 \text{ N-mm}$$

First of all, let us consider the failure of key due to shearing. We know that the maximum torque transmitted (T),

$$1.8 \times 10^6 = l \times w \times \tau_k \times \frac{d}{2} = l \times 14 \times 85 \times \frac{45}{2} = 26\,775 l$$

$$\therefore l = 1.8 \times 10^6 / 26\,775 = 67.2 \text{ mm}$$

Now considering the failure of key due to crushing. We know that the maximum torque transmitted by the shaft and key (T),

$$1.8 \times 10^6 = l \times \frac{t}{2} \times \sigma_{ck} \times \frac{d}{2} = l \times \frac{9}{2} \times \frac{340}{2} \times \frac{45}{2} = 17\,213 l$$

$$\dots \left(\text{Taking } \sigma_{ck} = \frac{\sigma_{yt}}{F.S.} \right)$$

$$\therefore l = 1.8 \times 10^6 / 17\,213 = 104.6 \text{ mm}$$

Taking the larger of the two values, we have

$$l = 104.6 \text{ say } 105 \text{ mm Ans.}$$



Assessment



1. Define key
2. List out the types of key
3. Write down the formula of saddle key
4. List out the application of key.



References

1. Khurmi, R.S. and Gupta, J.S.2001, A textbook of machine design. Eurasia Publi. House, Delhi.
2. machinedesign.com/
3. onesmartclick.com/engineering/machine-design.html
4. utm.edu/departments/engin/lemaster/machine_design.htm

Thank You!

A decorative graphic consisting of several horizontal brushstrokes in various colors including blue, purple, pink, red, and yellow, positioned below the 'Thank You!' text.