Course: Machine Design-I: MEC-212

Unit-2 Design of Keys

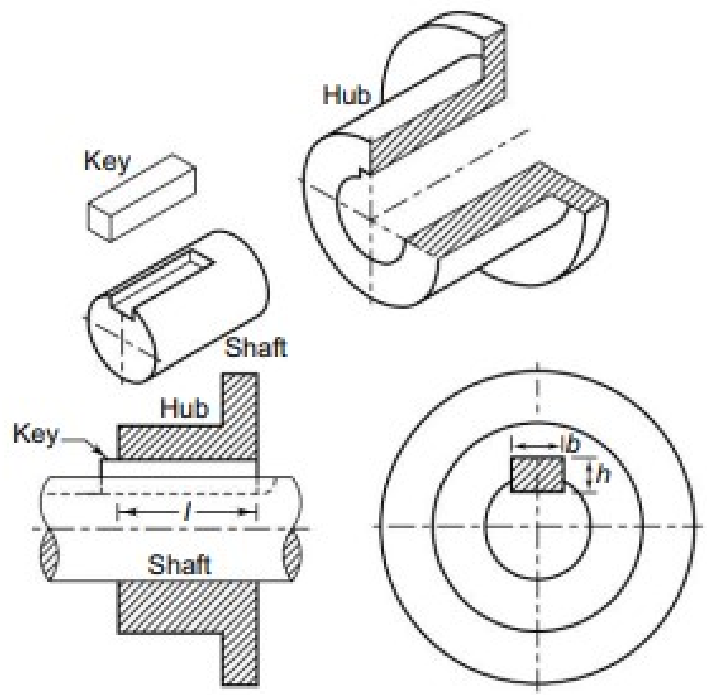
UNIT-II

Shafts, keys and couplings: Transmission Shafts, materials, design of shafts on strength & rigidity basis and under combined torsional and bending loads as per ASME code. Keys, types and applications. Design of rigid and pin bushed flexible couplings.

Dr. Sumit Joshi
Assistant Professor
Department of Mechanical Engineering, MAIT, Delhi

KEYS

- A **key** is defined as a machine element which is used to connect the transmission shaft to rotating machine elements like **pulleys, gears, sprockets or flywheels**.
- **Two basic functions of the key** are as follows:
  1. To transmit the torque from the shaft to the hub of the mating element and vice versa.
  2. To prevent relative rotational motion between the shaft and the joined machine element like gear or pulley. Key also prevents axial motion between mating elements, except in case of feather key or splined connection.
- A **recess or slot** machined either on the shaft or in the hub to accommodate the key is called **keyway.**



CLASSIFICATION OF KEYS

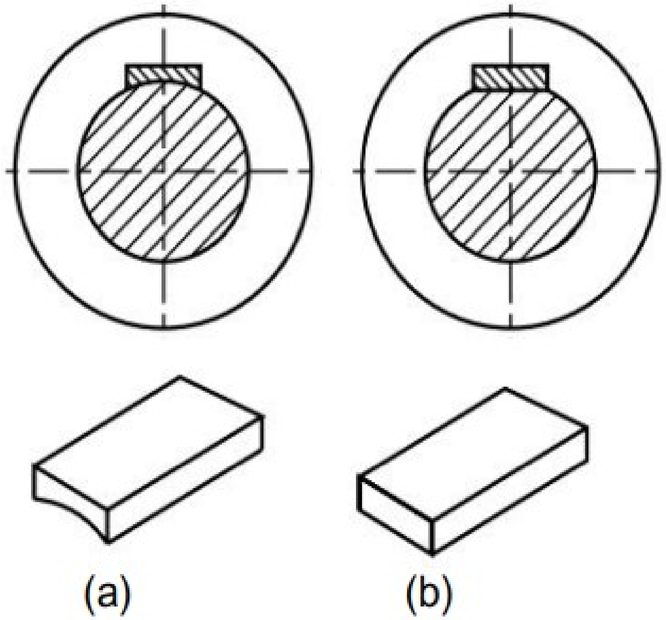
- Saddle key and sunk key
- Square key and flat key
- Taper key and parallel key
- Key with and without Gib-head

Special Keys:

1. Woodruff key
2. Kennedy key
3. feather key.

SADDLE KEY

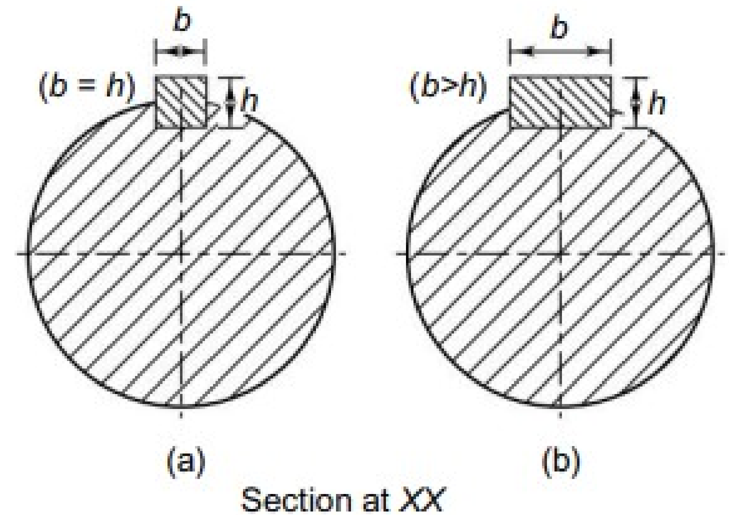
- A saddle key is a key which fits in the keyway of the hub only. In this case, there is **no keyway on the shaft**.
- Cost of the saddle key joint is less since it requires keyway only on the hub.
- Two types: **hollow and flat.** Flat saddle key is slightly superior to hollow saddle key
- The power is transmitted by means of friction. Therefore, saddle keys are suitable **for light duty or low power transmission.**
- Saddle key is liable to slip around the shaft when subjected to heavy torque. Therefore, not suitable for **medium and heavy duty applications.**



(a) Hollow Saddle Key (b) Flat Saddle

SUNK KEY

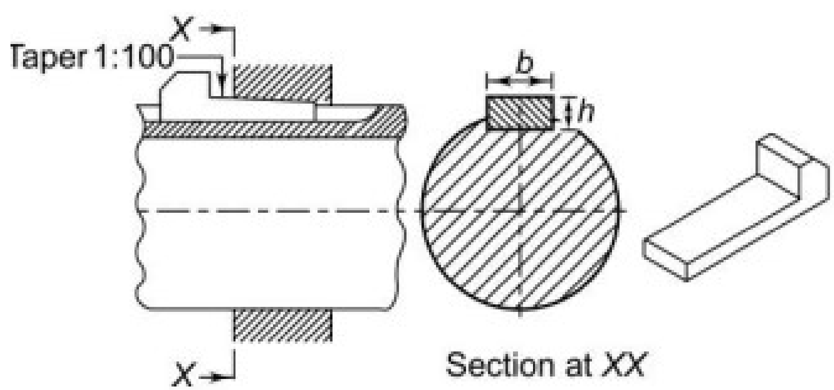
- A **sunk key** is a key in which half the thickness of the key fits into the keyway on the shaft and the remaining half in the keyway on the hub.
- Power is transmitted due to **shear resistance of the key.** The relative motion between the shaft and the hub is also prevented by the shear resistance of key.
- Suitable for **heavy duty application**, since there is no possibility of the key to slip around the shaft.
- Cost is more than that of the saddle key joint**.**
- A sunk key with rectangular cross-section is called a **flat key.**
- Flat key has more stability as compared with square key.
- Flat keys are more suitable for machine tool applications while square keys are used in general industrial machinery

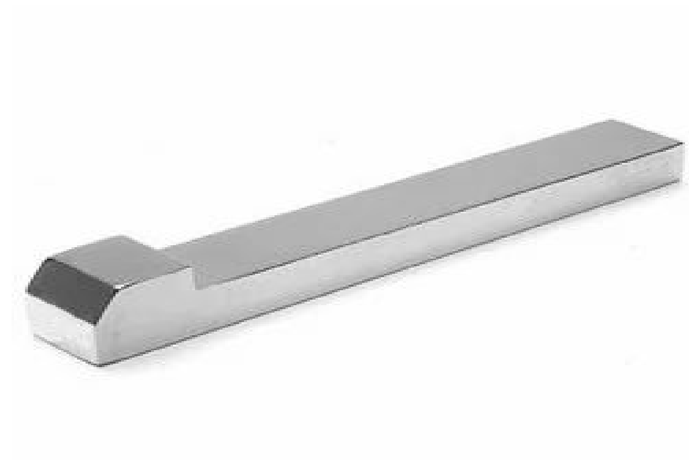


(a) Square Key (b) Flat Key

SUNK KEY

- Sunk keys with square or rectangular cross-sections are classified into two groups, namely, **parallel and taper keys.**
- Taper is provided because: (i) When the key is inserted in the keyways of shaft and the hub and pressed by means of hammer, it becomes tight due to wedge action. This insures tightness of joint in operating conditions and prevents loosening of the parts. (ii) Due to taper, it is easy to remove the key and dismantle the joint.
- Tapered keys are often provided with **Gib-head** to facilitate removal.





SUNK KEYS

The sunk keys are provided half in the keyway of the shaft and half in the keyway of the hub or boss of the pulley

Let

‘d’ – diameter of the shaft or diameter of the hole in the hub

‘w’ – width of the key

‘t’ – thickness of the key

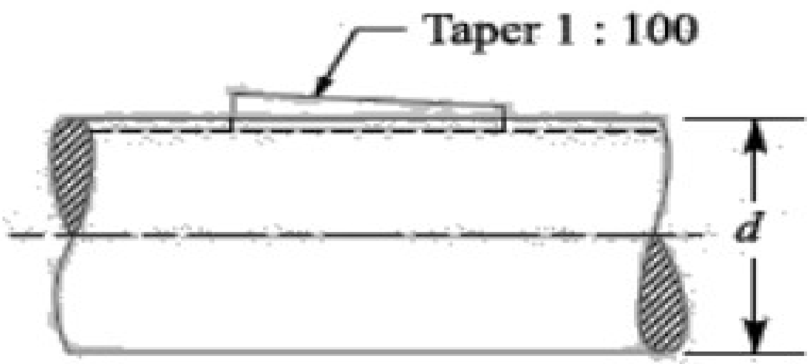
SUNK KEYS

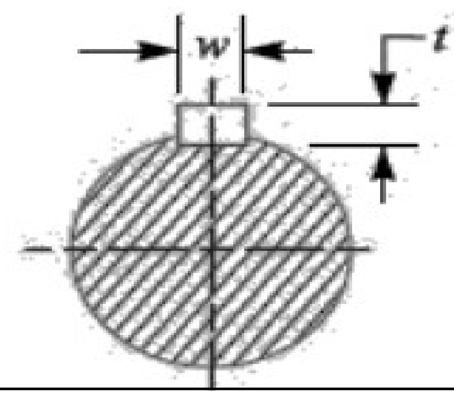
For **RECTANGULAR SUNK KEY**

- Width of key ***w = d/4***
- Thickness of the key ***t = 2w/3 = d/6***
- The key has the taper **1 in 100** on the topside.

For **SQUARE SUNK KEY** the width is equal to thickness. ***w = t = d/4***

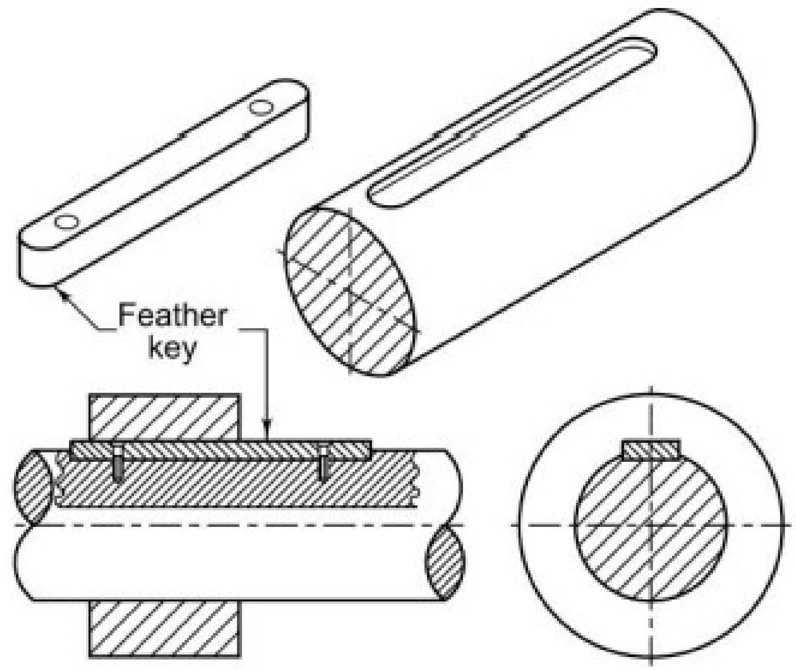
PARALLEL SUNK KEY contains uniform width and thickness through out and are taperless





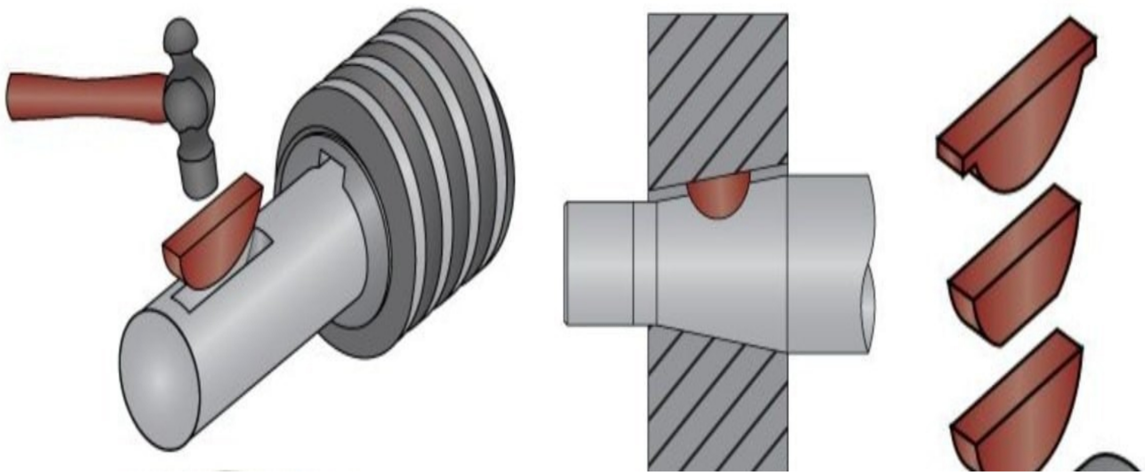
FEATHER KEY

- A **feather key** is a **parallel key** which is **fixed** either to the shaft or to the hub and which permits relative axial movement between them.
- Feather key transmits the torque and at the same time permits some axial movement of the hub **(Clearance fit between the key and the keyway in the hub).**
- Feather keys are used where the parts mounted on the shaft are required to slide along the shaft such as **clutches or gear shifting devices.** It is an alternative to splined connection.



WOODRUFF KEY

- A **Woodruff key** is a sunk key in the form of an almost **semicircular disk** of uniform thickness.
- The keyway in the shaft is in the form of a semicircular recess with the same curvature as that of the key.
- The Woodruff key can be used on tapered shaft because it can align by slight rotation in the seat.
- The extra depth of key in the shaft prevents its tendency to slip over the shaft.
- Extra depth of keyway in the shaft increase stress concentration and reduces its strength.
- The key does not permit axial movement between the shaft and the hub.



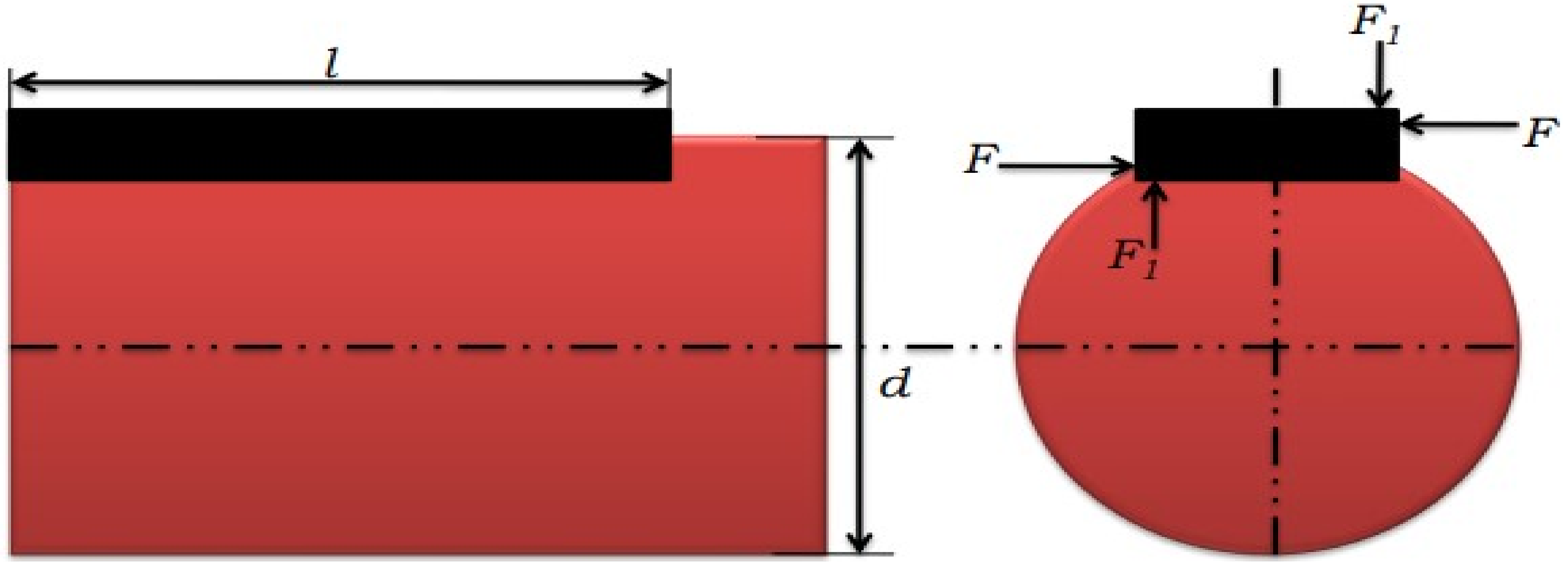
FORCES ACTING ON SUNK KEY

When key is used in transmitting torque from a shaft to rotor or hub the following two types of forces act on the key

1. The forces produced due to tight fitting of the key leads to compressive stresses on the key
2. The forces produced due to torque transmitted by the shaft leads to shearing and compressive (crushing) stresses in the key

Since the forces are concentrated near the torque input end the distribution of forces along the length of the key is not uniform

FORCES ACTING ON SUNK KEY



F1 is the compressive stresses in the key caused by the torque transmitted by the shaft

F is the shear stresses in the key caused by the torque transmitted by the shaft

The forces due to fit of the key are neglected in the design of the key and it is assumed that the distribution of forces along the length of key is uniform

STRENGTH OF THE KEY

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

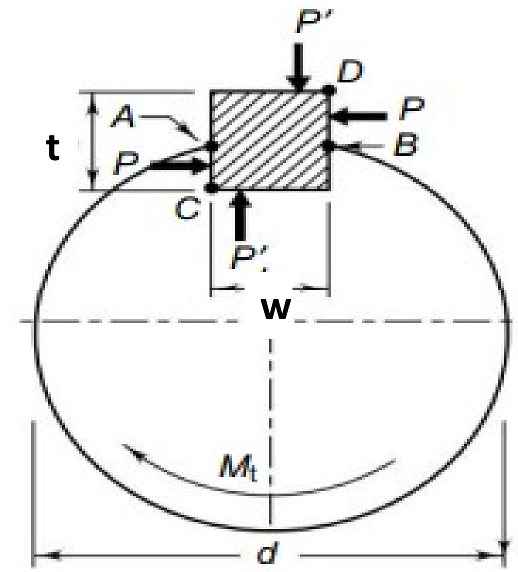
t - Thickness of key

τ - Shear stresses for the material of key

σ_c - Crushing stresses for the material of key

τ_1 - shear stress for the shaft material

STRENGTH OF THE KEY



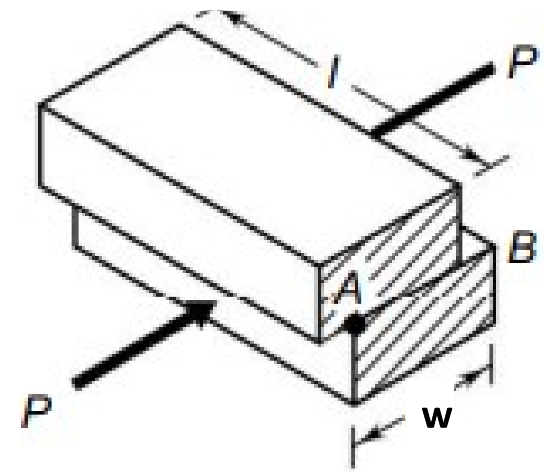
1.Shearing of the key

The tangential shearing force acting at the circumference of the shaft

F = Area resisting shearing x Shear stress = $l.w.\tau$

Torque transmitted by the shaft $T = F\,.\,(d/2)$

$$T = l\,.\,w\,.\,\tau\,.\,(d/2) \longrightarrow (i)$$



STRENGTH OF THE KEY

2. Crushing of the key

The tangential crushing force acting at the circumference of the shaft

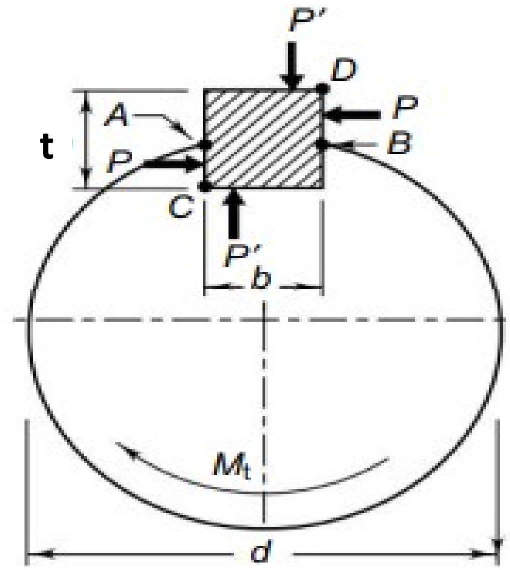
F = Area resisting crushing x Crushing stress

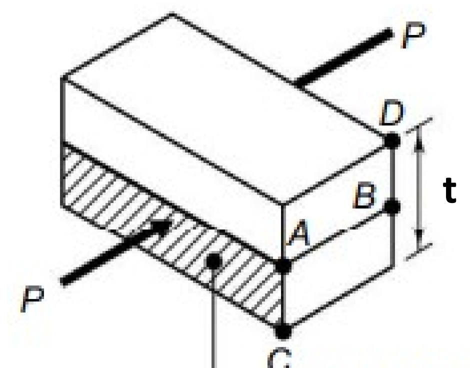
$$F = l \,.\, (t/2) \,.\sigma_c$$

Torque transmitted by the shaft

$$T = F \,.\, (d/2) = l \,.\, (t/2) \,.\sigma_c \,.\, (d/2)$$

$$\boldsymbol{T = l \,.\, (t/2) \,.\sigma_c \,.\, (d/2) \longrightarrow (ii)}$$





(b)

Numericals

Q1 Design the rectangular key for a shaft of 50 mm diameter. The shearing and crushing stresses for the key material are 42MPa and 70 MPa.

Q2 A 45mm diameter shaft is made of steel with yield strength of 400Mpa. A parallel key of size 14mm wide and 9mm thick made of steel with a yield strength of 340MPa 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