Lecture # 6

Keys

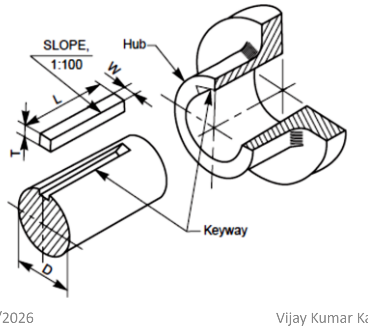
Keys

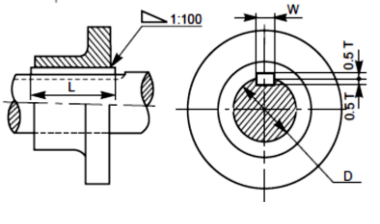
Keys, cotters and pin joints are some examples of removable (temporary) fasteners.

Assembly and removal of these joints are easy as they are simple in shape.

Keys are machine elements used to prevent relative rotational movement between a shaft and the parts mounted on it, such as pulleys, gears, wheels, couplings, etc.

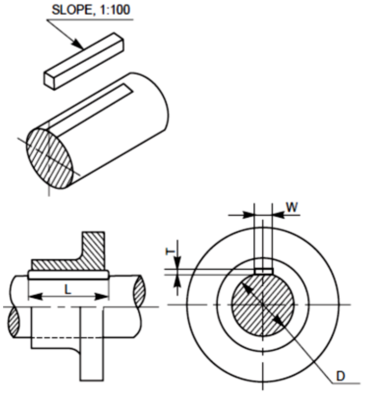
Figure shows the parts of a keyed joint and its assembly.





Keys

For making the joint, grooves or keyways are cut on the surface of the shaft and in the hub of the part to be mounted.



After positioning the part on the shaft such that, both the keyways are properly aligned, the key is driven from the end, resulting in a firm joint.

For mounting a part at any intermediate location on the shaft, first the key is firmly placed in the keyway of the shaft and then the part to be mounted is slid from one end of the shaft, till it is fully engaged with the key.

Keys

Keys are classified into three types:

1. Saddle Keys

These are taper keys, with uniform width but tapering in thickness on the upper side.

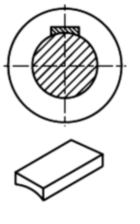
The magnitude of the taper provided is 1:100.

These are made in two forms:

(a) Hollow saddle – This key has a concave shaped bottom to suit the curved surface of the shaft, on which it is used.

A keyway is made in the hub of the mounting, with a tapered bottom surface.

When a hollow saddle key is fitted in position, the relative rotation between the shaft and the mounting is prevented due to the friction between the shaft and key



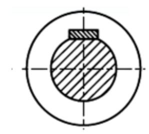
Keys

Keys are classified into three types:

1. Saddle Keys

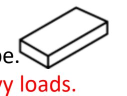
(b) Flat saddle – similar to the hollow saddle key, except that the bottom surface of it is flat.

Apart from the tapered keyway in the hub of the mounting, a flat surface provided on the shaft is used to fit this key in position.



Both are suitable for light duty only.

However, the flat one is slightly superior compared to the hollow type.



Saddle keys are liable to slip around the shaft when used under heavy loads.

5

Keys

Keys are classified into three types:

2. Sunk keys

These are the standard forms of keys used in practice and may be either square or rectangular in cross-section.

The end may be squared or rounded.

Generally, half the thickness of the key fits into the shaft keyway and the remaining half in the hub keyway.

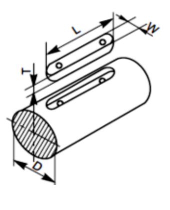
These keys are used for heavy duty, as the fit between the key and the shaft is positive.

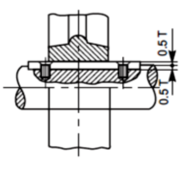
Sunk keys may be classified as:

(i) taper keys,

(ii) parallel or feather keys and

(iii) woodruff keys.





6

Keys

Keys are classified into three types:

2. Sunk keys

(i) Taper Sunk Keys

These keys are square or rectangular in cross-section, uniform in width but tapered in thickness.

The bottom surface of the key is straight, and the top surface is tapered, the magnitude of the taper being 1:100.

Hence, the keyway in the shaft is parallel to the axis and the hub keyway is tapered.

A tapered sunk key may be removed by driving it out from the exposed small end.

If this end is not accessible, the bigger end of the key is provided with a head called gib.

Following are the proportions for a gib head:

If D is the diameter of the shaft, then, Width of key, W = 0.25 D + 2 mm

Thickness of key, T = 0.67 W (at the thicker end)

Standard taper = 1:100, Height of head, H = 1.75 T, Width of head, B = 1.5 T

Keys

Keys are classified into three types:

2. Sunk keys

(i) Taper Sunk Keys

(ii) Parallel or Feather Keys

A parallel or feather key is a sunk key, uniform in width and thickness as well.

These keys are used when the parts (gears, clutches, etc.) mounted are required to slide along the shaft; permitting relative axial movement.

To achieve this, a clearance fit must exist between the key and the keyway in which it slides.

The feather key may be fitted into the keyway provided on the shaft by two or more screws or into the hub of the mounting.

These keys are of three types: (*i*) peg feather key, (*ii*) single headed feather key and (*iii*) double headed feather key.

Keys

Keys are classified into three types:

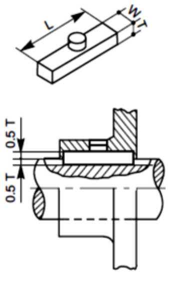
2. Sunk keys

(i) Taper Sunk Keys

(ii) Parallel or Feather Keys

These keys are of three types:

(*i*) peg feather key



In this key, a projection known as peg is provided at the middle of the key.

The peg fits into a hole in the hub of the sliding member Once placed in a position, the key and the mounting move axially as one unit.

Keys

Keys are classified into three types:

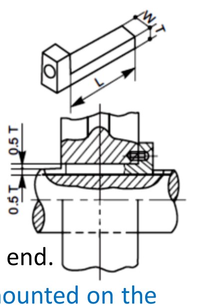
2. Sunk keys

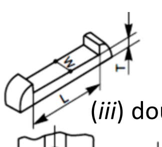
(i) Taper Sunk Keys

(ii) Parallel or Feather Keys

These keys are of three types:

(*ii*) single headed feather key

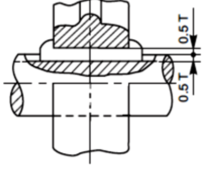




In this, the key is provided with a head at one end.

The head is screwed to the hub of the part mounted on the shaft.

(*iii*) double headed feather key

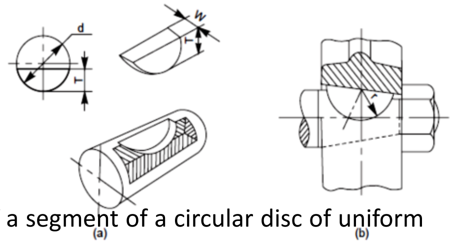


In this, the key is provided with heads on both ends.

These heads prevent the axial movement of the key in the hub. Here too, once placed in position, the key and the mounting move as one unit.

Keys

Keys are classified into three types:



2. Sunk keys

(i) Taper Sunk Keys,

(ii) Parallel or Feather Keys

(iii) Woodruff Keys.

It is a sunk key, in the form of a segment of a circular disc of uniform thickness.

As the bottom surface of the key is circular, the keyway in the shaft is in the form of a circular recess to the same curvature as the key.

A keyway is made in the hub of the mounting, in the usual manner. Woodruff key is mainly used on tapered shafts of machine tools and automobiles.

Once placed in position, the key tilts and aligns itself on the tapered shaft.

The following are the proportions of woodruff keys: If D is the diameter of the shaft, Thickness of key, W = 0.25 D, Diameter of key, *d* = 3 W, Height of key, T = 1.35 W, Depth of the keyway in the hub, T1 = 0.5 W + 0.1 mm, Depth of keyway in shaft, T2 = 0.85 W

11

Keys

Keys are classified into three types:

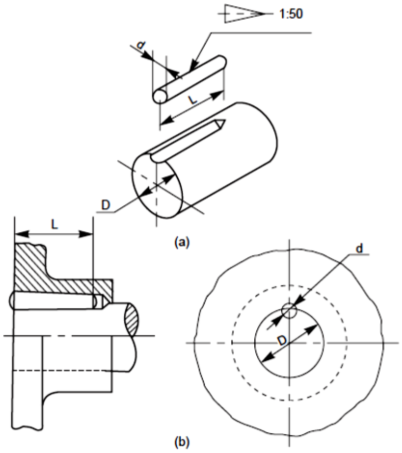
3. Round Keys

This keys are of circular cross-section, usually tapered (1:50) along the length.

A round key fits in the hole drilled partly in the shaft and partly in the hub.

The mean diameter of the pin may be taken as 0.25 D, where D is shaft diameter.

Round keys are generally used for light duty, where the loads are not considerable.



12

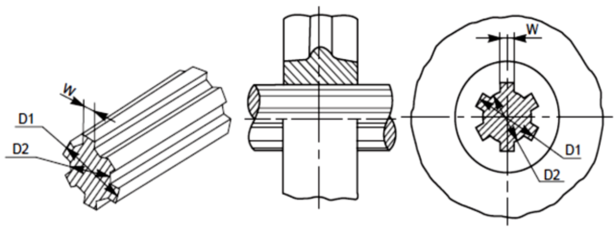
Keys

Splines

Splines are keys made integral with the shaft, by cutting equi-spaced grooves of uniform cross section.

The shaft with splines is called a splined shaft.

The splines on the shaft, fit into the corresponding recesses in the hub of the mounting, with a sliding fit, providing a positive drive and at the same time permitting the latter to move axially along the shaft.

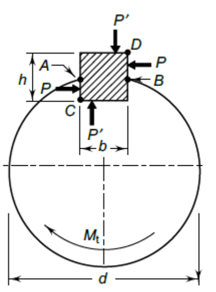


Keys

Design of Square and flat Keys

The forces acting on a flat key, with width as b and heigh as h, are shown in Fig.

- The transmission of torque from the shaft to the hub results in two equal and opposite forces denoted by P.
- The torque M_t is transmitted by means of a force P acting on the left surface AC of the key.
- The equal and opposite force P, acting on the right surface DB of the key is the reaction of the hub on the key.
- It is observed that the force P on left surface AC and its equal and opposite reaction P on the right surface DB are not in the same plane.
- Therefore, forces P' (P' = P) act as resisting couple preventing the key to roll in the keyway.
- The exact location of the force P on the surface AC is unknown.



Forces Acting on Key

Keys

Design of Square and flat Keys

The forces acting on a flat key, with width as b and heigh as h, are shown in Fig.

- In order to simplify the analysis, it is assumed that the force P is tangential to the shaft diameter.

Therefore,

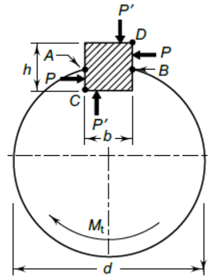
$$P = \frac{T}{d/2}$$

where,

T = transmitted torque (N-mm),

d = shaft diameter (mm),

P = force on key (N)



Forces Acting on Key

Keys

Design of Square and flat Keys

The forces acting on a flat key, with width as b and heigh as h, are shown in Fig.

The design of square or flat key is based on two criteria, viz.
failure due to shear stress
and
failure due to compressive stress.
The shear failure will occur in the plane AB.
It is illustrated in Fig.
The shear stress τ in the plane AB is given by,

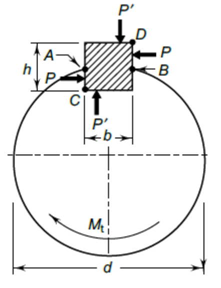
$$\tau = \frac{P}{\text{area of plane } AB} = \frac{P}{bl}$$

where,

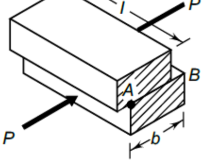
b = width of key (mm)

l = length of key (mm)

$$\therefore \tau = \frac{2T}{dbl} \quad \text{........A}$$



Forces Acting on Key



(a)

Keys

Design of Square and flat Keys

The failure due to compressive stress will occur on surfaces *AC* or *DB*. The crushing area between shaft and key is shown in Fig. b.

It is assumed that, $\overline{AC} \cong \overline{BD} \cong \frac{h}{2}$

where, *h* = height of key (mm)

The compressive stress σ_c in the key is given by,

$$\sigma_c = \frac{P}{Area\ of\ Surface\ AC} = \frac{P}{\left(\frac{h}{2}\right)l} = \frac{2P}{hl}$$

$$\therefore\ \sigma_c = \frac{4T}{dhl} \ldots\ldots.B$$

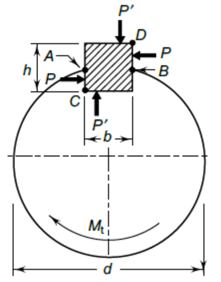
Equations (A) and (B) are stress equations of flat key.

For square key, $h = b$,

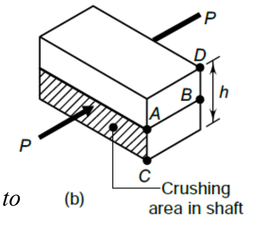
Substituting the above relationship in Eqs (A) and (B),

$$\tau = \frac{2T}{dbl} \text{ and } \sigma_c = \frac{4T}{dbl} \quad \therefore \sigma_c = 2\,\tau$$

Therefore, the compressive stress induced in a square key due to the transmitted torque is twice the shear stress.



Forces Acting on Key



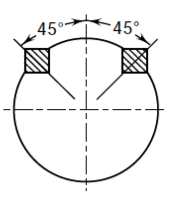
(b)

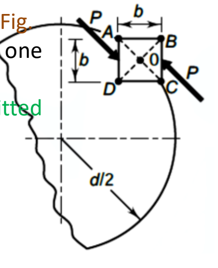
17

Keys

Design of Kennedy Key

- The Kennedy key consists of two square keys as shown in Fig.
- In this case, the hub is bored off the centre and the two keys force the hub and the shaft to a concentric position.
- Kennedy key is used for heavy duty applications.
- The analysis of the Kennedy key is similar to that of the flat key.
- It is based on two criteria, viz., failure due to shear stress and failure due to compressive stress.
- The forces acting on one of the two Kennedy keys are shown in Fig.
- Since there are two keys, the torque transmitted by each key is one half of the total torque.
- The two equal and opposite forces *P* are due to the transmitted torque.
- The exact location of the force *P* is unknown.
- It is assumed to act tangential to the shaft diameter. Therefore,





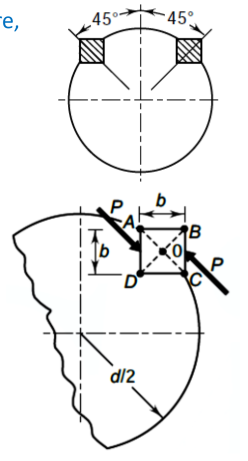
18

Keys

Design of Kennedy Key

- It is assumed to act tangential to the shaft diameter. Therefore,

$\frac{T}{2} = P(\frac{d}{2})$ *or* $P = \frac{T}{d}$



The failure due to shear stress will occur in the plane AC.
The area of the plane AC is $[\overline{AC} \times l]$ or $[\sqrt{2}bl]$.
The shear stress is given by, $\tau = \frac{P}{\sqrt{2}bl}$

Or $$\tau = \frac{T}{\sqrt{2}dbl}$$

The Compressive stress is given by,

$$\sigma_c = \frac{P}{Projected\ Area} = \frac{P}{[\overline{OB} \times l]} = \frac{P}{\left(\frac{b}{\sqrt{2}}\right) \times l}$$

Or $$\sigma_c = \frac{\sqrt{2}T}{dbl}$$

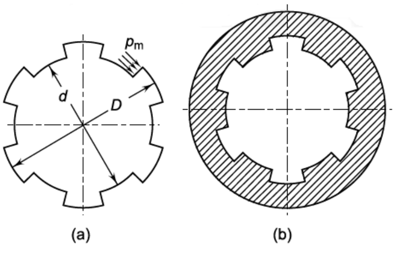
where l is the length of the key

Keys

Splines

- Splines are keys which are made integral with the shaft.
- They are used when there is a relative axial motion between the shaft and the hub.
- The gear shifting mechanism in automobile gearboxes requires such type of construction.
- Splines are cut on the shaft by milling and on the hub by broaching.
- A splined connection, with straight splines, is shown in Fig.

  The following notations are used:
  D = major diameter of splines (mm)
  d = minor diameter of splines (mm)
  l = length of hub (mm)
  n = number of splines



Splines: (a) Shaft (b) Hub

Keys

Splines

The torque transmitting capacity of splines is given by,

$T = P_m A R_m$

where,

T = transmitted torque (N-mm)

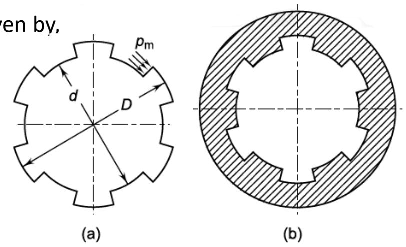
P_m = permissible pressure on spline (N/mm^2)

A = total area of splines (mm^2)

R_m = mean radius of splines (mm)

The area A is given by,

$A = \frac{1}{2}(D - d)\,\mathrm{ln} \quad and\ R_m = \frac{D+d}{4}$



Splines: (a) Shaft (b) Hub

Substituting the above values in torque equation, $T = \frac{1}{8}P_m(D^2 - d^2)\,\mathrm{ln}$

The permissible pressure on the splines is limited to 6.5 N/mm^2.

The above analysis and Fig. refer to straight-sided splines.

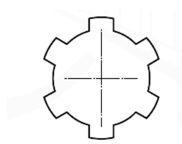
In addition, there are two other types of splines, namely, involute splines and serrations as shown in next Fig.

Keys

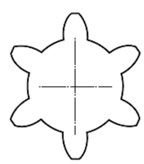
Splines

(i) Involute Splines

- Involute splines are in the form of concentric external and internal gear teeth.
- They are stub teeth with a pressure angle of 30°.
- These splines are specified by module.
- Involute splines are more popular than straight splines due to greater strength relative to their size.
- Involute splines are self centering and tend to adjust to an even distribution of load.
- However, the cost of involute splines is more than straight-sided splines.



(a) Straight sided splines



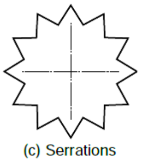
(b) Involute splines

Keys

Splines

(ii) Serrations

- Straight-sided serrations are used in applications where it is important to keep the overall size of the assembly as small as possible.
- They are used as interference joints.
- Serration joints are also used to obtain small angular relative adjustment between the joined members.


(c) Serrations

Types of Spline Profiles

Keys

Shaft diameter (mm) Over	Shaft diameter (mm) Upto and including	Width, W (mm)	Thickness, T (average value) (mm)
6	8	2	2
8	10	3	3
10	12	4	4
12	17	5	5
17	22	6	6
22	30	8	7
30	38	10	8
38	44	12	8
44	50	14	9
50	58	16	10
58	65	18	11
65	75	20	12
75	85	22	14
85	95	25	14
95	110	28	16

Keys

Problem 1:

It is required to design a square key for fixing a gear on a shaft of 25 mm diameter. The shaft is transmitting 15 kW power at 720 rpm to the gear. The key is made of steel 50C4 (S_{yt} = 460 N/mm^2) and the factor of safety is 3.

For key material, the yield strength in compression can be assumed to be equal to the yield strength in tension ($S_{yc} = S_{yt}$).

Determine the dimensions of the key.

Keys

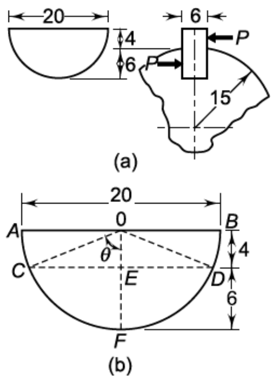
Problem 2:

Find the dimensions of suitable key for a steel shaft 90 mm diameter to transmit 120 H. P. at 300 rpm with mild fluctuations.

Keys

Problem 3:

The dimensions of a Woodruff key for a 30 mm diameter shaft are shown in Fig. below. The shaft is transmitting 5 kW power at 300 rpm. The key is made of steel 50C4 (S_{yt} = S_{yc} = 460 N/mm^2). Calculate the factor of safety used in design.



Woodruff Key

Keys

Problem 4:

A standard splined connection 8 x 52 x 60 mm is used for the gear and the shaft assembly of a gearbox. The splines transmit 20 kW power at 300 rpm. The dimensions of the splines are as follows:

Major diameter = 60 mm

Minor diameter = 52 mm

Number of splines = 8

Permissible normal pressure on splines is 6.5 N/mm^2. The coefficient of friction is 0.06.

Calculate:

(i) The length of hub of the gear

(ii) The force required for shifting the gear

Keys

Problem 5:

The standard cross-section for a flat key, which is fitted on a 50 mm diameter shaft, is 16 x 10 mm. The key is transmitting 475 N-m torque from the shaft to the hub. The key is made of commercial steel (S_{yt} = S_{yc} = 230 N/mm^2).

Determine the length of the key, if the factor of safety is 3.

Keys

Problem 6:

A shaft, 40 mm in diameter, is transmitting 35 kW power at 300 rpm by means of Kennedy keys of 10 x 10 mm cross-section. The keys are made of steel 45C8 (S_{yt} = S_{yc} = 380 N/mm^2) and the factor of safety is 3.

Determine the required length of the keys.