15. Couplings and Keys

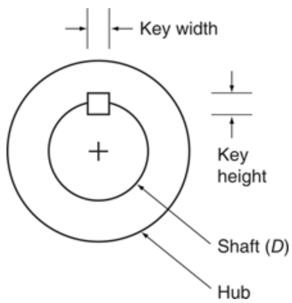
Objectives

- Recognize different types of keys and their standard sizes.
- Size keys for appropriate structural loads.
- Recognize many types of couplings and their advantages and disadvantages.
- Understand principles of splines and analyze appropriate loads.
- Understand basic types of universal joints and how and when they may be used.
- Recognize and understand principles of miscellaneous shaft attachment mechanisms such as setscrews, clamps, and cross pins.

Keys

- It is a device that mechanically connects a member such as gear to a shaft.
- Most common type is a flat key.

Fig. 15.1 Flat Key



Flat Key

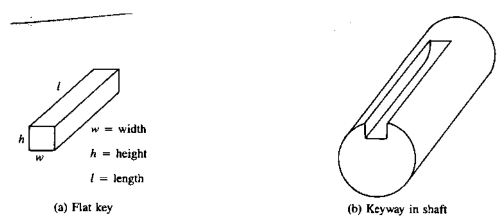


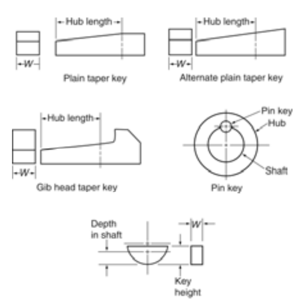
FIGURE 5.14 Key design

Table 15.1

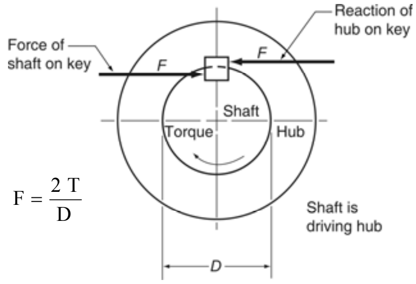
TABLE Standard Size Square and Flat Keys

Shaft Diameter	Square Key Size, w or h	Flat Key Size, $w \times h$
$\frac{1}{2}$–$\frac{9}{16}$	$\frac{1}{8}$	$\frac{1}{8} \times \frac{3}{32}$
$\frac{5}{8}$–$\frac{7}{8}$	$\frac{3}{16}$	$\frac{3}{16} \times \frac{1}{8}$
$\frac{15}{16}$–$1\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4} \times \frac{3}{16}$
$1\frac{5}{16}$–$1\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16} \times \frac{1}{4}$
$1\frac{7}{16}$–$1\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8} \times \frac{1}{4}$
$1\frac{13}{16}$–$2\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2} \times \frac{3}{8}$
$2\frac{5}{16}$–$2\frac{3}{4}$	$\frac{5}{8}$	$\frac{5}{8} \times \frac{7}{16}$
$2\frac{7}{8}$–$3\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4} \times \frac{1}{2}$
$3\frac{3}{8}$–$3\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8} \times \frac{5}{8}$
$3\frac{7}{8}$–$4\frac{1}{2}$	1	$1 \times \frac{3}{4}$
$4\frac{3}{4}$–$5\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4} \times \frac{7}{8}$
$5\frac{3}{4}$–6/	$1\frac{1}{2}$	$1\frac{1}{2} \times 1$

Fig. 15.2 Other types of keys

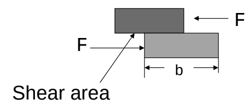


Design of Keys



$$F = \frac{2\,T}{D}$$

Shear failure



S_s = shear stress (lb/in^2)

F = force (lb)

b = width of the key

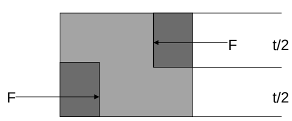
L = length of the key (in.)

D = shaft diameter

$$S_s = \frac{F}{b\,L}$$

$$L = \frac{2\,T}{b\,D\,S_s}$$

Crushing failure of flat keys



$$S_c = \frac{F}{L\,\frac{t}{2}}$$

$$F = \frac{2T}{D}$$

$$L = \frac{4\,T}{S_c\,t\,D}$$

S_c = compressive stress (lb/in^2) = S_y

t = total height of the key (in.)

Example Problem 15-1: Design of Keys

- A ½-inch shaft transmits 5 hp at 1750 rpm.
- The shaft is made from cold-drawn 1040 steel; hub is made from hot-rolled 1213 steel; and a cold-drawn 1020 steel key is to be used.
- If direction is regularly reversed, determine length of square key required for a SF = 2.5:
  - Material properties: (Appendix 4)

CD 1040	S_y = 71 ksi	
HR 1213	S_y = 58 ksi	
CD 1020	S_y = 51 ksi	S_u = 61 ksi

  - Determine the torque.

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  - Determine the torque.

$$T = \frac{63{,}000\,hp}{n} \qquad (2\text{-}6)$$

$$T = \frac{63{,}000\,(5)}{1750}$$

$$T = 180\,in - lb$$

Example Problem 15-1: Design of Keys (cont'd.)

(From Table 15-1, for 1/2-inch shafting, the key is 1/8 x 1/8 inch)

– Determine the length of the key for shear:

- Use: $S_s = .5\,(S_u) = .5\,(61\ ksi)$

  $S_s = 30.5\ ksi$

$$L = \frac{2T}{S_s\,b\,D} \qquad (15\text{-}2)$$

$$L = \frac{2\,(180\,in - lb)}{30{,}500\,lb/in^2\ \ .125\,in\ \ .5\,in}$$

$$L = .188\,inch$$

- With SF = 2.5

$L = 2.5\ (.188)$

$L = 1/2\ inch$

Example Problem 15-1: Design of Keys (cont'd.)

– Find length required for compression, using lowest value of yield, which is key value S_y = 51 ksi.

$$L = \frac{4T}{S_c\, t\, D} \qquad (15\text{-}4)$$

$$L = \frac{4\,(180\; in-lb)}{51{,}000\; lb/in^2 \;\; .125\, in \;\; .5\, in}$$

$$L = .226$$

– With SF = 2.5:

$$L = 2.5\ (.226)$$

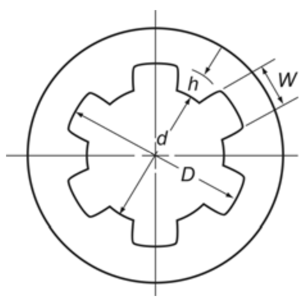
$$L = .565\ inch$$

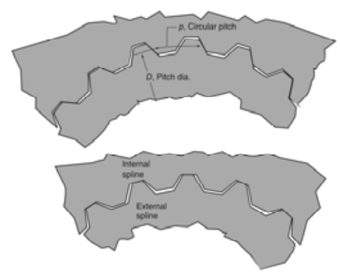
– This would be the minimum length. A longer key may be useful if the hub length is longer.

SPLINES

- Used for
  - Extra torque capacity
  - Axial sliding capacity
- Torque carrying capacity of a spline

$$T = \frac{S_s \pi\, D^2\, L}{16}$$





Example Problem 15-2: Splines

- A straight-sided spline like the one shown in Figure 15-4 has the following dimensions:
  - –D = 1 inch
  - – 6 splines
  - – d = .810 inch
- Determine torque capacity if system is made from 1020 steel as in previous example problem.
- Assume SF = 2 and spline has an engagement length of 2 inches.

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- Assume SF = 2 and spline has an engagement length of 2 inches.

$$T = \frac{S_s\, \pi\, D^2\, L}{16} \qquad (15\text{-}5)$$

$$T = \frac{30{,}500\; lb/in^2\; \pi\; (1\, in)^2\; 2\, in}{16}$$

$$T = 11{,}977\; in-lb$$

– With SF of 2:

$$T = 5988\; in-lb$$

Example Problem 15-2: Splines (cont'd.)

- If sliding under load is needed, assume 1000-psi contact pressure.
  - Find the area

$$A = \frac{(D-d)\,L}{2}\,(number\ of\ splines)$$
$$A = \frac{(1-.810)}{2}\,2\,(6)$$
$$A = 1.14\ in^2$$
$$T = S\,A\,r_m \qquad (15\text{-}6)$$
$$T = 1000\ lb/in^2\ 1.14\ in^2\left(\frac{1+.810}{4}\right)$$
$$T = 516\ in-lb$$

- This is far less than for the strength of the spline.

Rigid couplings

- A coupling is a device used to connect the end of one shaft to the end of a second.
- Rigid couplings do not allow any misalignment of connecting members.

Fig. 15.6 Three jaw (star) coupling

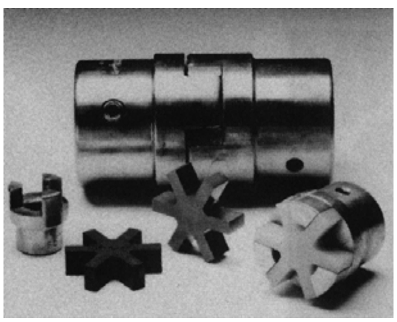
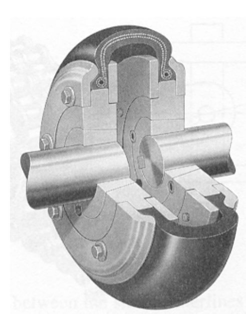


Fig. 15.7

Fig. 15.8 Coupling types

Paraflex coupling (Fig. 5.24)



Flexible coupling

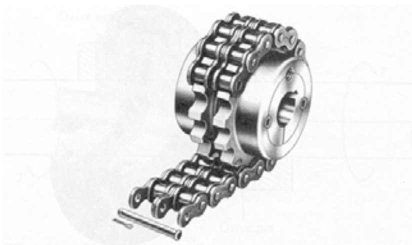


FIGURE 5.25 Chain coupling. *(Courtesy of Dodge Manufacturing Division, Reliance Electric Company)*

Flexible couplings

- Misalignment is attributed to
  - Lack of perfect collinearity of bearing support housings due to the manufacturing tolerances
  - Shaft bending deflection under load
  - Use of two separately mounted units, such as coupling a motor shaft to a pump shaft

Flexible couplings

- If rigid coupling is used with misalignment, the result will be
  - Excessive shaft bending loads
  - Excessive bearing loads
  - Increased vibration and noise

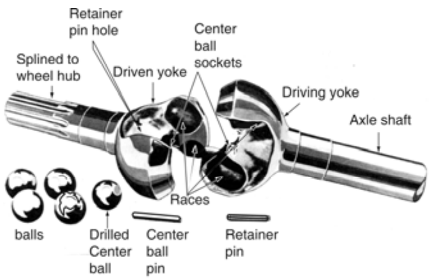
Universal Joints

- They allow for greater angles of misalignment.
- It also allows for the misalignment to change.

Fig. 15.9 Pin type universal joint

Fig. 15.10 Needle bearing spider-type universal joint

Fig. 15.11 Constant velocity joint



Universal joint

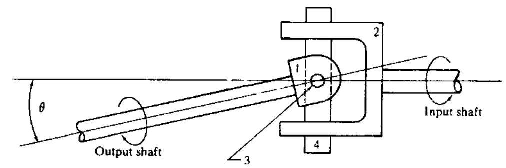


FIGURE 5.27 Universal joint

Universal joint

FIGURE 5.28 Single universal joint *(Courtesy of Lovejoy, Inc.)*

Universal joint

FIGURE 5.29 Double universal joint

Universal joint

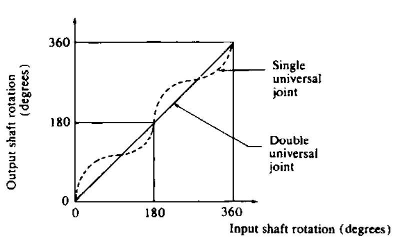
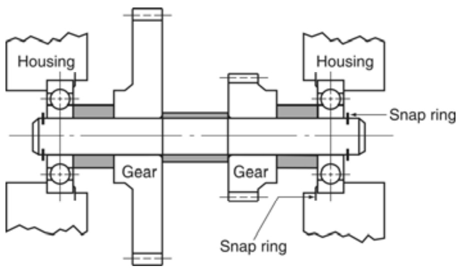


FIGURE 5.30 Angular displacements of universal joint output and input shafts

Other Shaft Attachment Methods

- Snap rings
- Set screws

Fig. 15.13


Housing
Housing
Snap ring
Gear
Gear
Snap ring


THE NUMBER ONE COMPLAINT FROM EMPLOYEES IS "UNCLEAR OBJEC-TIVES."
MY NUMBER ONE COMPLAINT IS THAT IT TAKES TOO MUCH EFFORT FOR ME TO BE CLEAR.
LET'S CALL IT A TIE.
WHY ARE THEY SO SELFISH?
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