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.

Table 15.1

<table>
<thead>
<tr>
<th>Shaft Diameter</th>
<th>Square Key Size, w or d</th>
<th>Flat Key Size, w x t</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8 – 1/4</td>
<td>1/8</td>
<td>1/8 x 1/16</td>
</tr>
<tr>
<td>1/16 – 3/32</td>
<td>1/16</td>
<td>1/32 x 1/16</td>
</tr>
<tr>
<td>1/32 – 1/64</td>
<td>1/32</td>
<td>1/64 x 1/16</td>
</tr>
</tbody>
</table>

Fig. 15.1 Flat Key

Flat Key

Fig. 15.2 Other types of keys
Design of Keys

Shear failure

- Shear stress (lb/in²)
- Force (lb)
- Width of the key
- Length of the key (in.)
- Shaft diameter

Crushing failure of flat keys

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:
    - CD 1040: $S_y = 71$ ksi
    - HR 1213: $S_y = 58$ ksi
    - CD 1020: $S_y = 51$ ksi
  - Determine the torque.

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: $S_y = 0.5(S_u) = 0.5(61$ ksi
  - $S_y = 30.5$ ksi
  - With SF = 2.5
    - $L = 2.5 \times (0.188)$
    - $L = 1/2$ inch

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

- Determine the torque.

- With SF = 2.5
  - $L = 2.5 \times (0.188)$
  - $L = 1/2$ 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.

$$L = \frac{4T}{S_y D}$$

$$L = \frac{4(100 \text{ in} \cdot \text{lb})}{31,000 \text{ in} \cdot \text{lb} / \text{ksi} \cdot 0.125 \text{ in} \cdot 5 \text{ in}}$$

$$L = 225$$

– With $SF = 2.5$:

$$L = 2.5 \times 225$$

$$L = .565 \text{ inch}$$

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

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
  – $d = 0.810$ 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.

\[ T = \frac{S_y \pi D^2 L}{16} \]

– With $SF = 2.5$:

\[ T = \frac{51 \times \pi (1)^2 \times 2.5}{16} \]

\[ T = 39.88 \text{ in} \cdot \text{lb} \]
Example Problem 15-2: Splines (cont’d)

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

\[
A = \frac{(D-d)l}{2} \text{ (number of splines)}
\]

\[
A = \frac{1}{2} l \left( d + D \right)
\]

\[
A = 1.14 \text{ in}^2
\]

\[
T = S = \frac{A}{t}
\]

\[
T = 1000 \text{ lb/in}^2 \cdot 1.14 \text{ in}^2 \cdot \left( \frac{1}{2} \right)
\]

\[
T = 516 \text{ in} \cdot \text{lb}
\]

- 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

- 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

Universal joint

Universal joint

Universal joint

Other Shaft Attachment Methods
- Snap rings
- Set screws