Introduction, types and uses of couplings

Instructional Objectives

At the end of this lesson, the students should have the knowledge of

- The function of couplings in machinery.
- Different types of couplings: rigid and flexible couplings.
- Types of rigid couplings such as sleeve, clamp, ring compression type and flange couplings.
- Types of misalignments and couplings suitable to connect misaligned shafts.

5.1.1 Introduction

Couplings are used to connect two shafts for torque transmission in varied applications. It may be to connect two units such as a motor and a generator or it may be to form a long line shaft by connecting shafts of standard lengths say 6-8m by couplings. Coupling may be rigid or they may provide flexibility and compensate for misalignment. They may also reduce shock loading and vibration. A wide variety of commercial shaft couplings are available ranging from a simple keyed coupling to one which requires a complex design procedure using gears or fluid drives etc. However there are two main types of couplings:

Rigid couplings

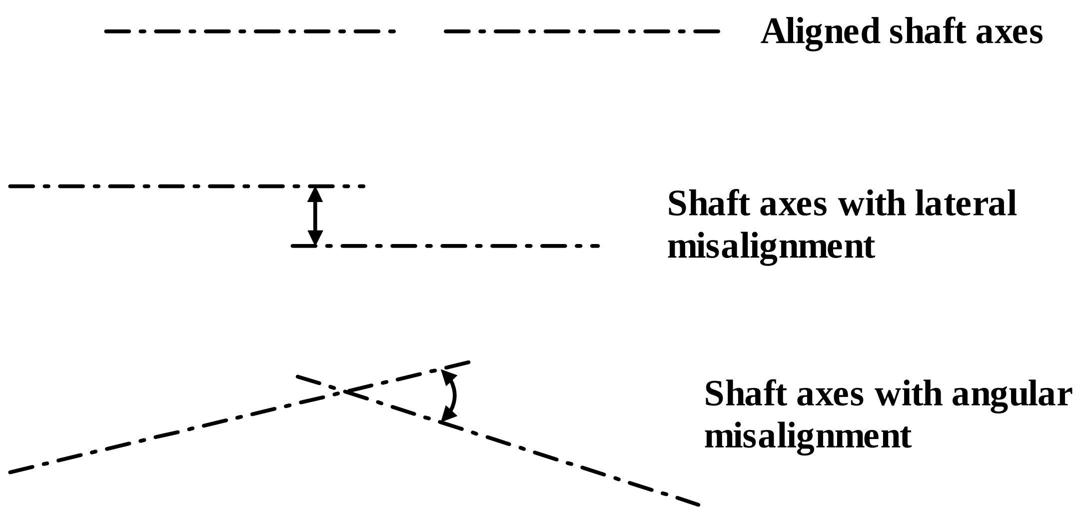
Flexible couplings

Rigid couplings are used for shafts having no misalignment while the flexible couplings can absorb some amount of misalignment in the shafts to be connected. In the next section we shall discuss different types of couplings and their uses under these two broad headings.

5.1.2 Types and uses of shaft couplings

5.1.2.1 <u>Rigid couplings</u>

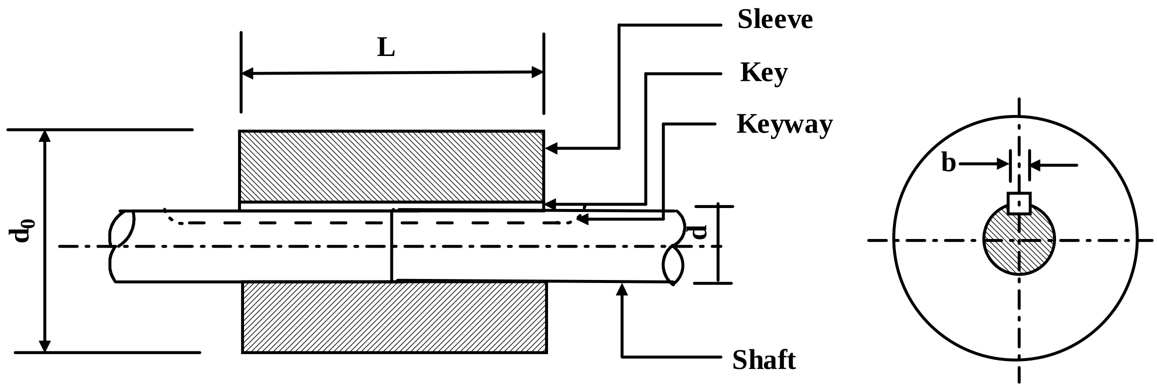
Since these couplings cannot absorb any misalignment the shafts to be connected by a rigid coupling must have good lateral and angular alignment. The types of misalignments are shown schematically in **figure-5.1.2.1.1**.



5.1.2.1.1.F*- Types of misalignments in shafts*

5.1.2.1.1 Sleeve coupling

One of the simple type of rigid coupling is a sleeve coupling which consists of a cylindrical sleeve keyed to the shafts to be connected. A typical sleeve coupling is shown in **figure- 5.1.2.1.1.1**.



5.1.2.1.1.1F- *A typical sleeve coupling*

Normally sunk keys are used and in order to transmit the torque safely it is important to design the sleeve and the key properly. The key design is usually based on shear and bearing stresses. If the torque transmitted is T, the shaft radius is r and a rectangular sunk key of dimension b and length L is used then the induced shear stress τ (**figure- 5.1.2.1.1.2**) in the key is given by

$$\tau = T \Big/ \left(b \frac{L}{2} r \right)$$

and for safety

$$\left(2T/bLr\right) < \tau_y$$

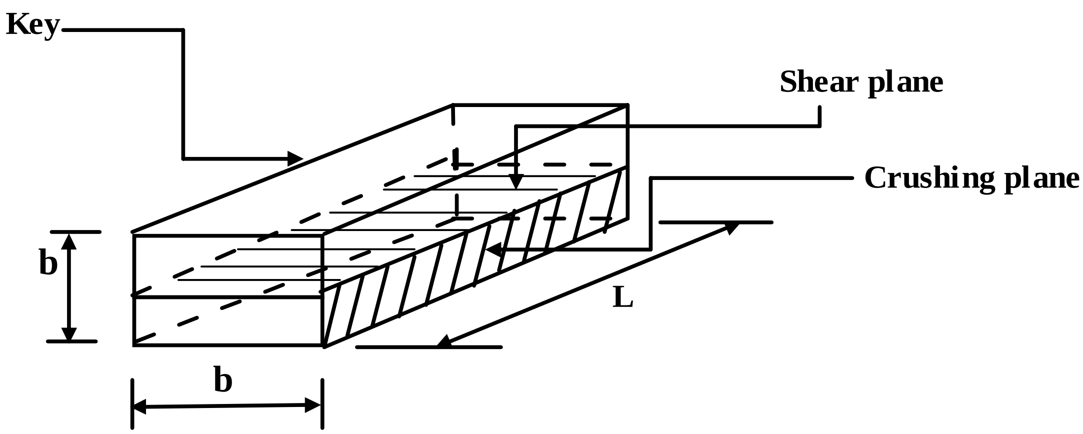
where τ_y is the yield stress in shear of the key material. A suitable factor of safety must be used. The induced crushing stress in the key is given as

$$\sigma_{br} = T \Big/ \left(\frac{b}{2} \frac{L}{2} r \right)$$

and for a safe design

$$4T/\left(bLr\right) < \sigma_c$$

where σ_c is the crushing strength of the key material.



5.1.2.1.1.2F- *Shear and crushing planes in the key.*

The sleeve transmits the torque from one shaft to the other. Therefore if d_i is the inside diameter of the sleeve which is also close to the shaft diameter d (say) and d_0 is outside diameter of the sleeve, the shear stress developed in the sleeve is $\tau_{sleeve} = \frac{16Td_0}{\pi\left(d_0^4 - d_i^4\right)}$ and the shear stress in the shaft is given by $\tau_{shaft} = \frac{16T}{\pi d_i^3}$. Substituting yield shear stresses of the sleeve and shaft materials for τ_{sleeve} and τ_{shaft} both d_i and d_0 may be evaluated.

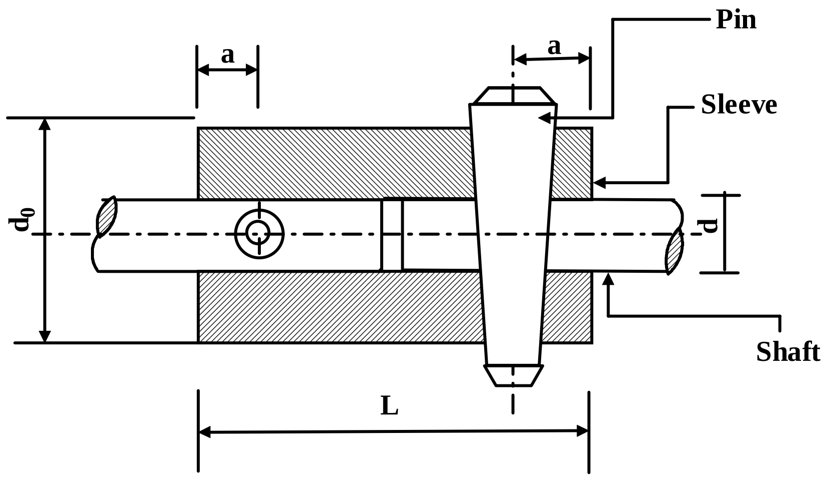
However from the empirical proportions we have:

$d_0 = 2d_i + 12.5$ mm and L=3.5d.

These may be used as checks.

5.1.2.1.2 Sleeve coupling with taper pins

Torque transmission from one shaft to another may also be done using pins as shown in **figure-5.1.2.1.2.1.**



5.1.2.1.2.1F*- A representative sleeve coupling with taper pins.*

The usual proportions in terms of shaft diameter d for these couplings are: d_0 = 1.5d, L = 3d and a = 0.75d.

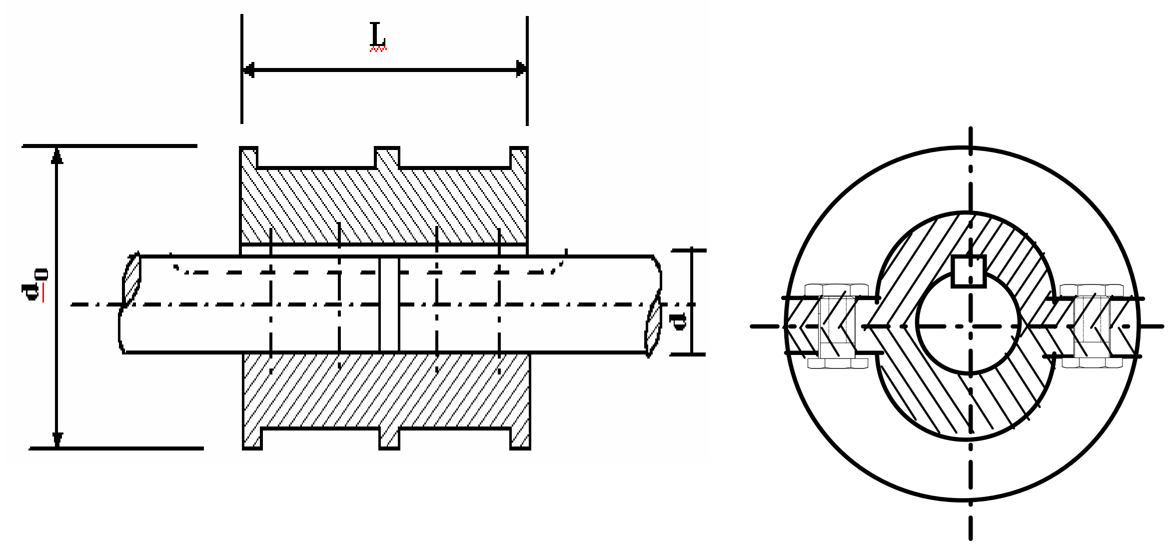
The mean pin diameter d_{mean} = 0.2 to 0.25 d. For small couplings d_{mean} is taken as 0.25d and for large couplings d_{mean} is taken as 0.2d. Once the dimensions are fixed we may check the pin for shear failure using the relation

$$2\left(\frac{\pi}{4}d_{mean}^2\right)\tau\left(\frac{d}{2}\right) = T.$$

Here T is the torque and the shear stress τ must not exceed the shear yield stress of the pin material. A suitable factor of safety may be used for the shear yield stress.

5.1.2.1.3 Clamp coupling

A typical clamp coupling is shown in **figure-5.1.2.1.3.1**. It essentially consists of two half cylinders which are placed over the ends of the shafts to be coupled and are held together by through bolt.



***5.1.2.1.3.1F**- A representative clamp coupling*

The length of these couplings 'L' usually vary between 3.5 to 5 times the and the outside diameter 'd_0' of the coupling sleeve between 2 to 4 times the shaft diameter d. It is assumed that even with a key the torque is transmitted due to the friction grip. If now the number of bolt on each half is n, its core diameter is d_c and the coefficient of friction between the shaft and sleeve material is μ we may find the torque transmitted T as follows:

The clamping pressure between the shaft and the sleeve is given by

$$p = \frac{n}{2} x \frac{\pi}{4} d_c^2 x \sigma_t \Big/ \left(dL/2 \right)$$

where n is the total number of bolts, the number of effective bolts for each shaft is n/2 and σ_t is the allowable tensile stress in the bolt. The tangential force per unit area in the shaft periphery is F = μ p. The torque transmitted can therefore be given by $T = \frac{\pi dL}{2} \mu p. \frac{d}{2}$.

5.1.2.1.4 Ring compression type couplings

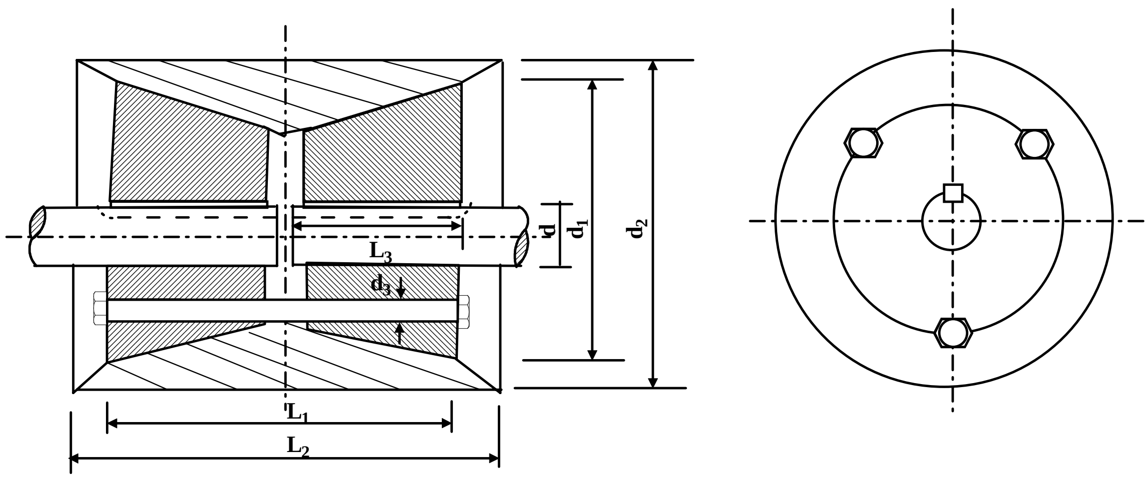
The coupling (**figure-5.1.2.1.4.1)** consists of two cones which are placed on the shafts to be coupled and a sleeve that fits over the cones. Three bolts are used to draw the cones towards each other and thus wedge them firmly between the shafts and the outer sleeve. The usual proportions for these couplings in terms of shaft diameter d are approximately as follows:

d_1 = 2d + 15.24 mm $\qquad$ L_1 = 3d

d_2 = 2.45d + 27.94 mm $\qquad$ L_2 = 3.5d + 12.7 mm

d_3 = 0.23d + 3.17 mm $\qquad$ L_3 = 1.5d

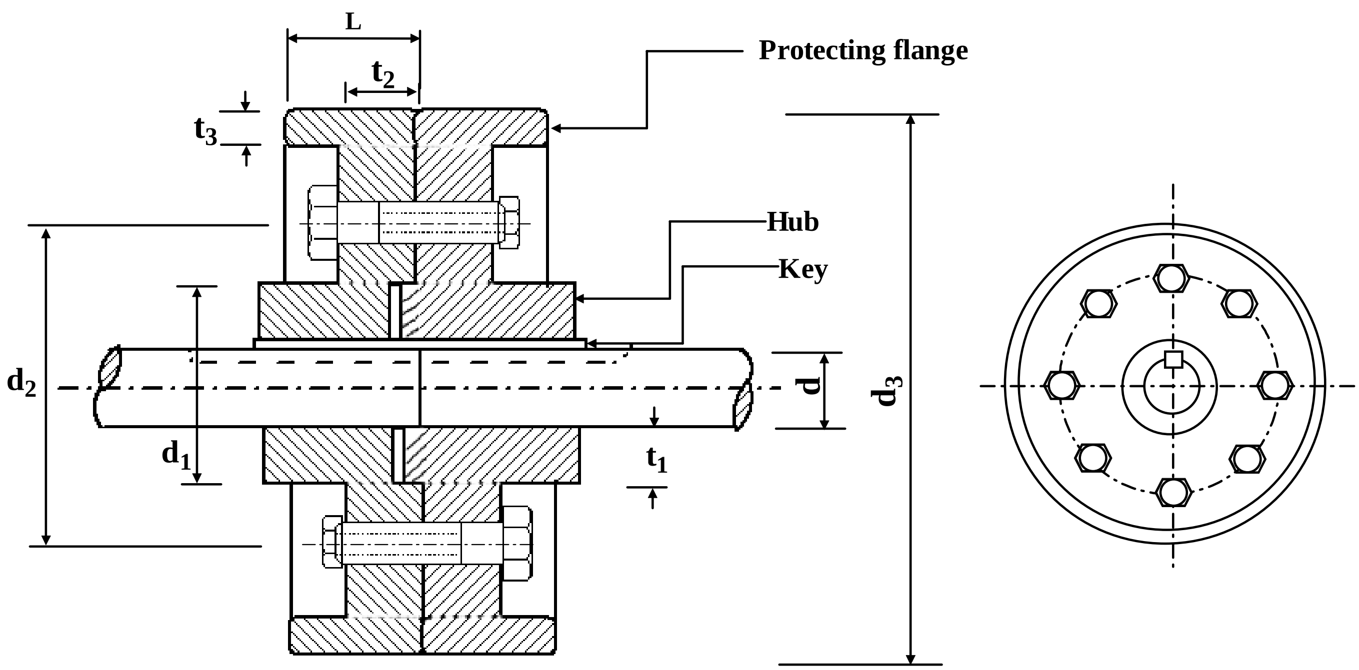
and the taper of the cone is approximately 1 in 4 on diameter.



5.1.2.1.4.1F*- A representative ring compression type coupling.*

5.1.2.1.4 Flange coupling

It is a very widely used rigid coupling and consists of two flanges keyed to the shafts and bolted. This is illustrated in **figure-5.1.2.1.4.2**.



5.1.2.1.4.2F- *A typical flange coupling*

Design details of such couplings will be discussed in the next lesson. The main features of the design are essentially

(a) Design of bolts

(b) Design of hub

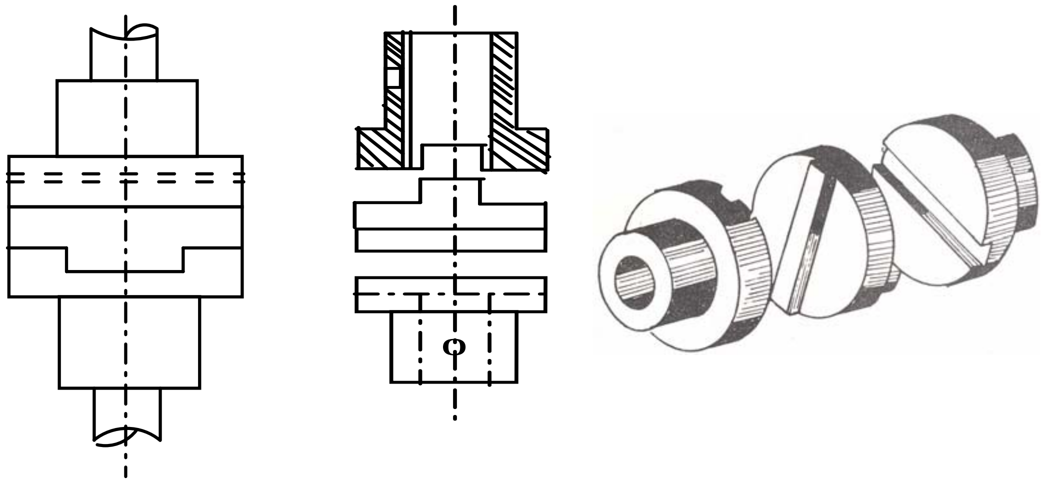
(c) Overall design and dimensions.

5.1.2.2 <u>Flexible coupling</u>

As discussed earlier these couplings can accommodate some misalignment and impact. A large variety of flexible couplings are available commercially and principal features of only a few will be discussed here.

5.1.2.2.1 Oldham coupling

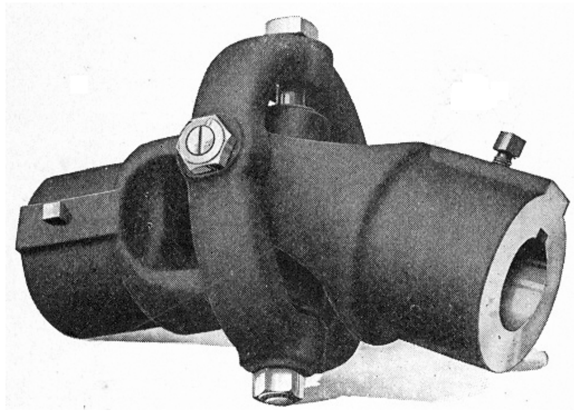
These couplings can accommodate both lateral and angular misalignment to some extent. An Oldham coupling consists of two flanges with slots on the faces and the flanges are keyed or screwed to the shafts. A cylindrical piece, called the disc, has a narrow rectangular raised portion running across each face but at right angle to each other. The disc is placed between the flanges such that the raised portions fit into the slots in the flanges. The disc may be made of flexible materials and this absorbs some misalignment. A schematic representation is shown in **figure-5.1.2.2.1.1.**



5.1.2.2.1.1F- *A schematic diagram of an Oldham coupling*

5.1.2.2.2 Universal joints

These joints are capable of handling relatively large angular misalignment and they are widely used in agricultural machinery, machine tools and automobiles.A typical universal joint is shown in **figure- 5.1.2.2.2.1.**There are many forms of these couplings, available commercially but they essentially consist of two forks keyed or screwed to the shaft. There is a center piece through which pass two pins with mutually perpendicular axes and they connect the two fork ends such that a large angular misalignment can be accommodated. The coupling, often known as, Hooke's coupling has no torsional rigidity nor can it accommodate any parallel offset.



***5.1.2.2.2.1F**- A typical universal joint (Ref. [2])*

5.1.2.2.2 Pin type flexible coupling

One of the most commonly used flexible coupling is a pin type flexible flange coupling in which torque is transmitted from one flange to the other through a flexible bush put around the bolt. This is shown in the next lesson and is shown in **figure-5.2.2.1.**

These are used when excessive misalignment is not expected such as a coupling between a motor and a generator or a pump mounted on a common base plate. Detail design procedure for these couplings will be discussed in the next lesson.

5.1.3 Summary of this Lesson

Basic function of shaft couplings, their types and uses have been discussed in this lesson. Among the rigid couplings some details of sleeve couplings with key or taper pins, clamp couplings, ring compression type couplings and flange couplings have been described. Among the flexible couplings the Oldham coupling and universal joints are described and the functions of pin type flexible couplings are given briefly.