1.0 INTRODUCTION

A coupling is a design component intended to connect shafts of two mechanical units, such as an electric motor and a hydraulic pump or compressor driven by this motor, etc. As stated in the Resolution of the First International Conference on Flexible Couplings [1, 3], "...a flexible coupling, although it is relatively small and cheap compared to the machines it connects, is a critical aspect of any shaft system and a good deal of attention must be paid to its choice at the design stage." The following is a brief engineering data on couplings. More details are available in [1, 3].

The application considerations for couplings are numerous. The most important are the following:

- Torque and Horsepower
- Allowable Shaft Misalignment
- Lateral and Axial Flexibility of Coupling
- Torsional Flexibility
- Backlash
- Rotational Velocity Error
- Service Conditions

2.0 APPLICATION CONSIDERATIONS

Flexible couplings are designed to accommodate various types of load conditions. No one type of coupling can provide the universal solution to all coupling problems; hence many designs are available, each possessing construction features to accommodate one or more types of application requirements. Successful coupling selection requires a clear understanding of application conditions. The major factors governing coupling selection are discussed below.

2.1 Torque and Horsepower

The strength of a coupling is defined as its ability to transmit a required torque load, frequently in combination with other factors.

Hence, a coupling may be selected whose rated torque capacity is many times greater than needed. For example, in a coupling subject to wear and increasing backlash, a useful torque rating would depend chiefly on backlash limitations rather than strength. For manually operated drives, the torque imposed through improper handling may be in excess of the drive torque required. Couplings are frequently specified in horsepower capacity at various speeds.

Horsepower is a function of torque and speed, and it can be readily determined from the formula:

$$HP = \frac{NT}{63{,}000}$$

where N = rotational speed in rpm and T= torque in lb. in. This relationship is graphically represented in Figure 1.

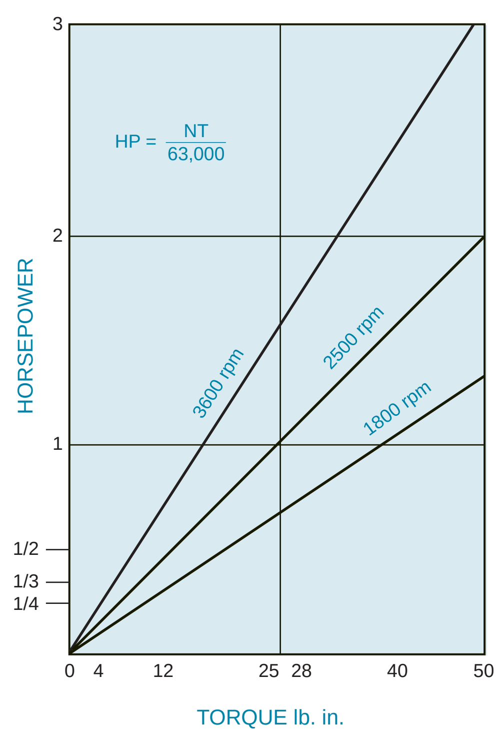

Figure 1 Relationship Between Horsepower, Torque and Rotational Speed

2.2 Shaft Misalignment

Shaft misalignment can be due to unavoidable tolerance build-ups in a mechanism or intentionally produced to fulfill a specific function. Various types of misalignment, as they are defined in AGMA Standard 510.02, are shown in Figure 2.

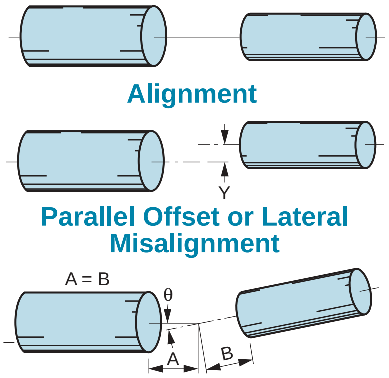

Figure 2 Various Types of Shaft Misalignment

2.3 Lateral and Axial Flexibility of Couplings

Lateral and axial flexibility of couplings are factors frequently overlooked. The term *flexible* does not mean that the coupling gives complete freedom of relative movement between the coupled shafts. More properly, flexible couplings give a limited freedom of the relative movement. Some forces are needed to make a flexible coupling flex. These forces are either lateral (at right angles to the shafts), or axial, or a combination of both. Lateral forces may produce a bending moment on the shafts and a radial load on the shaft support bearings. Axial force can produce undesirable thrust loads if not considered in the original design. Universal Cardan joints and Oldham couplings impose friction-generated lateral loads on the bearings. The elastomeric types of couplings will produce lateral forces in proportion to their stiffness. These issues are addressed below in Section 3.0.

2.4 Torsional Flexibility

Torsional flexibility of a coupling is the torsional (twisting) elastic deformation induced in a flexible coupling while transmitting torque. In some applications using encoders, it may be essential that the torsional flexibility be very low so as not to introduce reading errors caused by the angular displacements. On the other hand, torsional deflection may be desirable for reducing torque oscillations and peak torques in driving high inertia and/or dynamic loads.

2.5 Backlash

Backlash is the amount of rotational play inherent in flexible couplings which utilize moving parts. In some applications, this "slack" may not be objectionable, but in an application in servo-controlled systems, such as described in the previous paragraph, backlash would rule out couplings of this type.

2.6 Rotational Velocity Error

In addition to the types of error already described, universal joints produce an error because of their kinematic behavior. If the input speed into a single universal joint is held constant, then the output will produce cyclic fluctuations in direct relation to the operating angles of the input and output shafts. This will be described more fully in the section dealing with Universal Joints.

2.7 Service Conditions

Service conditions encompass factors such as temperature, operating medium, lubrication, accessibility for maintenance, etc., and should be reviewed before a final selection is made.

3.0 GENERAL CLASSIFICATION OF COUPLINGS AND THEIR PERFORMANCE CHARACTERISTICS

Couplings play various roles in machine transmissions. According to their role in transmissions, couplings can be divided into four classes:

1. *Rigid Couplings.* These couplings are used for rigid connection of precisely aligned shafts. Besides torque, they also transmit bending moment and shear force if any misalignment is present, as well as axial force. The three latter factors may cause substantial extra loading of the shaft bearings. The principal areas of application: long shafting; very tight space preventing use of misalignment-compensating or torsionally flexible couplings; inadequate durability and/or reliability of other types of couplings.

2. *Misalignment-Compensating Couplings.* Such couplings are required for connecting two members of a power-transmission or motion-transmission system that are not perfectly aligned. "Misalignment" means that components that are coaxial by design are not actually coaxial, due either to assembly errors or to deformations of subunits and/or their foundations, Figure 2. The latter factor is of substantial importance for transmission systems on nonrigid foundations.

If the misaligned shafts are rigidly connected, this leads to elastic deformations of the shafts, and thus to dynamic loads on bearings, vibrations, increased friction losses in power transmission systems, and unwanted friction forces in motion transmission, especially in control systems.

Misalignment-compensating couplings are used to reduce the effects of imperfect alignment by allowing nonrestricted or partially restricted motion between the connected shaft ends. Similar coupling designs are sometimes used to change bending natural frequencies/modes of long shafts.

When only misalignment compensation is required, rigidity in torsional direction is usually a positive factor, otherwise the dynamic characteristics of the transmission system might be distorted. To achieve high torsional rigidity together with high mobility/compliance in misalignment directions (radial or parallel offset, axial, angular), torsional and misalignment-compensating displacements in the coupling *have to be separated* by using an intermediate compensating member. Frequently, torsionally rigid "misalignment-compensating" couplings, such as gear couplings, are referred to in the trade literature as "flexible" couplings.

3. *Torsionally Flexible Couplings.* Such couplings are used to change the dynamic characteristics of a transmission system, such as natural frequency, damping and character/degree of nonlinearity. The change is desirable or necessary when severe torsional vibrations are likely to develop in the transmission system, leading to dynamic overloads in power-transmission systems.

Torsionally flexible couplings usually demonstrate high torsional compliance to enhance their influence on transmission dynamics.

4. *Combination Purpose Couplings* are required to possess both compensating ability and torsional flexibility. The majority of the commercially available connecting couplings belong to this group.

3.1 Rigid Couplings

Typical rigid couplings are shown in Figure 3. Usually, such a coupling comprises a sleeve fitting snugly on the connected shafts and positively connected with each shaft by pins, Figure 3a, or by keys, Figure 3b. Sometimes two sleeves are used, each positively attached to one of the shafts and connected between themselves using flanges, Figure 3c. Yet another popular embodiment is the design in Figure 3d wherein the sleeve is split longitudinally and "cradles" the connected shafts.

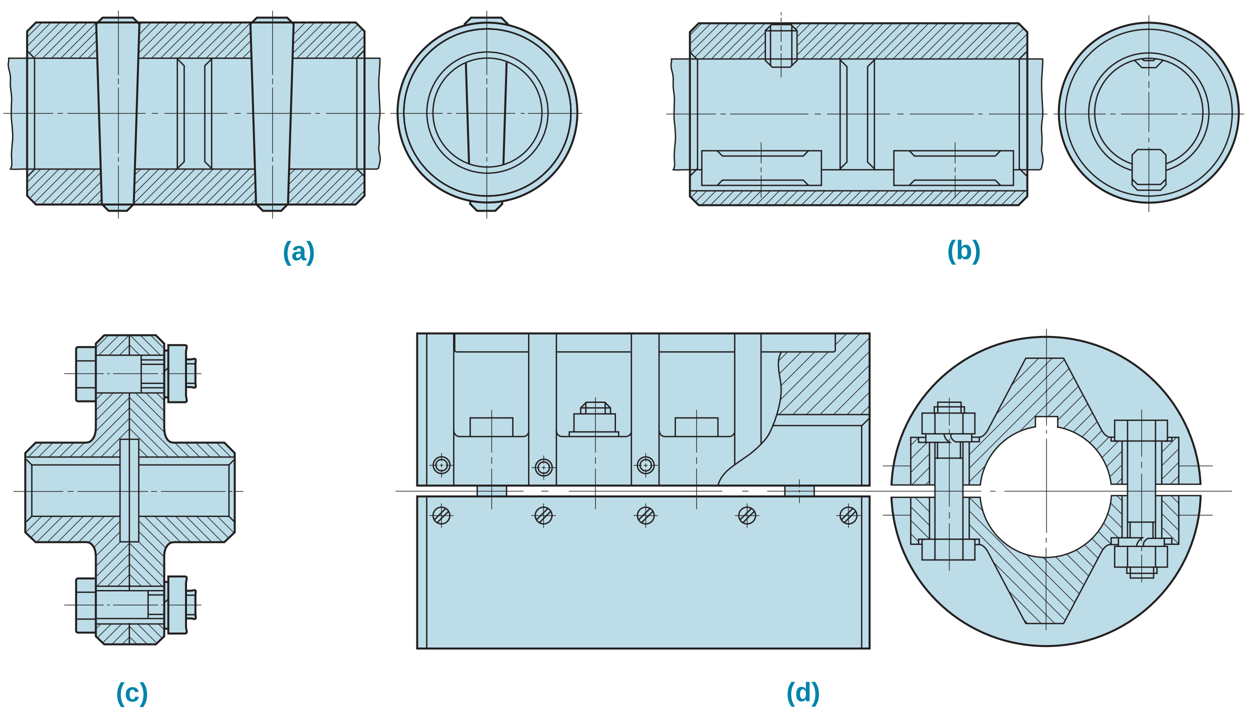

Figure 3 Examples of Rigid Couplings