GRUNDFOS

WHITE PAPER

COUPLINGS

by Greg Towsley

When considering the overall pumping system, the shaft coupling is not usually thought of as an important element in the system. Improper selection and maintenance of the coupling can affect not only the safety of the pumping system, but the operating and maintenance costs as well.

To transmit the rotating power supplied by a driver, a pump is usually connected to the driver with some type of power transmission device. These power transmission devices include couplings, belts, sheaves, chains, and sprockets. The shaft coupling will be discussed in this article.

A coupling is utilized in transmitting the rotary motion and torque of a driver, such as an electric motor, engine or turbine, to a pump. In addition, it is capable of transmitting axial thrust loads between machines and any axial growth that may occur due to high temperature pump product or steam turbine drives.

Pump couplings are categorized between the rigid and flexible types. Each has its own specific use and area of application. When selecting a coupling for use with a pump and driver, the type of coupling to use is as important as the size. The torque requirements are determined based on the horsepower and speed. The normal torque required is calculated by the following formula:

$$\text{Torque (lb-ft)} = \frac{\text{Shaft Power (hp)} \times 5252}{\text{Motor Speed (rpm)}}$$

The coupling should be selected to be able to handle the maximum torque that may result during any part of operations. This includes starts, stops, cyclical, or reversing loads. The coupling manufacturer will apply a service factor based on the type of driven equipment and the conditions of service.

In addition, the coupling design will limit the torque capabilities of the coupling. Elastomeric flexible couplings have low torque capabilities when compared to mechanical flexible couplings.

Although some elastomeric flexible couplings are capable of handling the higher torque requirements, they may not be the optimal selection in high torque applications due to their physical size and cost.

Some additional coupling design features provide specific functions:

- The key and keyway help in transmitting torque from the driver to the pump.
- A spacer coupling is utilized with an end suction pump with back pullout bearing frame. The spacer coupling provides ease of removal of the bearing frame for maintenance and seal installation, without disturbing pump casing, piping or motor, or disturbing the pump/motor alignment. This assists by shortening and simplifying the maintenance cycle.
- For rotating equipment with large shafts, a tapered design is used for ease of removal. The shaft fit is usually a shrink fit because of the taper.

Some industries provide guidelines or specifications for the selection and design of couplings.

The American Petroleum Institute's API 610 Standard[1] provides a set of minimum requirements for couplings in the petroleum, heavy duty chemical, gas industry services, and power industries. These robust specifications require couplings in these industries to have some of the following features:

- Flexible
- Steel

- Corrosion resistant
- Large spacer (5-inch shaft separation)
- Keyed to shaft as standard and for shafts greater than 2.5 inches (6.35 cm) shall be provided with a tapered fit
- Rated for maximum driver HP
- Coupling components shall be balanced

The American Petroleum Institute provides a more stringent specification for couplings in refinery service. API-671[2] provides specifications for pumps that operate continuously for extended periods, that are unspared, and that are critical to operation in a refinery.

In any case, and especially for critical applications, the coupling should be selected based on reliability, maintainability, and surveillability.

The reliability of the design of the coupling, while in or out of operation, should be unaffected by various forces, including speed, deflection, stretch, compression, shock loading and others. Reliability is also determined by the age and environment of the coupling components. Coupling elastomers should not be affected by time or temperature.

Maintainability is determined by the ease of installation, accessibility in the machine, availability of replaceable components and the number of parts in the coupling.

The surveillability is the ability to determine the condition of the coupling, such as wear showing up in lube oil of gear coupling, or as vibration that is detected.

RIGID COUPLINGS

Rigid couplings are typically used in applications involving vertical drivers. The rigid coupling transmits not only the rotational motion from the driver (typically an electric motor) to the pump, but any axial movement (up or down) that occurs between the two pieces of equipment is also transmitted between them. Because of rigidity of the couple, the equipment must be in precise alignment and cannot accept any misalignment.

Because the rigid coupling directly connects the pump shaft to the motor shaft, the pump transfers any axial thrust to the motor. The weight of the shafting and rotating element must be taken up by special thrust bearing in the motor or motor support. If a motor stand with a thrust bearing is not used, the motor must be selected and designed to carry the weight of the rotating element, as well as the axial thrust.

The most common design of the rigid coupling is of a split configuration (*Figures 1* and *2*). The coupling is split along axial centerline.

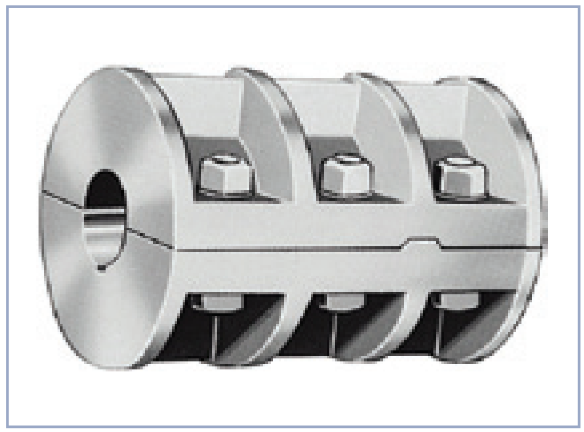


Figure 1. *Split Rigid Coupling*

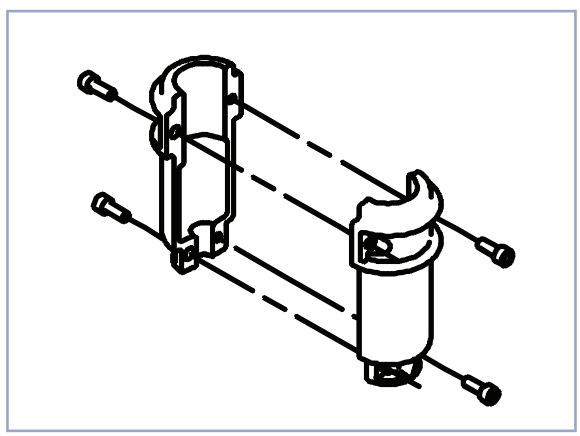
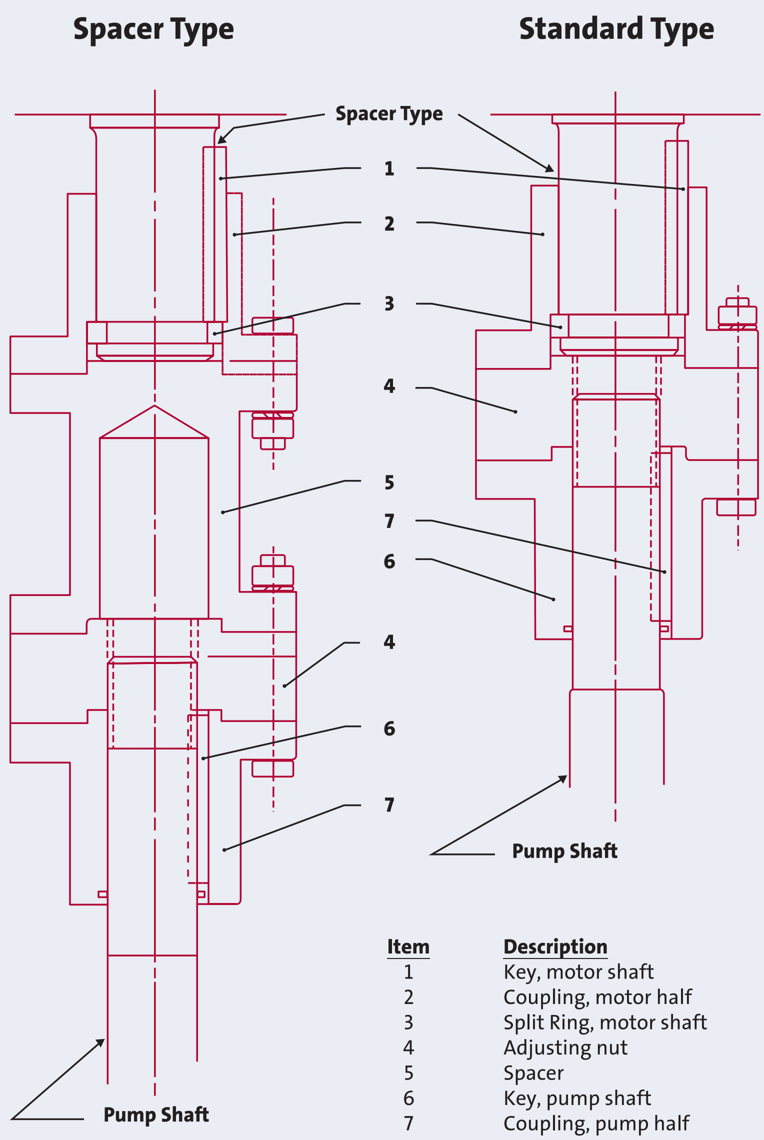


Figure 2. *Split Rigid Coupling*

VERTICAL TURBINE PUMPS FLANGE TOP SHAFT COUPLINGS



Item	Description
1	Key, motor shaft
2	Coupling, motor half
3	Split Ring, motor shaft
4	Adjusting nut
5	Spacer
6	Key, pump shaft
7	Coupling, pump half

Subject to change without notice.

Figure 3. *Flange Top Shaft Couplings*

The rigid coupling is also available in a flanged configuration. This configuration utilizes two couplings flanges bolted together, and may include a spacer to allow for the removal of a mechanical seal.

Proper design and installation of the bolted flanges allows for the transmission of the driver torque to occur with the friction contact of the flanges. In this case, the flange bolts are not subject to a shearing stress from the torque. *Figure 3* shows two rigid coupling configurations that are typically used on vertical turbines with solid shaft drivers.

As previously described, the driver will carry the weight of the rotating element. For proper pump operation, especially in the vertical position, the pump or coupling must have an adjustable feature in order to control the axial location of the impeller(s).

In the case of split rigid couplings, the adjustment is usually done using shim or special tools that lift the rotating element. Once the element is located in the proper location, the bolts on the split rigid coupling are tightened to the manufacturer's recommend torque values. For flanged rigid couplings, adjusting plates are utilized to set the proper vertical position.

Because of the precise alignment required of the rigid coupling, accuracy of manufacture is required. There is a high degree of concentricity and "squareness" needed for proper installation. The two coupling components are clamped together with bolts axially.

Rigid couplings are constructed of all metal materials. This allows the coupling to be used in applications that have high temperatures, high speeds, a solvent atmosphere, or high driver horsepower.

Many vertical turbine pumps utilize rigid or threaded couplings with hollow-shaft motors, especially when conventional packing is used for shaft sealing. Vertical turbine rigid and threaded couplings are shown in *Figures 4* and *5*, respectively. Where hollow shaft motors are

Figure 4. *Vertical Turbine Rigid Coupling*

Figure 5. *Threaded Coupling (with Slinger)*

Figure 6. Shaft Adjusting Nut

used, the standard arrangement is to provide for axial positioning of the impeller(s) to maintain proper clearances. An adjusting nut is shown in *Figure 6*.

FLEXIBLE COUPLINGS

Flexible couplings are more commonly used to transmit driving torque between a prime mover and a pump. Although designed to accommodate misalignment, Hydraulic Institute[3] recommends that a flexible coupling should ***never*** be used to compensate for misalignment of the pump and driver shafts.

The purpose of the flexible coupling is to compensate for temperature changes in the couplings and shafts, and to permit axial movement of the shafts without interference with each other while power is transmitted from the driver to the pump.

Flexible couplings are broken into two groups: elastomeric flexible (material flexible) or non-elastomeric flexible (mechanical flexible).

ELASTOMERIC FLEXIBLE COUPLINGS

The elastomeric flexible coupling typically utilizes a plastic or rubber element that allows for the temperature growth or axial movement. The elastomeric element is sufficiently resistant to fatigue failure to provide an acceptable life compared to the cost of the coupling.

Most elastomeric flexible couplings do not use lubrication, and are loaded in shear. Although not as common, jaw-and-pin and bushing design couplings are designed to be loaded in compression.

Due to the limitations of the flexible element, this type of coupling is used up to 50 hp (37 kW)

Figure 7. Elastomeric Flexing Sleeve Coupling

Figure 8. Molded Elastomeric Member

and 3600 rpm. In applications greater than that, the coupling becomes bulky and more expensive than a non-elastomeric flexible.

The coupling insert shown in *Figure 7* can be provided as a split sleeve or a solid sleeve. The split sleeve allows for the replacement of the sleeve on non-spacer couplings without moving the equipment.

A solid sleeve design, as shown in *Figure 8*, is stronger than the split sleeve and can handle higher torque requirements. Because it is a solid element, the design eliminates the sleeve-retaining ring, which could be a safety hazard. The solid sleeve is also typically used with spacer couplings.

NON-ELASTOMERIC (MECHANICAL) FLEXIBLE COUPLING

There are a number of different types of non-elastomeric, or mechanical, flexible couplings. The mechanical nature of this type of coupling allows for nearly unlimited horsepower and torque capabilities.

A common type of mechanical flexible coupling is the gear coupling (*Figure 9*). This coupling consists of two shaft hubs with external gear teeth cut integrally on the hubs, sleeve members having internal gear teeth, and a floating spacer.

Because of the close fitting tolerances and the sliding motion of the gear, lubrication, such as clean grease or oil, is required to prevent wear of the rubbing surfaces. The gear coupling provides good torque characteristics.

A roller-chain flexible coupling (*Figure 10*) utilizes two sprocket-like members, or hubs, that are mounted on the driver and pump shafts. They are connected by a section of roller chain. This type of coupling is typically applied in low speed pump services.

A hybrid design that utilizes features of both the elastomeric and mechanical flexible coupling is the spring grid style (*Figure 11*). This design utilizes two shaft hubs, an elastomeric grid, which couples the two hubs, and a split cover, which holds the grid in place.

Figure 9. *Gear Coupling*

Figure 10. *Roller-Chain Coupling*

Figure 11. *Spring Grid Flexible Coupling*

Other types of flexible couplings include limited end float, metal disk, diaphragm, and jaw-type. Each of these couplings has special uses due to the application or the size/type of the equipment.

INSTALLATION

The installation of a coupling is as important to the operation and life of the equipment as the proper selection. The alignment of the pump and drive is critical and requires additional discussion.

Following are important tasks that should be completed or checked before final alignment and start up of the equipment. As with any piece of equipment, the manufacturer's installation and maintenance instructions should always be followed for proper installation.

When installing the coupling in the field, the following additional checks should be verified and documented in the permanent files of the equipment:

- Before coupling installation, assemble the coupling to ensure that all parts are present and that they fit together properly.
- Make sure that the hub bore and shaft is clean and free of any nicks or burrs.
- Measure and document the bore of each hub and the diameter of each shaft.
- The keyways on the pump and the driver should be completely filled, and do not extend beyond the end of the shaft.
- The fit of both hubs should be verified, whether interference, clearance, or taper, based on the manufacturers recommendations.
- Taper fit – this fit should be checked to ensure that a good contact pattern is present.
- Clearance fit – a clearance fit is categorized as a "snug fit" or "easy slide fit." Refer to the manufacturer's instructions to insure the maximum clearance has not been exceeded.
- Interference fit – It is preferred that a coupling be heated in an oil bath or oven to 225° to 275°F (107° to 135°C). Refer to the manufacturer's installation instructions for the recommended and maximum temperature.

  It may also be required that the shaft be cooled simultaneously with dry ice. For most steel couplings, a temperature difference of 160°F (71°C) is required between the shaft and hub for every 0.001 inch per inch (0.00254 cm to cm) of interference measured between the shaft and the hub.

  Typically, an additional 0.002 inch (0.00508 cm) is required over the interference fit to obtain a slide fit.
- The spacing between the shafts and the hubs should be verified as correct and documented.
- When installing the coupling spacer in place, follow the manufacturer's recommendation for torque values and make sure the bolts are not bound.

REFERENCES

1. American Petroleum Institute (2004). *API Standard 610, 10th Edition, Centrifugal Pumps for Petroleum, Petro Chemical, and Natural Gas Industries*. American Petroleum Institute. http://www.api.org.
2. American Petroleum Institute (February 2007). *API Standard 671, 4th Edition, Special-Purpose Couplings for Petroleum, Chemical, and Gas Industry Services*. American Petroleum Institute. http://www.api.org.
3. Hydraulic Institute (2000). *ANSI/HI 1.4 – American National Standard for Centrifugal Operations*. Hydraulic Institute. http://www.pumps.org.

ACKNOWLEDGEMENTS

Figure 1:
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