# Sorting Out Flexible Couplings

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## Introduction

When the time comes to specify replacements for mechanical power transmission couplings, it's human nature to take the easy path—i.e., simply find something similar (if not identical) to the coupling that failed, maybe apply a few over-sizing fudge factors just to be conservative. Too often, however, this practice only invites a repeat failure—or more costly system damage.

The wiser approach is to start with the assumption (or at least the *suspicion*) that the previous coupling failed because it was the wrong type of coupling for that application. Taking time to determine the right type of coupling is worthwhile, even if it only verifies the previous design. But it might lead you to something totally different that will work better and last longer.

If so, that result also will reward you by extending the life of bearings, bushings and seals, preventing fretted spline shafts, minimizing noise and vibration, and cutting long-term maintenance costs.

In most cases, industrial power transmission calls for flexible rather than rigid couplings in order to forgive minor shaft misalignment. For that reason, this article will focus solely on the selection of flexible couplings.

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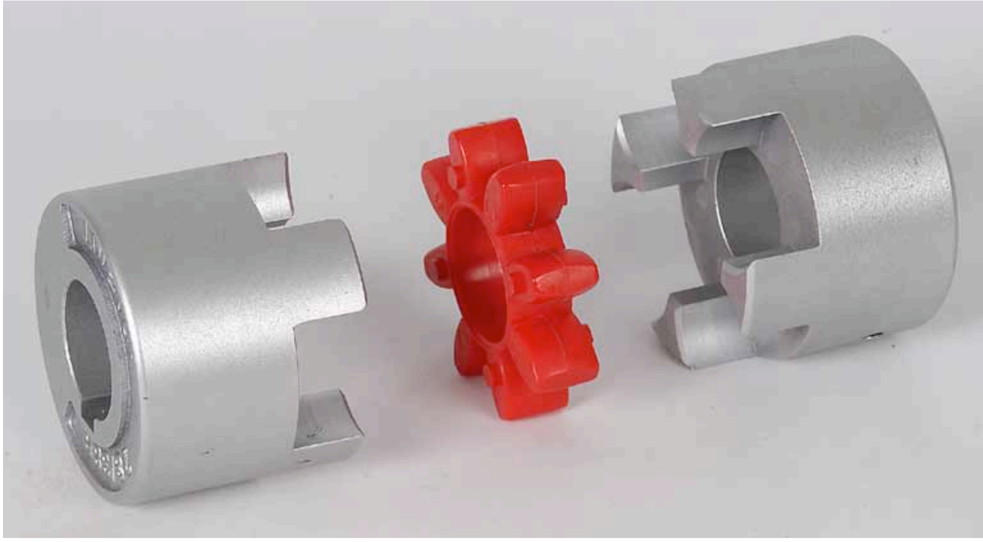

## Determining the Right Type of Flexible Coupling

Determining the right type of flexible coupling starts with profiling the application as follows:

- Type of prime mover (electric motor, diesel engine, other)
- Real horsepower and/or torque requirements of the driven side of the system, rather than the rated horsepower of the prime mover (note the range of variable torque resulting from cyclical or erratic loading, "worst-case" startup loading, and the amount of start-stop-reversing activity common during normal operation)
- Driven-system inertia values in relation to prime-mover inertia (equipment vendors can supply data)
- Vibration, both linear and torsional (experienced vendors or consultants can help you evaluate vibration)
- Shaft-to-shaft misalignment; note degree of angular offset (where shafts are not parallel) and amount of parallel offset (distance between shaft centers if shafts are parallel but not axially aligned); also note whether driving/driven units are or could be sharing the same base-plate
- Axial (in/out) shaft movement, BE distance (between ends of driving and driven shafts), and any other space-related limitations
- Ambient conditions (mainly temperature range and chemical/oil exposure)

The next step is to review available types of flexible couplings to see which type best suits your application profile.

Initially, flexible couplings divide into two primary groups—metallic and elastomeric. Metallic types are all-metal designs that gain their flexibility from movement of loosely fitted parts that roll or slide against each other, or from bending of non-moving metallic parts. Elastomeric types gain flexibility from using resilient, non-moving, rubber or plastic elements to transmit torque between usually metallic driving/driven hubs.

Metallic types are best suited to applications that require or permit:

- Torsional stiffness (very little "twist" between hubs; in some cases providing positive displacement of the driven shaft for each incremental movement of the driving shaft)
- Operation in relatively high ambient temperatures and/or presence of certain oils or chemicals

- Electric motor drive (metallics generally are not recommended for gas/diesel engine drive)
- Relatively constant, low-inertia loads (generally not recommended for driving reciprocal pumps, compressors, other pulsating machinery)

Elastomeric types are best suited to applications that require or permit:

- Torsional softness (allows "twist" between hubs, absorbs shock and vibration, can better tolerate engine drive and pulsating or relatively high-inertia loads)
- Greater radial softness (allows more angular misalignment between shafts, puts less reactionary or side load on bearings and bushings)
- Lighter weight/lower cost, in terms of torque capacity relative to maximum bore capacity; quieter operation.

Another way to look at it: wrong applications for each type are those characterized by the conditions that most readily shorten their life. In metallic couplings, premature failure of the torque-transmitting element most often results from metal fatigue, usually due to flexing caused by excessive shaft misalignment or erratic/pulsating/high-inertia loads. In elastomeric couplings, breakdown of the torque-transmitting element most often results from excessive heat—either from ambient temperatures or from hysteresis (internal buildup in the elastomer)—or from deterioration due to contact with certain oils or chemicals.

The preceding overview should help establish which group generally looks best for a given application; the following discussion presents the basic alternatives available in both groups to further guide your selection.

***Metallic coupling alternatives.*** Metallic flexible couplings group into three basic families:

1. Mated Parts
2. Membrane
3. Specialty

***Mated parts couplings.*** Mated-parts designs include gear, grid and chain types, in which torque is transmitted across separate metal elements that push against each other. Generally, these designs offer high torque-to-outside diameter ratios, accommodate misalignment up to 2°, but allow little parallel misalignment. They provide relatively high torsional stiffness, but due to moderate backlash, they usually are not recommended for pulsating or frequent stop-start applications. All require routine lubrication and maintenance of seals.

*Gear couplings* consist of two shaft-mounted hubs with gear teeth around their external circumferences. Both hubs are enclosed within a common connecting sleeve that has gear teeth around its internal circumference, which mate with the hubs' teeth. Continuous teeth along the length of the sleeve allow generous tolerance for axial (in/out) shaft movement. In lower torque ranges, nylon sleeves can eliminate need for lubrication and provide quieter operation; higher torque and/or RPM ranges can be achieved with special models having heat-treated teeth.

*Grid couplings* are the only metallic type to offer moderate torsional shock/vibration damping capacity. This design employs a spring steel grid pre-formed to snake back-and-forth between two shaft-mounted hubs, nesting in slots formed around the external circumference of each hub. The beam effect of this grid as it spans the gap between the two hubs gives this design its resilience. The grid also forgives minor axial shaft movement, but movement that significantly shortens the gap between hubs reduces grid resilience. A common sleeve encloses both hubs and grid.

*Chain couplings* consist of two sprocket-like shaft hubs linked around their circumference by a continuous length of double roller chain, which is enclosed in sleeve-type cover. Low-torque applications can opt for a low-noise plastic chain; high-torque applications can be accommodated by special heat-treated chains and sprockets.

***Membrane couplings.*** Membrane coupling designs comprise laminated disc, flexible link and diaphragm types, in which torque is transmitted through single, tightly fitted metal elements rather than across separate, loose metal elements pushing against each other. This assures positive displacement with zero backlash and no routine maintenance requirements. Membrane types cover a broad range of horsepower and torque capacities, with varying degrees of angular flexibility achieved by deflection of the metal elements. They generally do not allow parallel misalignment.

*Laminated disc couplings* transmit torque through a stack of thin, O-shaped metal discs suspended between two flange-type, shaft-mounted hubs. The disc stack is bolt-attached alternately to driving and driven hub flanges along a common bolt-circle diameter.

The beam effect of the disc stack's thin laminate construction, in free span between driving and driven bolts, allows an angular flexibility of up to 1 degree, but will not permit axial shaft movement or parallel offset.

*Flexible link couplings* are a variation of the disc design that uses three or more flat strip springs—called "flex-links"—in place of a laminated disc pack. The ends of the flex-links are attached (usually riveted) to carriers mounted on driving and driven shaft hubs, enabling the driving carrier to pull the driven carrier in rotation. The carriers are shaped with radial arms that position their flex-link attachments near the circumference of the coupling to maximize flex-link length.

The beam effect of the flex-links, in free span between driving and driven carrier arms, gives the three-link design high angular flexibility of up to 6°, with low reactionary load on bearings. Designs using four or six flex-links can accommodate greater torque, but reduce angular flexibility. Flex-link designs do not allow axial shaft movement, but will tolerate slight parallel offset.

*Diaphragm couplings* transmit torque through a stack of thin metal diaphragms (full but typically perforated discs). The stack is attached to one shaft-mounted hub near its OD, and attached to the other shaft-mounted hub near its ID, so torque flows between OD and ID rather than around the OD. The free span of the diaphragm between OD and ID deflects to accommodate moderate angular misalignment of to 1ø and to allow minor axial shaft movement.

***Specialty couplings.*** Specialty metallic couplings encompass a variety of designs such as wrapped spring, helically formed beam, bellows and offset types.

*Wrapped spring* couplings allow up to 4.5° of angular and up to .045" of parallel misalignment—plus high RPM ranges. These designs consist of three concentric, tightly wound, square-wire springs, with the inner and outer coils wrapped in the same direction opposing the direction of the center coil in order to enable coupling rotation in either direction. The spring pack is brazed to hubs at both ends, making a single-piece coupling that is very easy to install.

The spring coupling has no backlash, but it is not torsionally rigid and therefore may not be suitable for some positioning applications.

*Curved beam* couplings include two single-piece designs that feature high torsional stiffness and zero backlash, making them well suited for servomotor, encoder and other precise-positioning applications. They accommodate high angular misalignment with low reactionary loads on bearings and are good for applications with small-diameter shafts that could easily bend.

One curved-beam design—called the helically formed coupling—is machined from solid bar stock with spiral patterns cut through to its core, creating a long, curved beam. Its torsional stiffness varies in a linear fashion—i.e., the amount of "twist" is directly proportional to the torque load. In special high-speed designs, RPM can range up to 50,000 RPM.

The other curved beam design—the bellows coupling—is made from a single piece of tubular stock axially compressed into a series of rounded "accordion" folds. This design offers extremely high torsional stiffness, measured in arc. sec./in. oz.

*Offset couplings* are unique in their ability to accommodate extremely large, parallel misalignment between shafts—up to 17" offset in the largest coupling size—although maximum angular misalignment is limited to 0.5°. An alternative design allows up to 3ø angular misalignment, but will accept only up to 0.5" of parallel offset. These highly specialized and complex designs have many moving parts and must be very carefully specified.

***Elastomeric coupling alternatives.*** Elastomeric couplings classify into two main categories by the way their elastomeric element transmits torque—i.e., the element is either "in compression" or "in shear."

When the element is in compression, parts of the driving hub push parts of the driven hub. The element separates driving from driven parts like a cushion, absorbing some of the torque force by being compressed between them.

When the element is in shear, the driving hub pulls the driven hub through their mutual connection to the element, which absorbs some of the torque force by being stretched through twisting.

Compression-type couplings generally offer two advantages over shear types. First, because elastomers have higher load capacity in compression than in shear, compression types can transmit higher torque and tolerate greater overload. Second, they offer a greater degree of torsional stiffness, with some designs approaching the positive-displacement stiffness of metallic couplings

Shear-type couplings in turn offer two general advantages over compression types. First, they accommodate more parallel and angular offset while inducing less reactionary bearing load; this makes them especially appropriate where shafts may be relatively thin and susceptible to bending.

Second, they offer a greater degree of torsional softness, which in some cases provides greater protection against the destructive effects of torsional vibration.

***Compression-type designs.*** Elastomeric, compression-type couplings comprise three main designs: jaw, donut and pin-and-bushing.

Jaw couplings are distinguished by hubs that have two to seven axially oriented jaws (thick, stubby protrusions) arranged around their circumferences. Jaws of driving and driven hubs mesh loosely; filling the gaps between them are cushions of elastomeric material, usually molded into a single asterisk-shaped element called a "spider."

Permanent compressive set occurs as the element ages in service; a 25 percent reduction from original thickness signals replacement. In most applications, compression is applied only to the spider cushions forward of the driving jaws, so spider life can be doubled by advancing the unused trailing cushion into the driving position.

Jaw designs are considered "fail-safe" because if the spider breaks away, the driving jaws can contact the driven jaws directly, maintaining operation until the spider can be replaced.

Jaw couplings generally are recommended for electric motor-driven machinery, pumps, gearboxes, etc. Most jaw designs typically are limited to angular shaft misalignment of 1° and tolerate very little parallel offset. Backlash due to spacing between jaws and element cushions usually makes jaw couplings inappropriate for true positive-displacement applications.

Donut couplings use a donut-shaped ring of elastomeric material installed with a set of bolts or pins alternately engaging the ring from the driving and driven hub. Torque is transmitted through the donut material via compression between driving and driven bolts. But, while the "leading" portion of the donut is in compression, the "trailing" portion may be in tension, depending on the donut/hub design. This feature eliminates backlash and allows the coupling to absorb torsional vibration.

Standard donut designs may vary in torsional stiffness and are rated for medium to heavy-duty service, with angular misalignment allowance as much as 3° in some cases, and good parallel misalignment allowance.

Pre-compressed natural rubber donut designs are torsionally softer than most compression couplings, and widely favored for high-shock, start/stop applications such as engine-driven systems, compressors, violent pounding or crushing equipment, marine and off-road equipment.

Pin-and-bushing couplings transmit torque through driving pins that project from both driving and driven hubs; each pin engages an elastomeric bushing, or "biscuit", suspended in a rigid disk between the hubs. Similar in concept to the donut design, this coupling is torsionally softer than other compression types and does a better job of absorbing torsional shock. It allows angular misalignment up to 2°, but not much parallel offset.

***Shear-type designs.*** Elastomeric shear-type couplings include three main designs: sleeve, tire and molded-element.

Sleeve couplings are characterized by a tubular elastomeric element molded with serrated flanges at both ends. These flanges mate with serrated sockets molded into the coupling's hubs.

Sleeve types in some cases may twist as much as 15° between hubs, providing excellent protection against torsional shock and vibration. They accommodate angular misalignment up to 2ø, and parallel offset up to approximately .05", without imposing much reactionary load on bearings.

Because of their open-center construction, sleeve-type couplings allow shaft-to-shaft applications with very little clearance between shaft ends.

Tire couplings, named for their resemblance to an auto tire, consist of two flanged hubs equipped with clamping plates that grip the coupling's hollow, ring-shaped element by its inner rims. Furthering the similarity, tire coupling elements usually are rubber-derivative elastomers with layers of cord, such as nylon, vulcanized into the tire shape.

Design variations are available, including an inverted tire coupling in which the tire element arcs inward toward the axis, designed for higher RPM service.

The tire coupling is torsionally soft and can damp vibration. High radial softness accommodates angular misalignment up to 4° and parallel offset up to ⅛". Rare among elastomeric couplings is its capability to allow a certain amount of axial shaft movement. These properties afford tire designs a wide variety of applications, including those using internal combustion engines.

Molded-element couplings feature an elastomeric element that is molded into the metallic hub of the coupling, usually in a socket having a serrated perimeter. These designs are most often recommended for connecting internal combustion engine flywheels to pumps, transmissions, blowers, generators and compressors—especially where close coupling is desired.

A very broad range of element materials—from torsionally soft to stiff—allows wide latitude in adjusting natural frequencies of engine-driven systems to avoid inducing destructive resonance at critical RPM ranges. Angular misalignment ranges from 0.5°–2°—depending on coupling construction and element hardness—and parallel offset is generally limited to .05".

In general, the torsionally softer alternatives are used with high-inertia loads and where good coupling alignment is difficult to attain. Torsionally stiff alternatives are favored for low-inertia loads, but demand careful attention to alignment.

Flexible couplings have evolved into a rich variety of types, providing a wide range of performance tradeoffs. When selecting among them, resist the temptation to overstate service factors. Coupling service factors are intended to compensate for the variation of torque loads typical of different kinds of driven systems, and to provide for reasonable service life of the coupling. If chosen too conservatively, they can misguide selection and raise coupling costs to unnecessary levels—perhaps even invite damage elsewhere in the system. Remember that properly selected couplings are supposed to serve as a fuse; i.e., if the system is overloaded, improperly operated or somehow drifts out of specification, the coupling should break—before something more expensive does.

Thoroughly review the suggested application profile with your coupling vendors and seek not only their recommendations for the right type of coupling, but also the reasons behind those recommendations. With the variety of couplings available today, careful selection usually leads to a long-lasting match between coupling characteristics and the demands of the application.

## For more information:

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