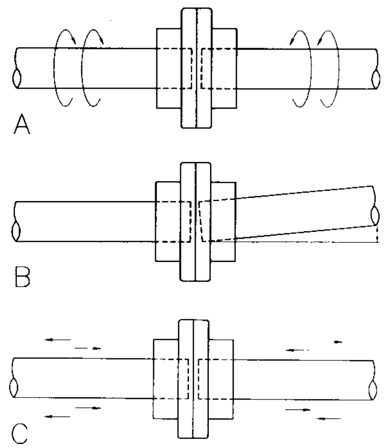
JUST HOW FLEXIBLE IS YOUR FLEXIBLE COUPLING IN REALITY?



By Jon R. Mancuso
World Pumps September 2000
Engineering Manager
Kop-Flex Emerson Power Transmission Corp.

Misaligned rotating machinery has caused, and will continue to cause, a heavy financial loss to almost every industry. In many plants there may be thousands of pumps. It is difficult to calculate how much money is wasted on prematurely damaged machinery and failures of equipment due to misalignment.

The capability of having most of your rotating equipment well aligned and running smoothly is directly related to your knowledge, ability and desire to do it well. It seems foolish to install well designed or rebuilt machinery only to watch it be destroyed in one to two years; It's difficult sometimes to justify spending four to eight hours carefully attaching rotating machinery to frames and foundations, and then carefully aligning the shafts. And also monitoring the alignment as a preventive maintenance too. Not spending this time up front may cost 16-24 hours in lost production time which may cost as much as $10,000 per hour or more. Proper alignment can double or triple the life of the equipment bearings, prevent disastrous failure.

Flexible couplings are used to account for "some" misalignment and reduce the forces and moment reacted back into the equipment. But how ***flexible*** is that coupling?

There are several types of couplings that are primarily used on pumps, gear couplings, grid couplings, disc couplings and elastomeric types. Several of these couplings have misalignment capacities to 1-2 degrees. But then why worry about aligning equipment. Since they have so much ***flexibility***. The main reason is that one needs to align to better than the coupling capacity is that these coupling can impose an axial and radial load on the connected shafts, seals and bearing causing them to wear and/or fail prematurely. If it were possible to align equipment perfectly and we could be assured that it would stay, a flexible coupling would not be required. Another reason is that alignment change, over time. This may be due to such items as foundation settling, thermal changes and pipe strain. When alignment is carefully done initially there should be enough capacity left in the coupling for it to handle unforeseeable increases in misalignment with time or if one gets really sophisticated and can determine where the equipment really runs when at load and speed. One can set the alignment at no load and zero speed so at load and speed it would run close to zero and produce minimal loading on the equipment.

Definition of Misalignment

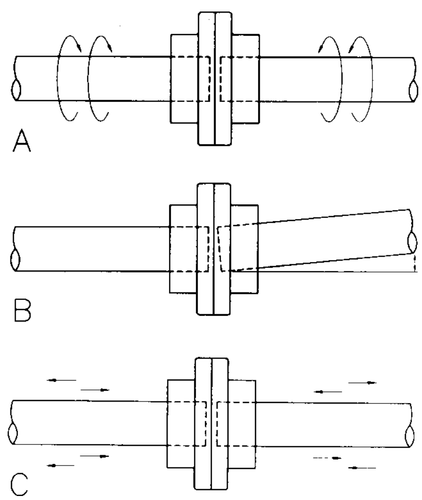
Misalignment is the deviation of relative shaft position from a collinear axis of rotation measured at the point of power transmission when the equipment is running at normal operating conditions

Why we use Flexible Couplings

Flexible couplings join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both. The three basic functions of a flexible coupling are to (Figure 1)

1. Transmit power (Figure1A)
2. Accommodate misalignment (Figure 1B)
3. Compensate for end movement (Figure 1C)

Figure 1 Functions of a Flexible Coupling



Transmit Power

Couplings are primarily used to transmit mechanical power from one machine to another. The power is in the form of mechanical torque at some speed, or work per unit of time, In general; the power lost by a flexible coupling is small, although some couplings are more efficient than others.

Misalignment

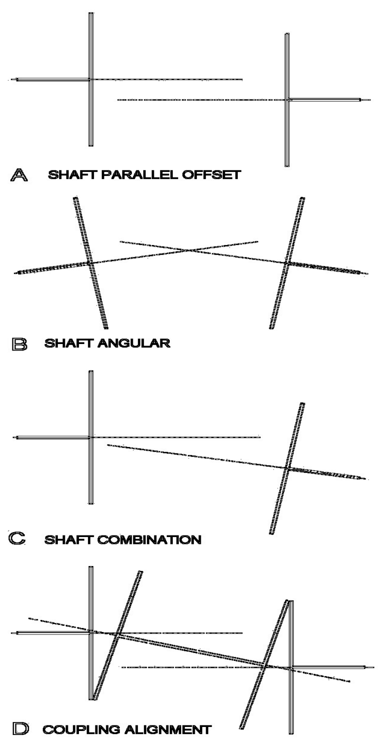
There are two types of misalignment - shaft misalignment and coupling misalignment.

- Shaft Misalignment:
  Shaft misalignment is the relationship between the driver and driven shafts. This can be broken down into parallel offset - the axes of the connected shafts are parallel, but not in the same straight line (Figure 3-A) or angular - the axes of the shafts intersect at the center (Figure 3-B). A more common misalignment is a combination of parallel offset and angular coupling misalignment (Figure 3-C).
- Coupling Misalignment

Coupling misalignment comes into play when you look at how the coupling accommodates for shaft misalignment. There are two general approaches. One is when using a double-flex coupling such as a gear, disc or diaphragm. These couplings can only accept angular misalignment at each flexing plane. This means there must be two flex elements in order to accept shaft misalignment (Figure 3-D).

For elastomeric couplings parallel offset and angular shaft misalignment are accommodated through one elastomeric flex element.

Figure 3 Types of Misalignments



<u>End Movement</u>

Most flexible couplings are designed to accommodate axial movement of the connected equipment or shaft ends. In pumps that are driven by motors with sleeve bearings, the couplings are usually required to limit the axial end float to prevent internal rubbing of the bumping collars of the motor bearings.
It is important to recognize that while the equipment may see these three types of misalignment, the coupling sees only angular and axial displacement. The *"Flexible Elements"* see only angularity and axially therefore equipment needs a coupling with more than one flexible element to accommodate offset. The exception being some Elastomeric Element coupling which can accommodate all three types of misalignments.

Accommodation of misalignment and end movement must be done without inducing abnormal loads in the equipment. Generally, machines are set up at installation quite accurately.

How to Align Equipment

There are many methods used to align equipment from very simple straight edge to complex laser system that does all the thinking for you. One could write a book on this, in fact one does exist (see reference 2)

Things You Need to Know When Aligning Rotating Machinery

- Where is the machinery located when the equipment is not running
- What position will the machinery move to when operating?
- If the machinery moves from off-line running conditions, what acceptable range of position could the machinery shafts be in when the machinery is aligned off line and still maintained acceptable alignment tolerances during operation?

Or Simply

Where are they?
Where will they go?
Where should they be?

Most rotating machinery operate with some misalignment. Perfect alignment is nearly impossible to achieve in the real world. It is important to know when to stop moving the machinery. There comes a point where no beneficial returns can be made if alignment tolerances have adequately been met.

The Difference Between Equipment Alignment and Coupling Tolerances

It is important to remember when selecting and/or using a coupling not to be confused by the terms "allowable misalignment". Coupling catalogs rate this as capacity of the coupling. This is not to be confused with the allowable limits set for successful operation of the equipment. Some times this number can be ten times what the equipment can accept. The limits given by the coupling manufacturer are usually based on the life or fatigue limits of the various components of the coupling.

Which Coupling is more Flexible

There are three basic types of couplings

Mechanically Flexible Coupling
Metallic Element Coupling
Elastomeric Element Coupling

The mechanical element types generally obtain their flexibility from loose-fitting parts or rolling or sliding of mating parts or from both. The most common types are the gear coupling and the grid coupling. They usually require lubrication unless one moving part is made of a material that supplies it own lubrication need (e.g., a nylon gear coupling). The metallic element types obtain their flexibility from the flexing of thin metallic, disc or diaphragms. The elastomeric element types obtain their flexibility from stretching or compressing a resilient material (rubber, plastic, etc.,). There are two basic types; the shear type and the compression type.

Flexible Couplings can also be classified by their usage.

There are over 100 variations of these types of couplings. The three basic types serve two basic types of applications. These can be broken into two categories:

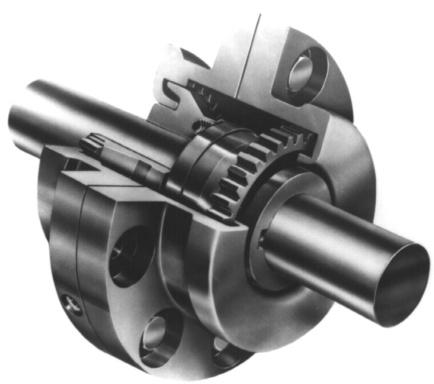
1. General Purpose Couplings
2. Special Purpose Couplings

A coupling moves from general purpose to special purpose (high speed - generally over motor speeds) once it is applied to very critical equipment within the production or process system. Couplings used in the petroleum, chemical, and gas industries are covered thoroughly in API 671 (Special - Purpose Couplings for Service in Petroleum, Chemical and Gas Industries)

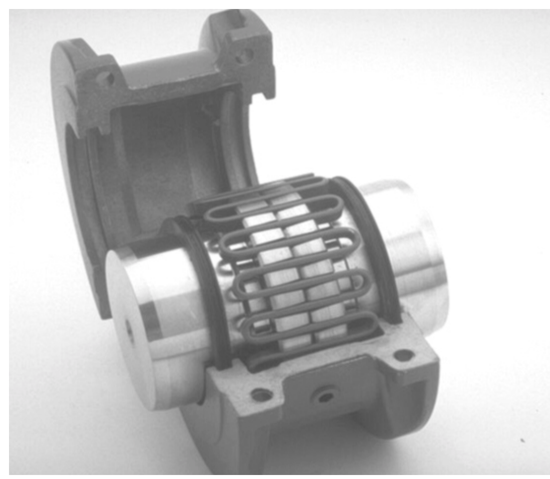
For general purpose applications like pumps
There are five basic types that are used

Gear Coupling (Figure 4)
Grid Coupling (Figure 5)
Disc Coupling (Figure 6)
Elastomeric Compression Type (Figure 7)
Elastomeric Shear Type (Figure 8)

Gear Coupling Figure 4

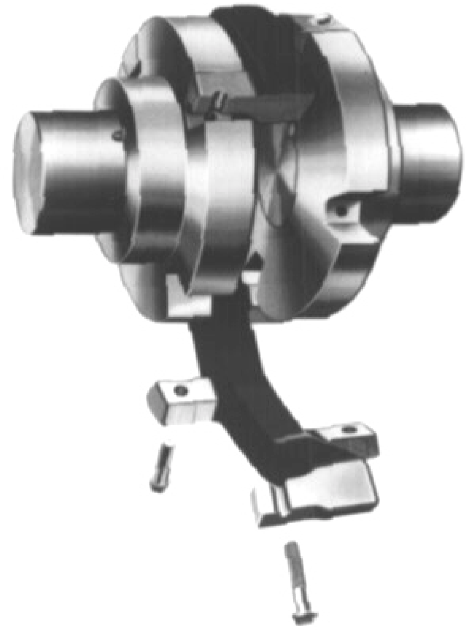


Grid Coupling Figure 5

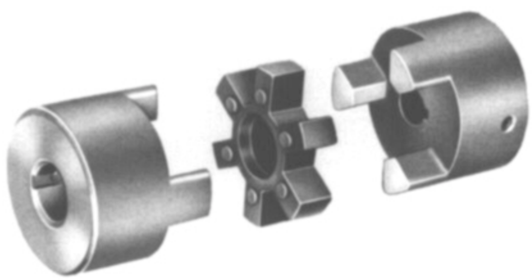


Disc Coupling Figure 6

Elastomeric Shear Type Figure 8



Elastomeric Compression Type Figure 7



We will only cover general purpose couplings (low speed-generally motor speeds) such as pumps General-purpose types are generally more standardized and less sophisticated in design, and are substantially cheaper and are used in quantities substantially greater than special purpose types.
General Purpose equipment uses couplings where the flexible element can be easily inspected and replaced, often considered “throw away parts”. These types of couplings are usually very flexible and can be aligned by simple alignment techniques and larger limits than those used on special purpose .

The most common types of **Mechanical Element Coupling** are the gear and the grid type .
Gear couplings consist of two hubs with external teeth that engage internal teeth on a two- or one-piece sleeve. Gear couplings are used for medium-large applications general on applications over 100 hp

Grid couplings are similar to gear couplings. Usually composed of all metal they have some degree of resilience. They have two hubs with serrations (grooves) rather than teeth. A steel grid connects the grooves. A cover keeps the lubrication in. Grid couplings are generally used for applications under 1000 hp.

The Metallic Element Coupling comes in two basic types, the **disc** and the **diaphragm**.
The diaphragm coupling is ***usually not used in general-purpose applications*** usually because it tends to be more costly than the other types.
The disc coupling transmits torque by a simple tensile force between alternating driving and driven bolts on a common bolt circle. These coupling are generally used on applications over 100 hp.
Elastomeric Element couplings come to basic type Shear Type and Compression Type.

- **The shear type** are generally found on applications under 100 hp.
- **The compression type** is usually used on application over 100 hp

Which Couplings are more Flexible

There are several rules of thumb for aligning equipment. None of them consider the flexibility of the coupling.
The most common one, recommended for general-purpose equipment alignment should be within 0.001 inch/inch of separation between flex points. For high-speed applications (generally over 3600 rpm), alignment should be within 0.0005 inch/inch of separation between flex points. For general-purpose equipment and couplings it is usually sufficient to “zero” align statically. For most general applications the misalignment under load and at speed are then handled by the coupling without producing high reactionary loads to cause equipment problems or damage. When alignment is carefully done initially, there should be enough capacity left in the coupling for it to handle increases in misalignment during operation.

In reality equipment alignment tolerance should be a function of the flexibility of the coupling.

The general rule above of 0.001 in/in for general-purpose applications was developed with the advent of the usage of disc couplings. If we work with this and knowing the relative magnitude of the reactionary loads the various couplings produce we develop a more meaningful misalignment limit based on the flexibility of the other types of couplings.

Table 1 Misalignment Limits Based on Flexibility

Type of Coupling	Reactionary Moments and Forces	Misalignment Limit In/in of separation between flex points
Gear Coupling	Very High	0.0005in/in
Grid Coupling	High	0.00075in/in
Disc Coupling	Moderate	0.001 in/in
Elastomeric (Compression)	Low	0.0015 in/in
Elastomeric (Shear)	Very low	0.002 in/in

From this chart one should spend more time in alignment of a gear coupling than if an elastomeric shear type is used.

Other Things to Consider Besides Flexibility

There are other coupling considerations besides flexibility that can affect the life or cause equipment failure.
For example, rubber tire couplings are very flexible when misaligned. But they are much larger to transmit the same torque as a gear coupling. Therefore the forces on the equipment from unbalance could be larger than the gear coupling and large enough to cause sufficient loading to cause the bearing to fail. Also at high speed the centrifugal force of an elastomeric shear type coupling can cause an axial pull which could over load the bearings in thrust.

Summary
In conclusion not all couplings have the same flexibility.. Therefore to align equipment to the same tolerance or tight tolerances will only take extra time and give very little benefit. Knowing how flexible the coupling you are using should allow one to align to larger limits. In fact advancements in technology are constantly moving forward so new and more flexible couplings will be developed. If you have aligned equipment, you know that to get alignment from 0.020" to 0.010" would probably take less time than trying to get the final alignment from 0.005" to 0.002". Therefore using practical alignment limits can save initial alignment time without causing premature equipment problems.

References

1. Mancuso, Jon "Couplings and Joints, Design, Selection, and Applications – 2nd Edition Published by Marcel Dekker 1999

2. Piotrowski, John "Shaft Alignment Handbook, 2nd Edition, Published by Marcel Dekker, 1995

3. Some of the information in this article were presented in a short course for the Twenty-seventh Turbomachinery Symposium