Causes of Coupling Failures

By Rathi Transpower Private Limited

Shaft couplings are critical parts of any transmission system, providing the smooth transmission of power from drive to driven equipment. If properly **designed, selected** and **maintained**, the coupling can last long and give satisfactory service on drive and driven equipment. However the useful life of flexible coupling is limited due to following factors:-

1) Human Errors
2) Corrosion
3) Wear
4) Fatigue
5) Hardware failure
6) Shaft failure

Investigating the causes of coupling failure and to eliminate them is important. However, often, the maintenance personnel rushes to eliminate the effect of failure, rather than probe the cause, so as to get the equipment quickly back on stream. This lack of eliminating the causes of failure may translate in reoccurrence of the same problem.

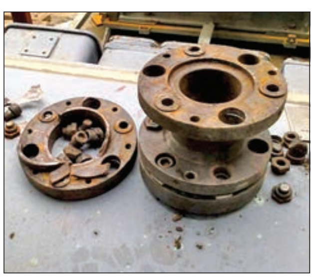
1) Human Errors

Human errors relating to coupling failures are inevitable. They can be divided into:-

a) Improper selection

Incorrect Type Solutions

Over Loading



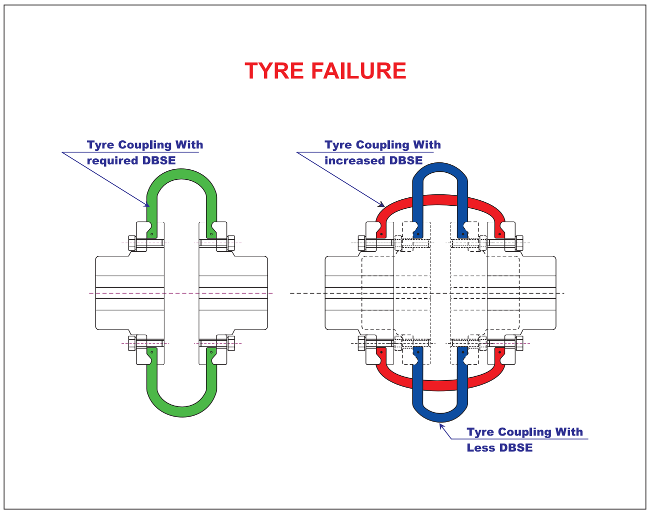
Incorrect Selection - Lower Size

Undersize Coupling for Application

Many coupling failures happen because of incorrect type and size of coupling that cannot accommodate the requirement of the application. Coupling manufacturers can guide in the selection of the best coupling for an application. Coupling failures that are caused by improper selection are usually very costly.

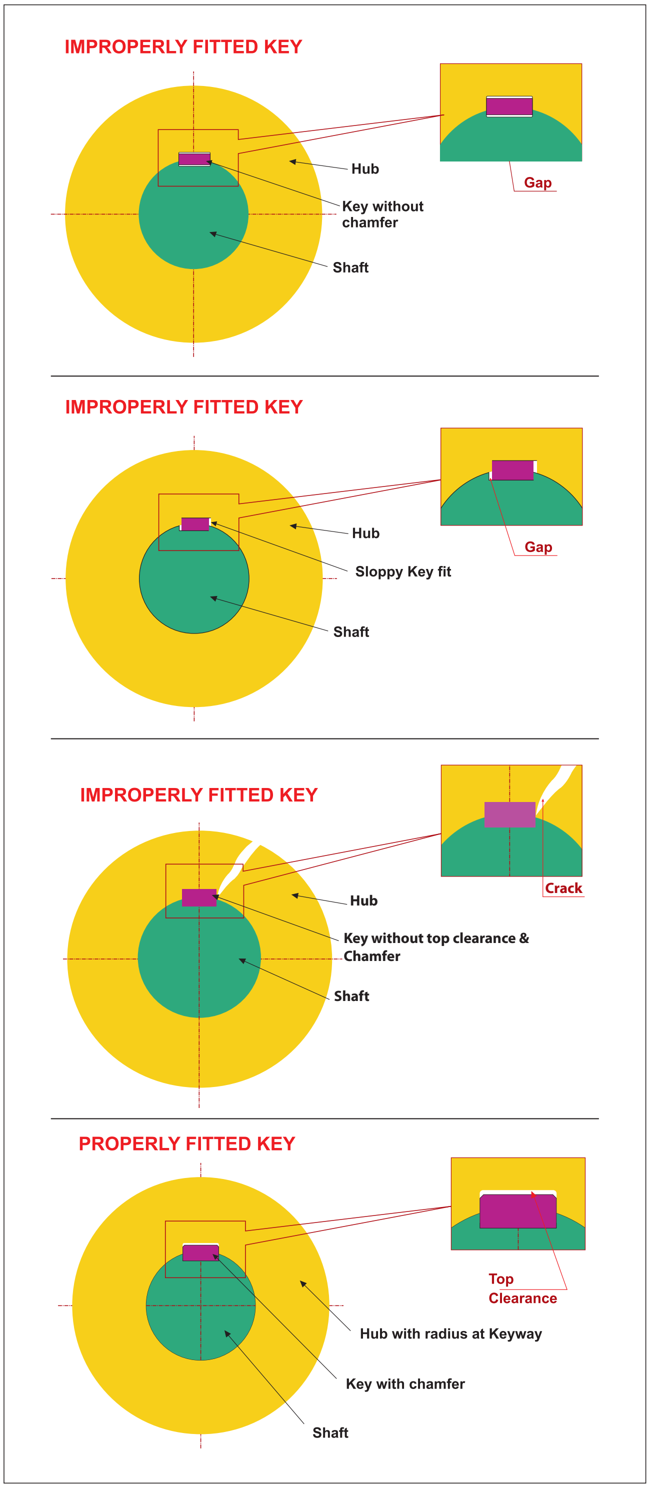
An oversized coupling is specified with the hope that it will last longer. However, this may not be true, as it will increase the radial loads on the shafts if misalignment exists. If the load transmitted is too low, the oversized coupling may actually wear out much faster. When oversized coupling is selected due to shaft sizes, care must be taken to align the coupling more accurately than usual.

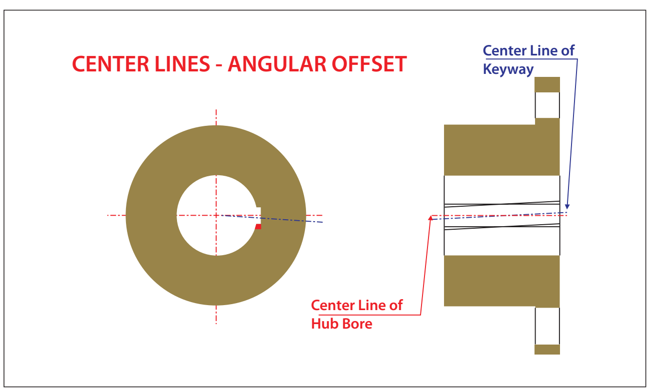
Speed limits should be strictly adhered to for Elastomeric couplings. Speed generates centrifugal forces that can place high stress on the flexible components. Tyre type Elastomeric coupling can "Balloon" and eventually rupture at high speed. Compression type Elastomeric couplings may whirl or vibrate laterally. Many of these couplings may need some type of lateral support for use at high speeds.



b) Improper Manufacturing: -

It is not only important to design & select proper coupling; it should also be properly manufactured, installed and maintained to get satisfactory performance. Finish bore and key way with appropriate tolerances as per various international standards also needs to be maintained. Concentricity of finish bore with respect to power transmitting part is very important.

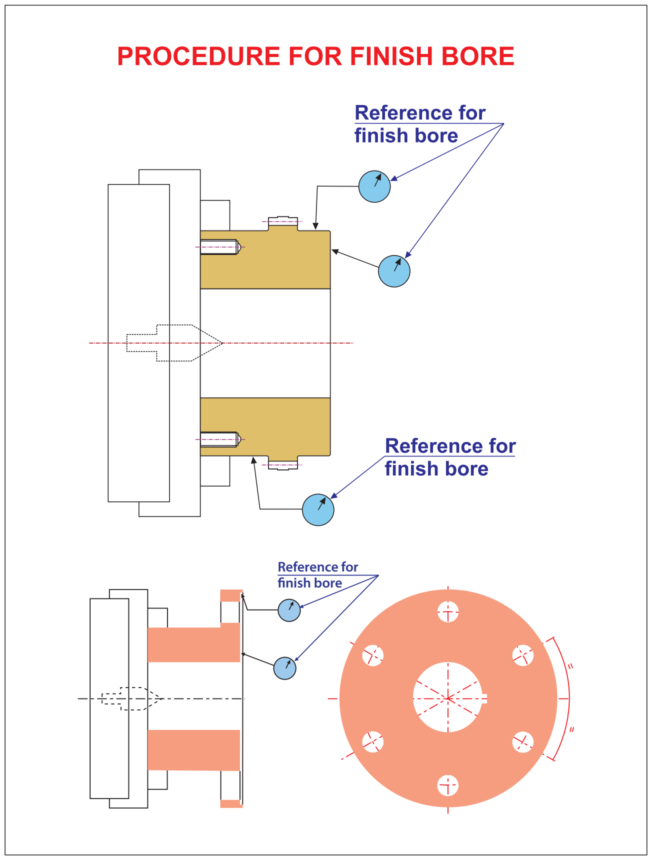




1) Elastomeric Jaw coupling – Jaw OD
2) Gear Coupling – Teeth OD
3) Pin Bush coupling – PCD
4) Metallic Disc coupling – Locating steps

Maintaining centerline of bore and key way width within specified limit is also important along with the tolerances, key size, and key material.

The figure show how common errors can be avoided.



c) Incorrect installation:

There are many reasons why incorrect installation results in coupling failure, the most frequent being improper tightening of bolts, use of low quality bolts, keys made of soft steels, incorrect hub spacing, incorrect hub installation, guards that are too close to elastomer elements, improper coupling sealing etc.

A coupling is to be installed within the “Initial Alignment Limit” specified by the manufacturer. This is around 25% of the misalignment limits specified by the manufacturer. It has been observed that lack of Installation and alignment procedure results in improper installation. This will result in vibration and additional loads which, depending on their severity, can produce premature wear, or even catastrophic failure of bearings, seals, the coupling itself, and other machine components.

Horizontal coupling used vertically

Over Loading/Loose Clamping

- Excessive Interference Fit: Hub Cracked at 3 Holes

Coupling alignment should be an organised and simple process. It is important to establish a set procedure to perform alignments. Identifying a simple shaft alignment procedure that can be followed for every alignment saves time effort and money. Following are the six steps to form a comprehensive outline to follow for every shaft alignment:

1. Safety
2. Clean up
3. Rough Soft Foot Correction
4. Rough Alignment
5. Final Soft Foot Correction
6. Final Alignment.

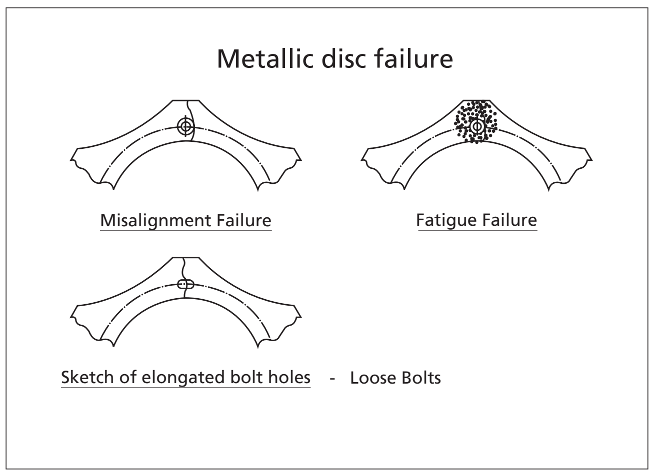
However, it is a misunderstanding to take advantage of coupling flexibility for accommodating excessive misalignment, as flexing of the coupling and the shaft will impose forces on the drive and driven equipment bearings. Effects of these forces include premature bearing, seal or coupling failures, shaft breaking or cracking, and excessive radial and axial vibrations. Secondary effects include loosening of foundation bolts, loose or broken coupling bolts. Operating life is shortened whenever shafts are misaligned.

d) Lack of periodic maintenance

Coupling maintenance is generally a simple matter. It requires a regular scheduled inspection of each coupling. The inspection can include:

- Performing visual inspection, checking for abnormal operating characteristics such as unusual noise, excessive component temperature, vibrations, and signs of wear or fatigue.
- Checking and changing lubricant if the coupling is lubricated. This maintenance is required at regular interval say twice in a year for most couplings and more frequently for couplings operating in adverse environments or in demanding operating conditions.
- Documenting the maintenance performed on each coupling, along with the date.

- Incorrect Lubrication
- Insufficient Lubricant
- No maintenance



No Lubrication

In most cases, these maintenance steps should be sufficient to keep couplings working smoothly and to enable them to reach their full service life. In addition to these, it is also recommended that after the equipment has operated long enough to become temperature stabilized, it is best to shut it down and immediately recheck alignment. Due to thermal growth, equipments that are aligned in the "COLD " pre-operating condition are almost always out of alignment when operating temperatures are attained.

Alignment can be performed with lot of different tools. The easiest way is to use a ruler or a straight edge and filler gauge over the two coupling halves and align by eyesight. This is called as EYEBALL alignment. The result is not very accurate, but widely used for general industrial applications. To achieve a better result is to use mechanical dial indicators. A skilled and experienced user can achieve good and reliable result. The easiest way, and most accurate, is to use laser based alignment system. They do not require special skill and delivers very accurate and repetitive results.

With today's optimized equipments, alignment is a vital part in the daily maintenance work. Equipments need to be on-line continuously with a minimum of interruptions. Equipment breakdown causes divesting loss of production and nearly 50% of equipment breakdowns are caused by misalignment. The costliest failures are those where maintenance is not performed even when alarms are triggered by high vibrations, temperatures, or high noise. Overfilling of grease should be avoided, as it locks the movement of hubs.

How to Recognize Misalignment

There are several symptoms indicating misalignment. By keeping eye on them, one can find the fault without any special instruments. These include:

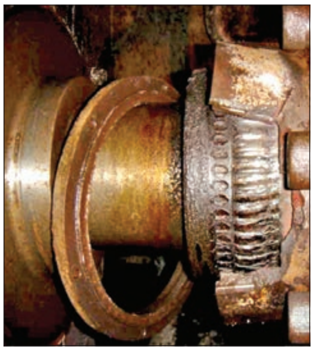
- Premature bearing, seal, shaft and coupling failure.
- Excessive radial and axial vibrations.
- High casing temperature at or near the bearings or high temperature discharge oil.
- Excessive amount of oil leakage at the bearing seal.
- Loose foundation bolts.
- Loose or broken coupling bolts.
- The coupling is hot while it is running and immediately after the unit is shut down. Look for rubber powder inside the coupling shroud.
- Excessive amount of grease on the inside of coupling guard.
- The shafts are breaking (or cracking) at or close to the inboard bearings or coupling hubs.

Misalignment and Power Consumption

Misalignment has a direct impact on the power consumption. It is proved the power saving is between 2 and 12%.

Effects of base Conditions and Thermal Variations

If the equipments are aligned when they are cold and no compensation for thermal growth is considered, the equipments will probably be running severely misaligned at running temperature. The couplings that accommodate misalignment through sliding, the useful life is determined by the type of wear and by its rate. For example: Lubricated metallic Flexible couplings.



Excessive angular mis-alignment beyond limits

Mis-aligned coupling - Vibration

The couplings that accommodate misalignment through flexing of metallic element, the useful life is determined by fatigue, in some cases by corrosion & fretting. For example: Dry Metallic Flexible Couplings.

The couplings that accommodate misalignment through flexing of elastomeric element, the useful life is determined by the deterioration in properties which is caused either by aging of the material or by damping. For example: Elastomeric couplings in compression and Shear.

2) Corrosion Induced Failures:

Corrosion affects every type of couplings: Salt, chlorides, hydrogen among others corrode ferrous components. Aluminum is corroded by alkali and salt. Rubber elements are affected by some hydraulic oils and by ozone. There are applications which suffer from corrosion namely:-

1) Air born corrosion: Flexible couplings create air movement through and around them. Air / gases / steam / hydrogen gas enters into a coupling above the shaft key depending on the environment in which the cou-

pling is running, corrosion takes place. The solution to this problem is quite simple. Before installing hubs on the shaft a bead of sealant compound should be placed on the top of the key. The sealant will close the gap that MUST exist over the key, and prevent any corrosive gases to penetrate in to the coupling.

2) Just as air or corrosive gases can enter into a coupling over the key, so can water. Water is often found in grease lubricated coupling that operate outdoors. Rain water can be sucked inside a coupling, it is retained by centrifugal effect.

3) Fretting Corrosion

4) Failure to provide air circulation in the coupling enclosure leads to failure.

5) Oil borne corrosive elements are normally found in oil-lubricated gear couplings, corrosive agents carried into couplings by oil. Acids and water are found mixed in the lubricants.

3) Failures Caused by Wear

Abrasive wear can occur in all couplings that accommodate misalignment through sliding, whenever lubrication conditions become poor or marginal. Marginal lubrication causes tooth surfaces to wear. These wear particles mix with the remaining lubricant, creating an abrasive lubricant.

If couplings are not periodically cleaned of the contaminated lubricant, the wear rate becomes higher and higher, and coupling teeth can become so thin that they fail in bending.

Steel Grid couplings can wear at the hub teeth, at the grid spring, and also at the covers. The spring and hub teeth wear in a similar way as the gear coupling. Wear of cover is an indication of unusual operating conditions, to be checked and rectified.

Wear of cover is caused by the large forces generated when the coupling operates at excessive misalignment, or when large amplitude torsional vibrations are present.

4) Fatigue Failure

All types of couplings suffer from fatigue failures. Fatigue is the type of failure that occurs gradually.

1) Lubricated coupling failure is caused by operating the coupling at an excessive misalignment than specified.

2) Fatigue failure of metallic disc coupling is very different than the gear coupling, and most often the failures of metallic discs occur without any kind of warning. Once the stresses in a flexible disc exceed the endurance limits, failure occurs within a short period without alarm of failure.

Fretting

Discs fail due to Fretting. Fretting occurs because adjacent blades slide back–and–forth over each other under the influence of misalignments. Discs of metallic couplings can also fail if the bolts are loose and do not provide required clamping force.

3) All elastomers have a certain amount of damping property, which causes some of the energy that is used to flex them, which gets converted into heat. The amount of energy absorbed depends on the characteristics of the material, on the amplitude and frequency of the flexing. If the heat generated by damping cannot be dissipated at the same rate, the temperature of the elastomer will increase and the ability of the element to flex and transmit torque is decreased. Rubber becomes brittle with time, particularly in the presence of ozone. Brittle flexible element can accommodate less and less misalignment and eventually fail.

5) Hardware Failure

Coupling bolts main function is to clamp together various components. Failures of coupling bolts occur exclusively in fatigue, which in turn occurs whenever bolts are not properly tightened. Bolts can fail if the holes in the coupling flanges are not equally spaced. Bolts can also fail if they have the wrong geometry, or too weak material.

Incorrect Selection / Incorrect Installation

6) Shaft Failures

Machine shaft failures can be caused by couplings in an application that had a relatively large offset between shafts. Loosely fitted hub on the shaft generates cyclic forces in the shaft. Under this condition besides the cyclic stresses, a shaft suffers a fretting fatigue and ultimately leads to failure at keyway. Keyless couplings induce large compressive stresses in the shaft. This stress is added to the shear stress caused by torque transmission, and can become excessive in the plane where the shaft enters its hub. Another reason of the higher stress is improper surface finish of the parts coming in contact with each other.

When power transmission equipment fails, user often blames the coupling rather than looking for the real causes. If more time is spent on selecting the coupling with proper analysis to suit the power transmitting train, it will result in fewer failures.

Equipment user may well assume that they have the best coupling for application, never suspecting that it is the coupling that is causing the periodic failure of bearings, shafts and other equipment components.

The majority of the problems described are caused by vibrations, and the phenomena of vibration are as complex as they are misunderstood. Misalignment is the principle source of most vibrations. In many years industry experience, vibration due to misalignment has been found to be the largest cause of premature failure in rotating equipment. These vibrations generate its own rotating force with exciting impulses that are related to the amount of misalignment and the speed of rotation.

Misalignment Data

Information on misalignment is not given freely to the coupling manufacturer although it is probably the most important piece of data needed to determine the best coupling for the job. Excessive misalignment is the killer of flexible couplings.

Any rotating equipment works well when it is well aligned and the coupling's misalignment characteristics act as a fall back when something goes wrong. **Better initial alignment of the coupling enhances its survival chance and that of the driving and driven equipment.**

Few Failure modes and fault diagnosis: Elastomeric Couplings

Sr.	Failure Mode	Probable Cause	Corrective Actions
1	Worn Flexible Element, Shaft Bearing Failure	Excessive shaft Misalignment	Realign coupling
2	Ruptured elastomeric flexible element Sheared hub, pins or teeth Loose hubs on shaft, sheared keys	Torsional shock, verload	Find and eliminate cause of overload Use torsionally soft coupling
3	Fatigue of elastomeric element, Overheated flexible element	Torsional vibration Excessive starts and stops High peak to peak torsional overload	Use larger coupling Add flywheel to hub
4	Swollen or cracked flexible member Severe hub corrosion	Chemical attack	Use more chemically resistant flexible member and hub. Coat hub with anti corrosive coating.
5	Distorted or deteriorated Elastomeric element	Excessive heat	Heat resistant flexible member
6	Shattered Flexible element	Low Temperature	Special low temperature rubber compound