Construction, Installation and Maintenance of Flexible Couplings

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The information contained in this article represents a significant collection of technical information on construction, installation, maintenance and troubleshooting of flexible couplings. This information will help to achieve increased reliability at a decreased cost. Assemblage of this information will provide a single point of reference that might otherwise be time consuming to obtain. Most of information given in this article is mainly derived from literature on the subject from sources as per the reference list given at the end of the article. For more information, please refer them. All information contained in this article has been assembled with great care. However, the information is given for guidance purposes only. The ultimate responsibility for its use and any subsequent liability rests with the end user. Please view the disclaimer uploaded on http://www.practicalmaintenance.net.

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Flexible Couplings

Rotating equipment that utilizes separate driving and driven machines requires some method of transmitting power between the two machines. This can be a drive shaft with universal joints, or a coupling of a particular design.

When two shafts are properly connected by a rigid coupling, they operate as a single shaft. A rigid coupling does not permit relative motion between the shafts of the driver and driven machines. A rigid coupling is primarily used for vertical applications, e.g., vertical pumps.

A flexible coupling is used to connect two axially oriented shafts. Its purpose is to transmit torque or rotary motion without slip and at the same time compensate for angular, parallel, and axial misalignment. Depending upon the design, they can also provide damping of vibration and torsional changes. Flexible couplings are often used to drive pumps, fans, compressors, motor generator sets, conveyors, crushers, vibrating screens, etc.

Because a flexible coupling joins two machines / equipment, it may be viewed with some lack of concern. However, in fact, it can be a major contributor to performance problems of the two machines. In view of this, information on construction, installation and maintenance of more common types of flexible couplings is given in this article.

Classification of Flexible Couplings

Flexible couplings are often classified based on the coupling falling into one or more of the following groups:

- General purpose / special purpose (high performance)
- Lubricated / non-lubricated (dry)
- Mechanical or metallic / elastomeric
- Low speed / high speed

General purpose couplings can generally be classified according to size and speed. A coupling connected to a rotating machine operating under 100 HP is classified as small and is sometimes referred to as “low.” Between 100 and 1000 HP is characterized as medium. Usually, HP over 1000 is considered critical and, therefore, the couplings are often considered to be special purpose or high performance.

Special purpose couplings are similar to general purpose couplings. They are designed to perform the same functions as general purpose couplings but at higher speeds and horsepower. Due to this improvement in performance, elastomer couplings do not qualify as special purpose couplings.

In this article, special purpose couplings will be referred to as "high performance" couplings. High performance couplings may be gear, disc, or diaphragm types and usually employ a spacer between shafts.

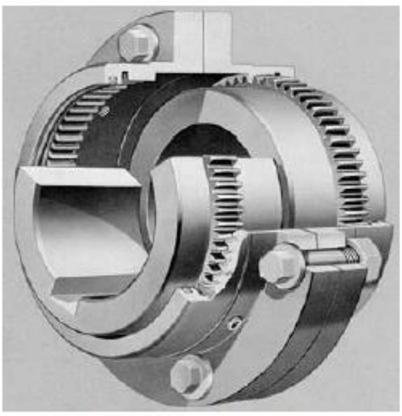
Typically, there are two general categories of high performance couplings: lubricated and non-lubricated. High performance gear couplings (a mechanical element) usually require continuous oil lubrication. Metallic element types require no lubrication and are typically designed as the disc type or diaphragm type.

Mechanical/Metallic Coupling

Differentiating Criteria	General Purpose Couplings	High Performance Couplings
Design Types	Gear, Grid, Chain, Disc and Diaphragm	Gear, Disc and Diaphragm
Material	AISI 1045	AISI 4140
Heat Treatment	Flame hardened gears	Nitrite hardened gears
Coupling Size (inch)	1 1/2 to 5	3 to 6
Horsepower (HP) @ rpm Ranges	0 - 1000 HP @ 3000 rpm > 1000 HP @ 1800 rpm	> 1000 HP @ 3600 + rpm
Balancing	Non balanced	Balanced
Configuration	Sometimes with spacers	Always with spacers

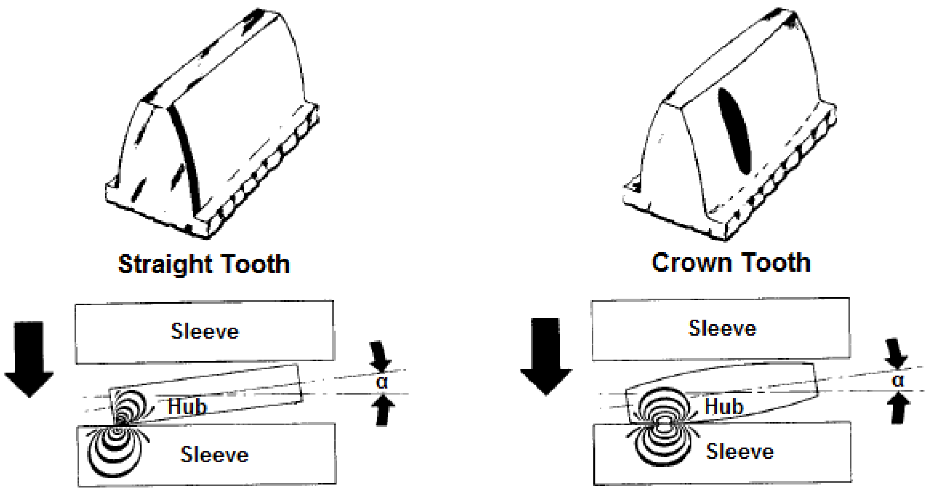
Above table shows a number of distinguishing design features for metallic flexible couplings.

Gear Type Coupling



Gear Type Coupling

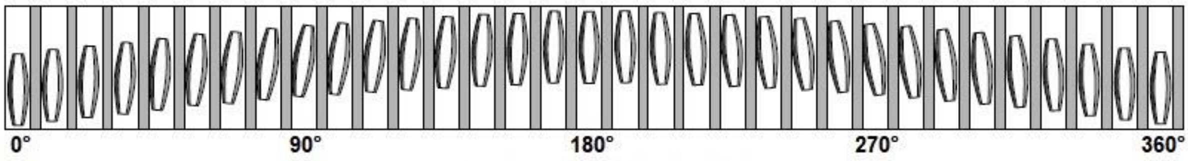
One of the most common types of couplings used for transmission of power above 100 HP is the gear coupling. As shown in above figure, gear type couplings consist of two hubs with external teeth that engage internal teeth on a one or two-piece sleeve. The teeth may be straight or curved (crowned). Torque is transmitted from one hub through the sleeve to the opposite hub through the meshing of the teeth. These couplings obtain their flexibility due to the looseness (backlash) between the mating teeth. These couplings accommodate axial (in-out) shaft movement better than other competing designs because their hub teeth easily slide along their sleeve teeth with no effect on coupling operation.



Straight Tooth and Crown Tooth

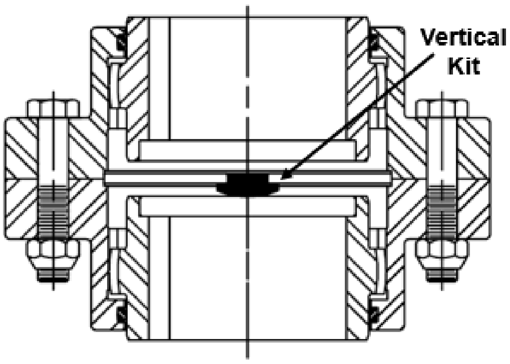
As shown in above figure, with straight hub teeth, there is a high concentration of load under misaligned conditions. As misalignment increases, more of the load is carried by the ends of the teeth, resulting in premature breakdown and coupling failure.

In a crown tooth, the contour of the tooth is a segment of an arc. The crowning can include tip crowns, flank crowns, and chamfers on the sharp edges. Under all operating conditions, contact areas equal or similar to contact areas shown in the figure exist between the hub teeth and the sleeve teeth. The larger contact area results in reduced stress in the crown tooth form. In addition, it prevents the sharp squared edges of the tooth from digging in and locking the coupling. Note that crowning applies to hub teeth only; sleeve teeth are straight except for a chamfer on the minor diameter edge. For application requiring over 0.25° angular misalignment, crowned/curved teeth may be more appropriate.



Gear Tooth Tracking Pattern

Above figure shows gear tooth tracking pattern (through 360° rotation) when subjected to misalignment condition.



Vertical Type Gear Coupling

As shown in above figure, gear couplings designed for use with vertical shafts consist of a vertical kit which keeps the sleeve in the designed position.

Generally, for a crown tooth coupling, maximum permissible angular misalignment per coupling half = ± 0.50 to 0.75°. For amount of maximum permissible parallel misalignment, please refer manufacturer’s literature/catalogue because the amount depends on coupling size. It may be noted that amount of maximum permissible misalignment depends on running speed (rpm) also. The amount is less for high speed application.

There are several methods of lubricating gear couplings. These are grease pack, oil fill and continuous oil flow. The vast majority of drives operate at 3600 rpm or less and use grease as the lubricant. Both grease and oil are used at speeds of 3600 to 6000 rpm. Oil is normally used as the lubricant in couplings operation over 6000 rpm. Most high speed couplings use a continuous oil flow to carry away the heat generated within the coupling.

The grease packed and oil filled units have end rings or seals which are used to retain the lubricant and restrict the entry of dust, grit, moisture, or other contaminants. Sleeves are provided with lubrication plugs which permit flushing and relubrication without disturbing the sleeve gasket or seals.

The major problem with gear couplings is lubrication. Grease tends to separate under centrifugal force (to prevent oil and soap separation, use grease recommended by the coupling manufacturer only) and, over time, O-ring type of seals begins to leak. If proper lubrication is maintained, these couplings will operate successfully for many years.

Lubrication problems result from one or several of the following causes:

- Use of improper amount of lubrication as described in manufacturer's literature.
- Loss of lubrication due to leakage.
- Excessive lubrication (grease), which can hydraulically lock the coupling in position.
- Excessive misalignment, which can overheat the lubricant.
- Perfect or very near perfect alignment, which can prohibit pumping of lubricant through the flex elements. The favorable condition can be deliberately set by aligning the drive with the machine shafts with a slight parallel/radial misalignment.
- Use of improper type of lubricant.

In view of the many problems that could arise with the use of an improper lubricant, it is necessary that the coupling manufacturer’s instructions be adhered to closely.

Generally, it is recommended to carry out periodic inspection and lubrication as under:

- After every 3000 hours - Carry out lubrication and check that sleeves are freely moving axially.
- After every 8000 hours or two years - Check alignment. Inspect gear teeth and O-rings. Carry out lubrication and check that sleeves are freely moving axially.

In case plugs are provided on the sleeves for relubrication, it is recommended to fill grease from one plug and ensure that it comes out from the other plug when the plugs are in horizontal position.

Grid Type Coupling

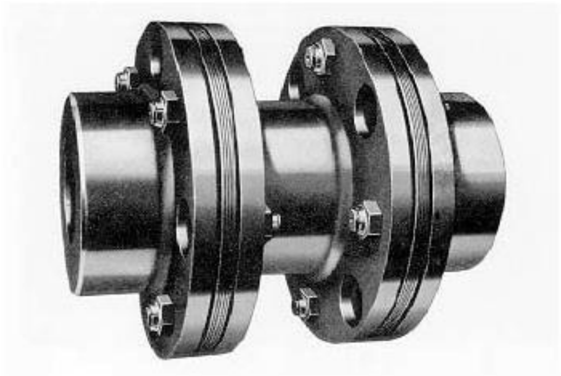
Grid Type Coupling

The grid type coupling was introduced around 1919 by Bibby Co. hence it is also known as Bibby coupling. A grid type coupling, shown in above figure is very similar to a gear type coupling. Grid type coupling are composed of all metal. They have two hubs with serrations (grooves) rather than teeth. The grooves are connected by a steel grid. Flexibility is achieved by sliding movement of the grid in the slots. Flexure of the grid in the curved slots provides some torsional resilience. The grid may be of one piece or may be provided in two or more sections. A cover keeps the lubrication contained inside the housing. The covers are either vertically split or horizontally split.

Grid couplings are used where both high torque levels and dampening requirements exist. Unlike gear and disc couplings (alternative metallic type couplings capable of transmitting high torque levels), grid couplings have a unique ability to reduce vibration by as much as 30%, and cushions shock loads to safeguard driving and driven equipment. However, grid couplings have limited ability to accommodate parallel shaft misalignment. These couplings do not transmit as much power (per the same outside diameter) as gear couplings but are usually less costly. Grid couplings are used for medium and small equipment applications.

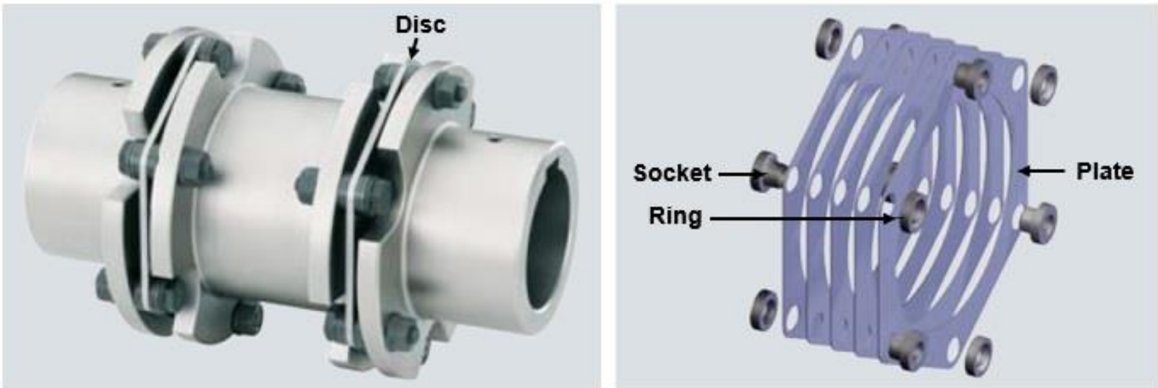
Like gear type coupling, proper lubrication is essential for grid type coupling also. In view of many problems that could arise with improper lubrication, it is necessary that the coupling manufacturer's instructions be adhered to closely.

Disc Type Metallic Coupling / Disc Coupling



Disc Type Metallic Coupling

In a disc coupling, a disc is used as a flexing element. Disc couplings are available in a number of forms, all of which have alternating driving and driven bolts on the same bolt circle. Misalignment is accommodated by the flexibility that comes from the length of material between the bolts. The amount of misalignment that each type can handle depends upon the length of material between bolts. Torque is transmitted by driving bolts pulling driven bolts through the disc material, which is in tension. More bolts provide greater capacity but reduce the coupling flexibility. These couplings are composed of all metal and do not require lubrication.



Disc Coupling and Disc Construction

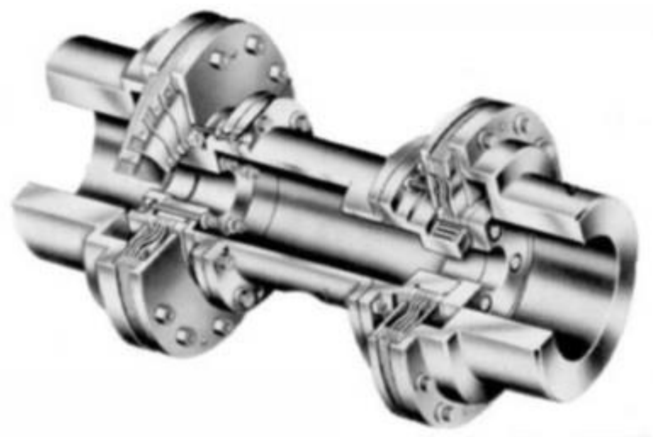
Above figure shows a disc coupling and construction of its disc. As shown in the figure, typically a disc is made up of individual thin plates that are held together by a socket and ring to form a compact plate pack. The number of plates stacked together depends on the design and application.

Generally, there are two discs (two flex planes) in a disc coupling. Two discs fastened to the intermediate spacer flanges permit compensation of shaft misalignments in an angular, parallel/radial and axial direction. Only angular and axial misalignments are possible in a coupling with single disc construction (two flanged hubs fastened to one disk).

Misalignment of the connected shafts should be restricted to within the manufacturer's recommendations. Generally, if the misalignment is beyond 1/2 to 3/4 degree during operation, then the flexible element will probably fail in fatigue.

Periodic visual inspection of the condition of the coupling is recommended. This can be done without disassembly or disturbing the connected equipment if the discs are visible. When the equipment cannot be shut down conveniently, a stroboscopic light can be used.

Diaphragm Type Metallic Coupling



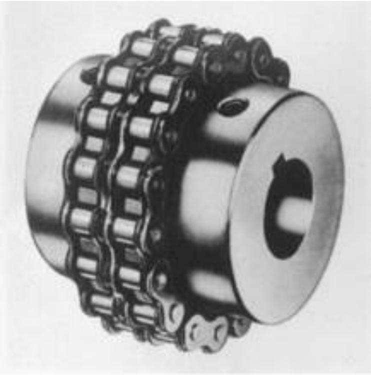
Diaphragm Type Metallic Coupling

The diaphragm coupling was developed in the mid-fifties for aircraft applications. It was introduced into industrial applications in the late sixties, initially to meet the demands of high speed and high horsepower service in petrochemical processing.

The diaphragm coupling is available in many sizes and styles. This coupling uses two flexing elements called diaphragms, separated by an intermediate member. The diaphragm is normally attached at the outside and inside diameter by bolts to connect the hubs to the intermediate member. The torque goes through the diaphragm assembly from the outside to inside diameter, or vice versa. Each flexing element is made up of one (tapered profile) or more (contoured or cut-out profiles) diaphragm elements depending on the design. The flexibility of the diaphragm design accommodates angular and parallel misalignment as well as a limited amount of axial misalignment (end float). Misalignment of the connected shafts should be restricted to within the manufacturer's recommendation for long coupling life.

Chain Coupling

Chain couplings are compact units capable of transmitting proportionately high torques at low speeds. Generally, they are used for unsophisticated applications (for example, agricultural/farming equipment and machinery). As shown in the following figure, they consist of two hubs having sprocket teeth which are connected by a strand of single-roller or double-roller chain. Shaft misalignment is accommodated by clearances between the chain and the sprocket teeth and/or clearances within the chain itself. A number of special features such as hardened sprocket teeth, special tooth forms, and barrel-shaped rollers are available which are designed to increase flexibility and reduce wear.



Chain Coupling

Coupling covers are recommended where the rotating speed is capable of slinging the lubricant or where the atmosphere is wet, corrosive, or abrasive. They protect the coupling and greatly extend its life by retaining the lubricant and preventing dirt or other foreign materials from coming in contact with or between the sliding parts. Most covers rotate with the coupling.

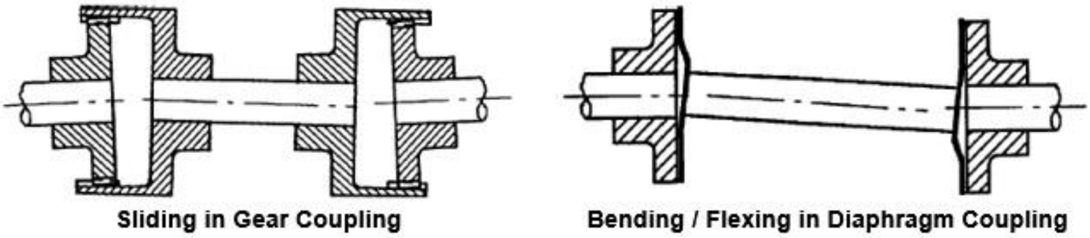
Routine flushing and relubrication is required. It is generally recommended that a roller-chain coupling be relubricated every 6 months or sooner depending on the conditions of operation.

To obtain maximum service with chain couplings, misalignment of the connected shafts must be restricted to the manufacturer's recommendations. Excessive amounts can cause rapid wear of the chain and sprockets as well as early failure of the cover seals and a resultant loss of lubricant.

A properly aligned coupling will allow the chain to be wrapped around the sprockets and the connecting pin inserted without any significant force.

Types of Movement to Accommodate Misalignment

A coupling accommodates misalignment in one of two ways: it either slides or flexes. Gear and grid couplings slide across the flex planes, while disc and diaphragm couplings flex (or bend) at the flex planes.



Sliding in Gear Coupling　　Bending / Flexing in Diaphragm Coupling

Types of Movement to Accommodate Misalignment

Above figure illustrates types of movement to accommodate misalignment - sliding in a gear coupling and bending or flexing in a diaphragm coupling.

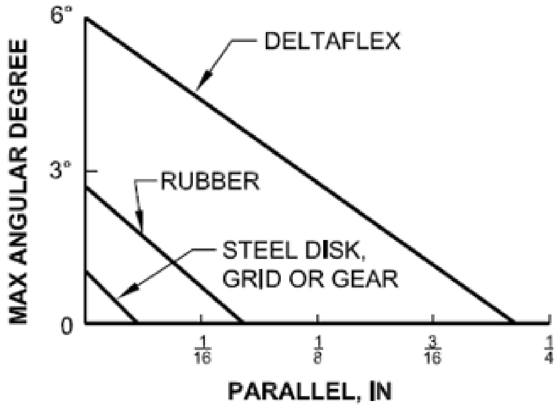
Above figure also shows how two flex planes permit compensation of shaft misalignments in an angular, parallel/radial and axial direction for gear and diaphragm couplings. One can also visualize why one flex plane permits misalignment only in angular and axial direction.

As noted earlier, couplings that slide to accommodate misalignment, such as a gear or grid couplings, are typically lubricated.

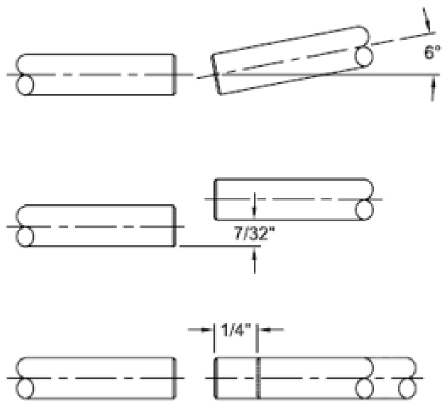
Deltaflex Coupling by Lovejoy Inc.

Deltaflex Coupling

Deltaflex Coupling, patented design concept (U.S. Patent Number: 4033144) by Lovejoy is the real solution to installation, misalignment, and performance problems. The Deltaflex coupling can handle greater shaft misalignment without generating heavy reaction loads on the equipment shaft bearings. They are available in 5 basic sizes, from 10HP to 900HP.



Deltaflex Coupling Capabilities Comparison



Misalignment Capability of Deltaflex Size 60

Capabilities of Deltaflex Coupling Compared to Conventional Coupling Designs

Above figure illustrates misalignment capabilities of the Deltaflex coupling as compared to conventional coupling designs.

These all-metal couplings do not require lubrication. For more information on these couplings, please visit website of Lovejoy Inc., www.lovejoy-inc.com.

Elastomeric Couplings

Elastomeric flexible shaft couplings are limited to general purpose applications. These couplings are typically used in applications below 100 HP. In these couplings, the elastomer is placed in shear or compression. Their ability to compensate for shaft misalignment is obtained by flexure and/or displacement of the elastomeric element. It may be noted that in an elastomeric coupling, elastomeric element in a single plane distorts enough for parallel/radial as well as angular misalignment. These couplings require no lubrication.

These couplings basically consist of two hubs separated and connected by elastomeric element. In shear type couplings, the elastomer may be bonded, clamped, or fitted to matching sections of the hubs. The compression type couplings usually utilize projecting pins, bolts, or lugs to connect the components. The elastomeric flexing elements may be natural rubber, neoprene, nitrile, urethane, Hytrel® or impregnated cloths and fibers.

Elastomeric type couplings are torsionally soft. This means that they will deform under torque and misalignment and also provide damping to some extent.

Synthetic gear, pin & bush, jaw/spider and tire (urethane or corded) type couplings falls under this category of couplings.

Synthetic Gear Type Coupling

Synthetic Gear Type Coupling

The basic theory of operation for synthetic gear type couplings is similar to that of metallic gear couplings except that synthetic gear couplings cannot sustain equivalent horsepower and speed due to the lesser-strength materials of the gears. In these couplings, gear teeth slide to accommodate misalignment. These couplings have their elastomeric elements in shear.

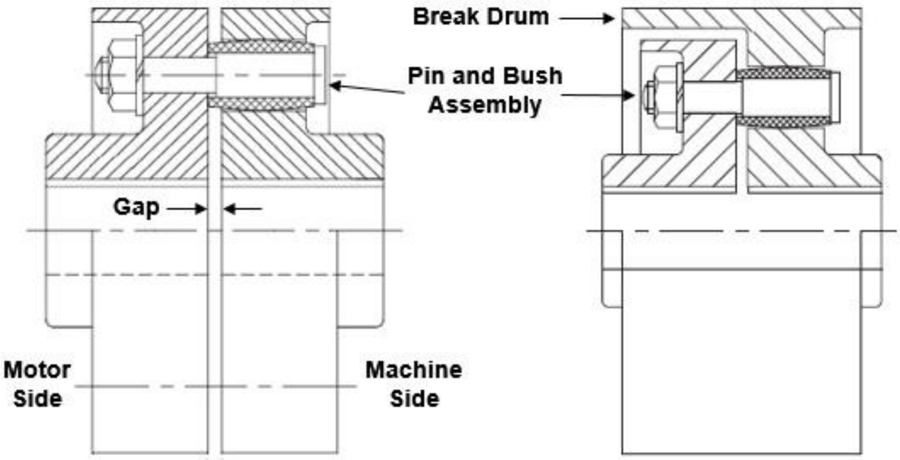
Pin and Bush Type Coupling

Pin and Bush Type Coupling

As shown in above figure, a pin and bush type coupling comprises two hub sections which are mounted on the machine shafts. The hubs are connected positively by steel pins and elastomer bushes. As shown in above figure, many times BARREL shaped bushes are used instead of plain (cylindrical) bushes. The barrel shaped bushes permit extra torsional flexibility as compared to plain bushes. Pin and bush couplings are very popular couplings for wide ranging general engineering applications.

The standard coupling is generally suitable for use at ambient temperature between −40°C and +80°C. However, by using alternative elastomer bushes, the permissible ambient temperature range can be extended to between −50°C and +100°C as shown in the following table.

Material / Description	Hardness, Shore A	Ambient Temperature °C
NBR (Nitrile Butadiene Rubber), standard type	80	−40 to +80
NBR, soft	60	−40 to +80
NBR, hard	90	−40 to +80
NR (Natural Rubber), for low temperature	80	−50 to +50
HNBR, high temperature	80	−10 to +100



Pin and Bush Coupling Arrangements With and Without Brake Drum

The coupling can be fitted with add-on parts such as brake disk or brake drum. Above figure shows typical coupling arrangements with and without brake drum. As shown in above figure, many coupling manufacturers provide guard on nuts for safety. Recommended amount of gap between coupling hubs is very important to compensate for shaft misalignment.

These couplings are economical but the rubber bushes are subjected to aging and consequent implications.

Jaw / Spider Type Coupling

Jaw / Spider Type Coupling

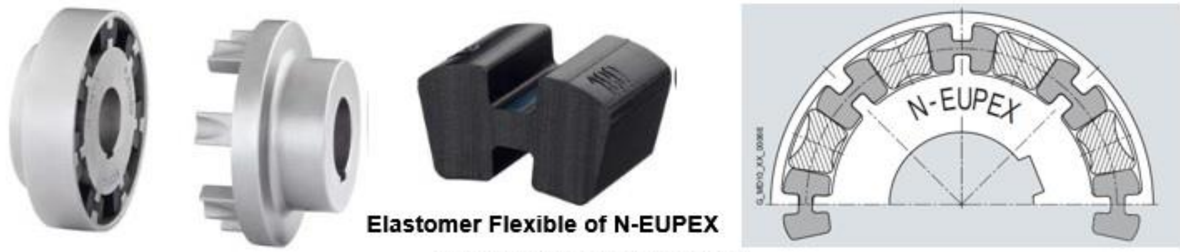
Jaw / spider type couplings have their elastomers in compression. This type of coupling is most often referred to as a spider coupling. The flex element can be one-piece or split to facilitate replacement. In case of split element, it can be wrap around the outside of the coupling, and then be held in place with a retaining ring. In American design, as shown in above figure, jaws are straight. Curved jaw are used in European designs. Small and medium-size equipment employ these types of couplings. These couplings are fail-safe type, that is, they will perform with failed elastomer. Flex elements are made of many types of elastomeric materials, such as Nitrile Butadiene Rubber (Buna N), urethane and Hytrel®.

The most standard jaw coupling spider material is Nitrile Butadiene (Buna N) rubber. This elastomer is oil resistant and has good chemical resistance. It has high dampening capacity. It operates effectively in a temperature range of −40°C to +100°C. It is well suited for cyclic loads (stop/start or reversing). The spider generally has a hardness of 80 Shore A.

Urethane has a greater torque capability relative to Buna N (approximately 1.5 times), but provides less dampening effect. Its operational temperature range is also reduced on both ends of the spectrum, −34°C to +71°C. (The in-shear type spider has a slightly different type of urethane and is rated for −34°C to +93°C). It does have good resistance to oil and chemicals, but is not recommended for cyclic or start/stop applications. Spiders are having shore hardness 40D or 55D. Their shelf life is 5 years.

Hytrel® (registered trademarks of DuPont) is used for high torque (approximately 2.5 times that of Buna N) and high temperature operations (−51°C to +121°C) and has excellent resistance to oil and chemicals. Hytrel® spiders are not recommended for cyclic or start/stop applications, and are also generally limited to a 0.5° degree of angular misalignment (vs generally 1° for Buna N and Urethane). Parallel misalignment handling ability does remain similar to Buna N & Urethane spiders at approximately 0.4 mm. Spiders are having shore hardness 55D. Their shelf life is 10 years.

The distance between coupling hubs is very important in these couplings. If the hubs are too close together, they can actually inhibit any capacity of the coupling to compensate for angular or parallel misalignment.



Elastomer Flexible of N-EUPEX

N-EUPEX Series Couplings

Elastomer Flexible of N-EUPEX DS

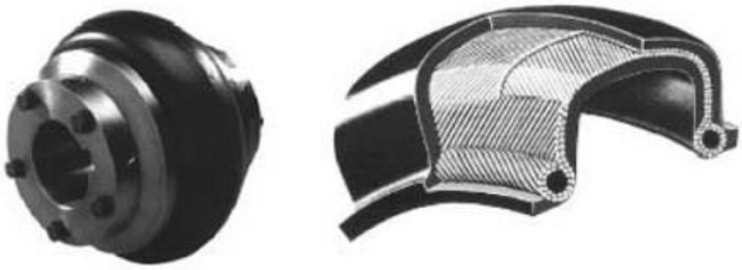
N-EUPEX DS Series Couplings

Construction of N-EUPEX and N-EUPEX DS Series Couplings by Flender

Flexible couplings - N-EUPEX and N-EUPEX DS Series by Flender are essentially like jaw coupling. However, in these couplings, identical jaws are not provided on both hubs. It also uses number of specially shaped flex elements. Above figure show construction of them. N-EUPEX coupling series are overload-holding (fail-safe type). By contrast, the N-EUPEX DS series is designed so that overload or advanced wear causes irreparable damage to the elastomer flexibles. The metal parts of N-EUPEX DS couplings can then rotate freely against one another without contact (non-fail-safe type).

For more information on N-EUPEX and N-EUPEX DS Series couplings, please contact A. Friedrich Flender AG (website: www.siemens.com or www.flender.com).

Tire/Tyre Type Coupling



Corded Tire Coupling

In these type of couplings, the tire bends/flexes to accommodate the misalignment. Such couplings have their elastomeric elements in shear. Many times they use a reinforced element (similar to auto tires). These couplings are highly flexible. Because of their low torsional stiffness and damping capacity, these couplings are especially suitable for coupling machines with a highly non uniform torque pattern. These couplings are also suitable for connecting machines with high shaft misalignment. These couplings can typically accommodate up to 4° of misalignment.

The coupling can be fitted with tires made of natural rubber for ambient temperatures of −50°C to +50°C. Chloroprene rubber (Neoprene) should be used in applications where exposure to greases and oils are likely. Chloroprene rubber can accommodate temperatures ranging from −15°C to +70°C. Urethane used for making tire is slightly different type than used to make spiders for jaw couplings and is rated for −34°C to 93°C.

The tire is slit at the circumference and can be changed without having to move the coupled machines. If the tire gets damaged or worn, the metal parts can rotate freely against one another because they are not in contact with one another. Most small-size and some medium-size equipment applications use these couplings.

Fits Associated with Couplings

The type of fit between a shaft and a hub can be one of the three types listed below:

- Clearance fit with key
- Interference fit with key
- Keyless interference fit

Torque is transmitted through the keys on all keyed couplings.

Couplings with **clearance fit** are limited to small horsepower applications. In case of clearance fit, set screws are used to minimize play between the hub and shaft and also to limit movement of the hub and/or key in the axial direction. Some coupling manufacturers recommend clearance fits that can be used on up to 4 inches (10 cm) of shaft diameter. However, in practice, clearance fits should not be used above a diameter of 2.75 inches (70 mm). Above 6 inches (153 mm), interference should be used whenever possible. Clearance fits are not normally used on shafts with speeds above 1800 rpm.

Couplings with **shrink fit** to shafts provide a tight fit, resist forces and moments applied across the coupling, and prevent their rocking on the shaft. This benefit subsequently prevents fretting, which can result in failure of the shaft and/or the coupling. Care should be taken not to have too tight a fit with keyed hubs, as this induces stresses and can cause cracking of the hub.

Shaft Fit Requirement

Required fit between the hub and the shaft for various types of couplings is as under.

- Gear, Disc and Diaphragm: Interference
- Grid and Chain: Clearance
- Elastomeric Couplings: Clearance

Some manufacturers recommend use of transition fit instead of clearance fit. However, this option is much less popular because it is not known in advance if the hub will be slightly interference or slightly clearance fit - creating unknown conditions. In view of this, clearance fits are extremely popular on smaller couplings while interference fit becoming more dominant in the 4 inch (100 mm) to 6 inch (150 mm) diameter range.

Amount of Interference (Shrink Fit) on Straight Shafts

Some coupling manufacturers provide a calculated interference that is based on the size of the shaft. This generally ranges from 0.00075 to 0.001 inch (0.019 to 0.0254 mm) per inch of shaft diameter. Experience has shown that, more commonly, these numbers should be reduced to around 0.0005 inch (0.0127 mm) per inch of shaft diameter. For a 3-inch shaft, a maximum of 0.002 inches (0.051 mm) is typical. For shafts larger than 3 inches, a good rule of thumb is to use 0.00025 inches (0.00635 mm) for each additional inch of shaft diameter.

Manufacturers also provide heating instructions for hubs. These recommendations usually request that a heater of some sort be used instead of an open flame from a torch (to prevent material from excessive exposure to heat). Oven heating is something similar to a welding rod oven. It is generally one of the better methods. Oil bath type heaters may also be considered but care should be taken to ensure that the elevated hub temperature remains well below the flash point of the oil. Manufacturer's limits on heating should be followed. Often they limit heating to less than 250°F (121°C). This can be verified with a Tempilstik® (temperature indicating crayon sticks) rated for the desired temperature. Experience has shown that a good method for determining if the hub is hot enough to be installed is to use a measuring device. One of the preferred methods is to use a telescoping gage set slightly larger (0.0005 to 0.001 inches; 0.00127 to 0.00254 mm) than the interference fit. When the temperature is acceptable for installation, the gage should easily pass through the hub.

As per ANSI/AGMA 9002-B04, clearance bore and interference bore shall be as under.

Nominal Bore Diameter (in)	Clearance Bore (in)	Interference Bore (in)
3/8 to 1 1/2	+ 0.001 / − 0.000	− 0.0005 / − 0.0010
1 9/16 to 2	+ 0.001 / − 0.000	− 0.0010 / − 0.0020
2 1/16 to 3	+ 0.0015 / − 0.000	− 0.0010 / − 0.0020
3 1/16 to 4	+ 0.0015 / − 0.000	− 0.0015 / − 0.0030
4 1/16 to 5	+ 0.0015 / − 0.000	− 0.0020 / − 0.0035
5 1/16 to 6 1/2	+ 0.0015 / − 0.000	− 0.0020 / − 0.0040
6 9/16 to 7	No Standard Tolerance	− 0.0020 / − 0.0040
7 1/8 to 8	No Standard Tolerance	− 0.0030 / − 0.0050
8 1/8 to 9	No Standard Tolerance	− 0.0035 / − 0.0055
9 1/8 to 10	No Standard Tolerance	− 0.0040 / − 0.0060
10 1/8 to 11	No Standard Tolerance	− 0.0045 / − 0.0065
11 1/4 to 12	No Standard Tolerance	− 0.0050 / − 0.0070
12 1/4 to 13	No Standard Tolerance	− 0.0055 / − 0.0075
13 1/4 to 14	No Standard Tolerance	− 0.0065 / − 0.0085
14 1/4 to 15	No Standard Tolerance	− 0.0070 / − 0.0090
15 1/4 to 16	No Standard Tolerance	− 0.0075 / − 0.0100

16 1/4 to 17	No Standard Tolerance	− 0.0080 / − 0.0105
17 1/4 to 18	No Standard Tolerance	− 0.0085 / − 0.0110

Notes:

- Class 1 clearance fits assumed; no standards for clearance fit above 6 ½ inches.
- Clearance fit bore tolerance is + 0.002 / − 0.000 for cast iron components on bores above 4 ½ inches.

The AGMA recently surveyed many motor, gearbox and pump manufacturers from around the world and have found that the most popular shafting on that type of equipment was k6, m6 and j6. The most popular bore tolerances that correspond to those shafts are H7 and P7.

Following table shows the recommended bores for **metric shafts** (mm) as per ANSI/AGMA 9112-A04; ISO/R775:1969 Standards which will produce a clearance, transition or interference fit.

Nominal Shaft Diameter			Bore Diameter Tolerance		
Over	**To (including)**	**Tolerance**	**Clearance**	**Transitional**	**Interference**
Including 12	18	j6	F7	H7	M6
18	30	j6	F7	H7	M6
30	50	k6	F7	H7	K6
50	80	m6	F7	H7	K7
80	100	m6	F7	H7	M7
100	120	m6	F7	H7	P7
120	180	m6	F7	H7	P7
180	200	m6	F7	H7	P7
200	225	m6	F7	H7	R7
225	250	m6	F7	H7	R7
250	280	m6	F7	H7	R7
280	315	m6	F7	H7	R7
315	355	m6	F7	H7	R7
355	400	m6	F7	H7	R8
400	450	m6	F7	H7	R8
450	500	m6	F7	H7	R8

It may be noted that most coupling manufacturers stock couplings hubs with H7 for transition fits and P7 for interference fits. They are chosen to cover the widest range of applications.

Shrink Fit on Tapered Shafts

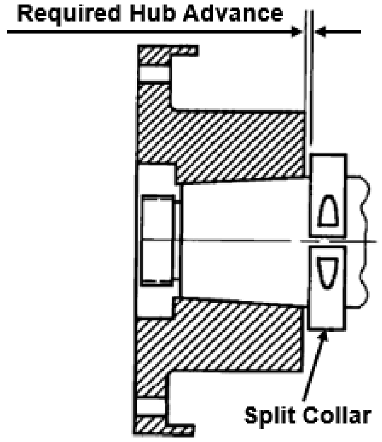
Tapered shafts are common on many equipment applications. The taper provides for easy installation and removal while allowing for a proper and tight fit from the hub to the shaft.

Tapered shafts are common on what are typically referred to as high-energy machines, such as boiler feed water pumps, large fans, and crushers.

Shafts are manufactured using various tapers, normally ranging from 1/2 inch per foot to 1 1/4 inch per foot. Manufacturers design a particular taper based on the fit required and the size of the shaft. Tapers may be described as either a ratio or a taper per foot. The most common tapers are 1/2, 5/8, and 1 1/4 inch per foot.

Manufacturers provide graphs showing the relationship between interferences and coupling advance. They also recommend required interference. Follow their recommendations.

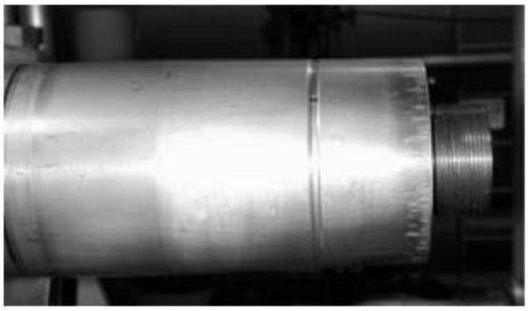
Proper heating of a tapered hub is extremely important. Getting the hub too hot will allow it to travel further on the shaft, making it almost impossible to remove. This problem can be remedied by installing a stop behind the hub.

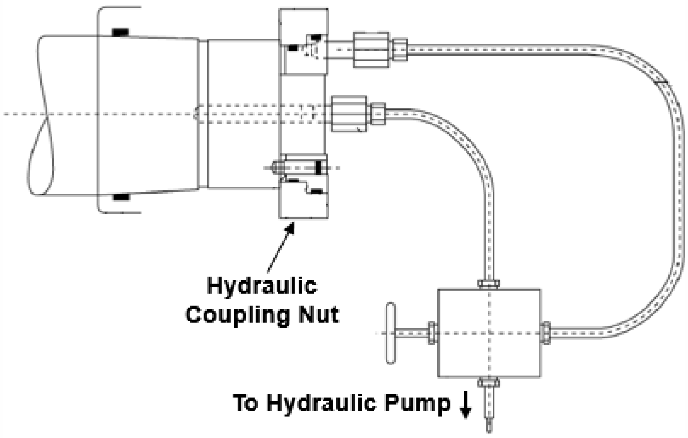


Hub Advance Stop

Above figure shows a stop in place, in the form of a split collar secured to the shaft, to limit the tapered hub during its advance up the taper. The coupling nut should immediately be placed on the shaft after hub installation to prevent the hub from "walking down the shaft." When the hub cools, it will shrink to some amount in the length direction. The coupling nut should then be tightened again.

A **keyless interference fit** coupling is usually referred to as a hydraulically dilated coupling. The hydraulically dilated coupling hub is used for ease of installation or in locations where heat or open flame is not acceptable.

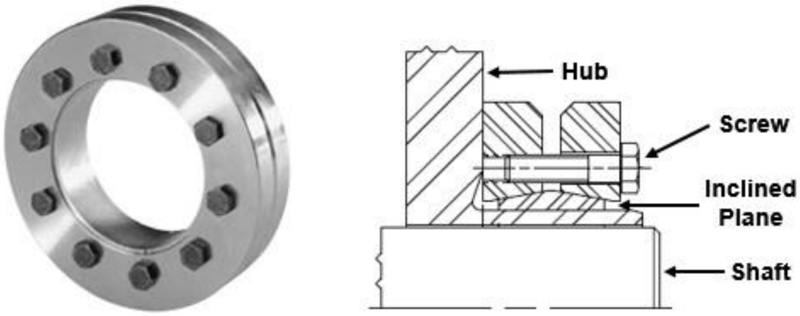

Keyless Hydraulically Dilated Coupling Shaft



Hydraulic Coupling Hub Installation Tool

Above figures show a keyless hydraulically dilated coupling shaft and the hydraulic coupling hub installation tool. For installing the coupling, a hydraulic pump is used to pressurize inside of the coupling via drilled passages in the shaft. When the hub is pressurized, the valve is diverted to push the hydraulic coupling nut and advance the hub to the prescribed amount. The pressure is then released between the coupling and the shaft, and the hub shrinks to the shaft. Once this is accomplished, the pressure is relieved on the hydraulic coupling nut and the pump is removed.

Shaft Locking Devices are also used to connect hubs solidly to shafts, using a keyless mechanical interference fit, to transmit torque or to withstand axial thrust. As shown in the following figure, the mechanical interference fit utilizes screw tension in the shaft locking device, converted into radial pressure via an inclined plane. This pressure contracts / expands the shaft locking device to eliminate the gap between the hub and the shaft. The shaft locking device uses the friction bond between shaft and hub or the shaft locking device and the shaft/hub to create a zero backlash connection. This connection is easily releasable to remove the mechanical interference fit.



Typical Shaft Locking Device

The contact pressures created using a shaft locking device can be greater than traditional interference fit pressures, allowing for more torque to be transmitted or shorter hubs to be used. The easy installation also allows the hub to be positioned more accurately on the shaft.

Design benefits of keyless interference fit are:

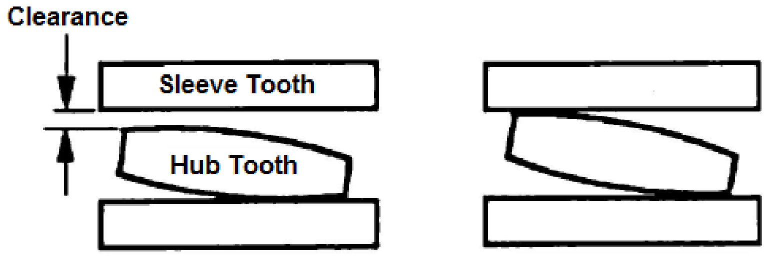
- Eliminate cost of machining keyways or splines.
- Reduce the shaft stress by removing keyways or splines.
- Eliminating keyways often allows the use of a smaller diameter shaft.

Coupling Failure

Couplings can fail as a result of human error, typically occurring during the design, installation, or maintenance of the item. Selection of an unsuitable design usually results in a coupling being placed in service that is too small or is the wrong design for the application. Coupling failure can also result from improper installation of the coupling itself. Installation practices that, if incorrectly performed, could lead to coupling failure are improperly torqued bolts, inadequate tolerances or fits, and/or improper lubrication. Information on major causes of failure for various types of couplings is given in this section.

Gear and Grid Couplings

As shown in the following figure, with an increase in misalignment, surface contact area decreases, resulting in increased loading on coupling components. This results in increased friction. This increased friction imposes a corresponding pre-load to the two shafts that are connected by the coupling. This prevents the coupling from moving axially, commonly called coupling lock-up to compensate for misalignment.



Normal Misalignment Jammed Condition

Gear Coupling Lock-Up Due to Excessive Angularity

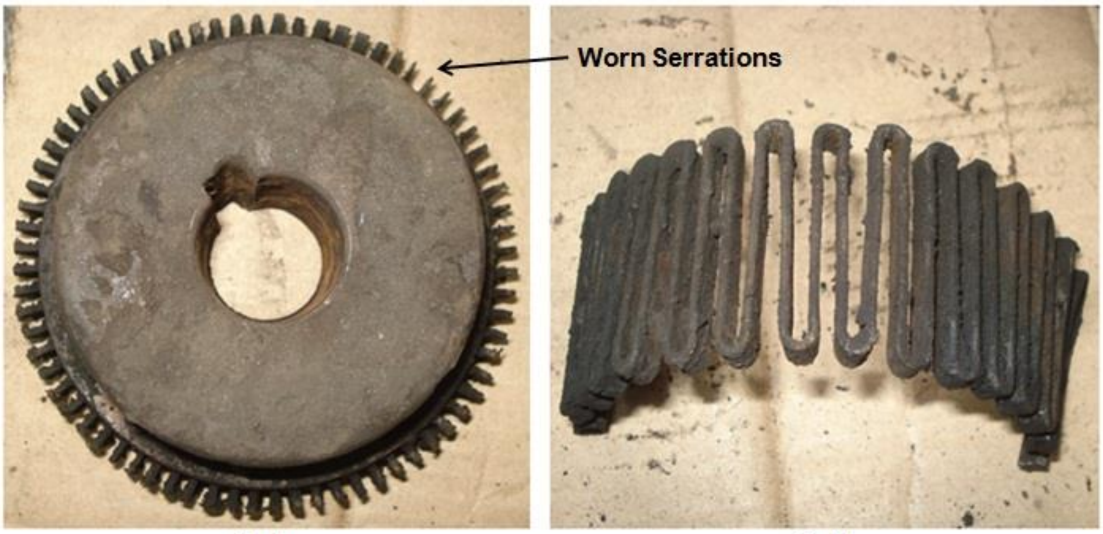
Fretting occurs when two surfaces move in relation to one another. The loading and heat generated by friction causes metal to be removed, to be transferred, or to crack. Fretting is actually fatigue of metal surfaces. In gear and grid couplings flex members slide in relation to each other. If the heat generated due to sliding exceeds the lubricant's ability to perform its function, major fretting occurs.

Sleeve Wear Wear on Hub Teeth

Fretting on Sleeve and Hub of a Gear Coupling

Above figure shows fretting on a sleeve and hub of a gear coupling caused by an extended run period with misalignment and lubrication breakdown.

Wear is the major problem with lubricated couplings. Most cases of wear can be traced to the lack of lubrication. Dirt in the lubricant can cause disaster.



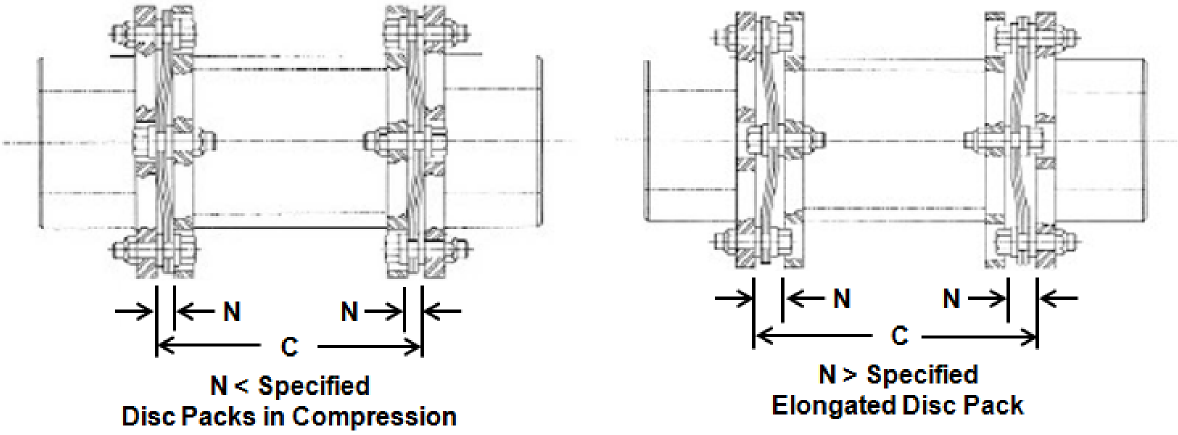
Hub Grid

Wear of Grid Coupling Serrations Due to Loss of Lubrication

Above figure shows wear of hub serrations due to loss of lubrication over a long period. This is a case of not inspecting the coupling at a predetermined frequency as recommended by the coupling manufacturer.

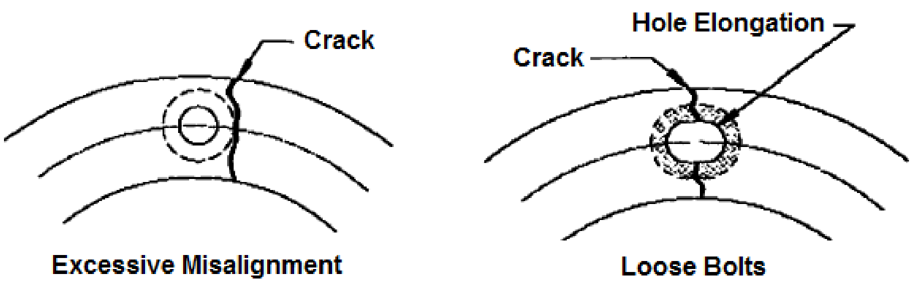
Overfilling with grease in a gear or grid coupling is a very common mistake and should be avoided because heat can build up in the coupling or cause a hydraulic lock. After packing, check that the coupling will move back and forth to ensure that the coupling is not grease-bound.

Disc Coupling



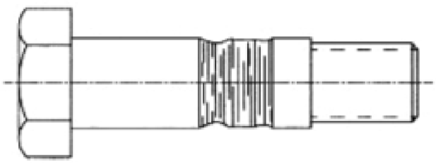
Disc Packs in Stressed Condition (Due to Compression or Elongation)

In a disc type coupling, failures result from fatigue due to excessive flexure from greater than designed misalignment. As shown in above figure, if a coupling is installed such that the distance between two shafts is too much or less as compared to designed distance, it leads to axial misalignment. A coupling can be inspected for damage without its disassembly if discs are visible. It can be checked with a strobe light while it is in operation. Under a strobe light the discs can be seen flexing and moving and a damaged disc would show up.



Disc Pack Failures

Above figure shows disc pack failure due to excessive misalignment and loose bolts. Due to excessive misalignment, cracks usually start on the outer discs and progress inward. If hole elongation and cracking is found, it is most likely due to loose bolting.



Loose Bolting

Above figure shows how a coupling bolt would look after loose bolting. Note that the disc has tried to embed in the bolt, causing a reduction in diameter or cutting of the bolt. When this failure occurs, the bolts and disc pack should be replaced. Torque should be applied to the nut and not the bolt.

Operating in an environment where corrosives are present will also cause cracking of the disc pack leading to premature failure of the coupling.

Please note that a disc coupling gives no warning of impending failure like a gear coupling which generates noise and vibration prior to failure.

Diaphragm Coupling Failure

A diaphragm coupling usually fails due to improper installation or, possibly, excessive misalignment. Excessive misalignment leads to fatigue failure that occurs after the endurance limit of the material has been reached. Fatigue failure occur almost instantaneously and without warning.

Elastomeric Couplings

Mistakes made in sizing of couplings, selecting the most suitable elastomers, installation and ongoing maintenance may lead to premature element / insert / spider failure. Things that influence the life of an insert or spider include:

- Proper selection
- Misalignment
- Over-torque
- Environment effects (chemical exposure and excessive temperature)
- Environmental contaminants (abrasive dust, sand, sawdust, etc.)
- Torsional vibration or improper application

Normal Wear of Coupling Spider

Inserts, or spiders, used in jaw couplings are designed to be the primary ‘wear’ component in the coupling. The elastomer, or spider, acts as a cushion between the metal jaws of the two coupling hubs. The driving hub pushes the driven hub through the spider resulting in an expected compression of the elastomer. Normal wear of a jaw coupling spider is not considered destructive wear but is instead a compressive “set” of the elastomer. Compressive “set" is defined as the decrease in the thickness of the spider leg as seen in above figure and is considered normal wear of the spider ages while in service.

This particular spider shown in above figure was used in a non-reversing application. The normal limit of allowable wear is roughly 20-30% of volume loss in the three spider legs that typically transmit torque.

Compression is only applied to the spider legs forward of the driving jaws and the trailing legs behind the driving jaws remain relaxed. Accordingly, when compressive set reaches 70-80% (representative of most manufacturers' standard) of its original spider leg volume, the spider needs to be replaced. If alternating spider legs display compression, the spider can be rotated by one leg advancing the good legs into the driving position. This is an acceptable step to take until a replacement spider can be installed. In reversing applications, all spider legs would show wear and the spider should be replaced immediately. If worn spiders are not replaced, the legs will eventually wear or shear off leaving no cushioning between the hubs' metallic jaws. This metal to metal contact will eventually cause jaw failure.

Misalignment is often a major cause for failure of elastomer type couplings. Large amounts of misalignment can cause the elastomers to be subjected to high loads, which can tear them apart.

Due to the damping effect of elastomeric couplings, heat is generated with the flexing or compressing of the material. If the temperature limits are in excess for the material used, the coupling will fail.

Spider and Hub Failures

Couplings are designed to transmit torque from one shaft to another through the coupling hubs and spider. The weakest link in a jaw coupling is the insert, or spider, and the coupling's torque capacity is determined by the rated capacity of the elastomer to transmit torque. When the elastomers' capacity to transmit torque is exceeded, an over-torque, or over load, situation can exist. This happens when the coupling has not been correctly sized for an application and typically results in the failure of the coupling, sometimes catastrophic as shown in above figure. A major factor influencing the selection of a coupling is the use of service factors to adjust the application torque for specific applications. When an incorrect service factor is selected or this calculation is not done properly, spider failure and often hub failure will occur.

Hub Break

Applying excessive torque or excessive interference fit to a coupling can cause the hub to break starting at the top corner of the keyway where the thinnest cross section occurs. Ultimately, the hub will split in half as shown in above figure.

When a spider is exposed to a chemical it is not compatible with, the elastomer material will break down quickly, often causing a rapid failure of the spider. Care should be taken at the time of coupling/spider selection to avoid issues related to chemical exposure.

Exposure to extreme temperature has always been a factor in selecting an elastomeric insert or spider for a jaw coupling. Many applications require adjustments in application designs to move away from elastomeric couplings to all metal coupling designs to counter issues raised due to temperature.

When making coupling selections, the user will need to take into consideration both chemical exposure and the temperature of the environment where the coupling will be operating. This will result in better coupling selection and longer life.

All rubbers and synthetics have a specified service life and shelf life. Exposure to chemicals and corrosives as well as ozone can precipitate a failure due to the loss of material properties. Broken pieces or dusting of material having the same color as the flexing element around the coupling is an indication of material degradation.

All Couplings

Couplings are designed to use a specific property class (grade) of bolts. Use of incorrect grade of bolts may result in their failure resulting in coupling failure.

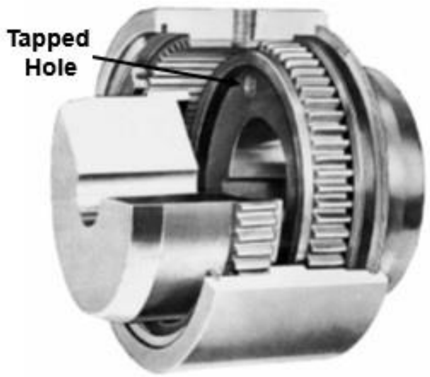
Bolt failures generally occur from improper tightening. The manufacturer's guidelines should be adhered to where bolting is concerned. The proper torque and lubricant for bolts should be used. Many manufacturers stipulate that no lubricant be used on coupling bolts.

Proper fitting of the key as well as its material are important for proper operation of a coupling. Manufacturer's drawings or technical literature should be consulted if concerns arise regarding the suitability of the coupling key and keyway.

Alignment

In general, it is recommended that all couplings must be aligned within relatively close tolerances (i.e., 0.001 to 0.002 in. / 0.025 to 0.05 mm).

Coupling Removal



Coupling with Tapped Holes

Interference fit coupling hubs on straight shafts require a method of removal to avoid damage to the shaft or the coupling. Above figure shows a one-piece sleeve gear coupling with draw-off tapped holes for installing a puller.

Unless specified, when coupling hubs are received, whether bored to size or rough-bored, they typically do not have holes tapped to facilitate a puller. The manufacturer can usually provide guidelines for the hole size, thread, and location for layout of the holes.

Many times coupling hubs are heated with a heating / cutting torch for ease of their removal. In such cases one should start heating the hub from outside diameter. If heating is started at inside diameter, shaft will also get heated making hub removal difficult.

High-performance couplings are sometimes furnished with two keys to distribute the shear stress on two keys instead of only one. Care should be taken when using a hub and shaft, which employ two keys. The coupling and the shaft should be match-marked to ensure that the coupling is returned to same orientation on the shaft each time. This is especially true when rotor balancing is to be performed. Lubrication of the key with a slight coat of "never seize" will prevent galling.

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Frequently Asked Questions on Metric Bores and Keyways in Couplings by Mechanical Power Transmission Association (website: www.mpta.org)

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http://www.couplinganswers.com