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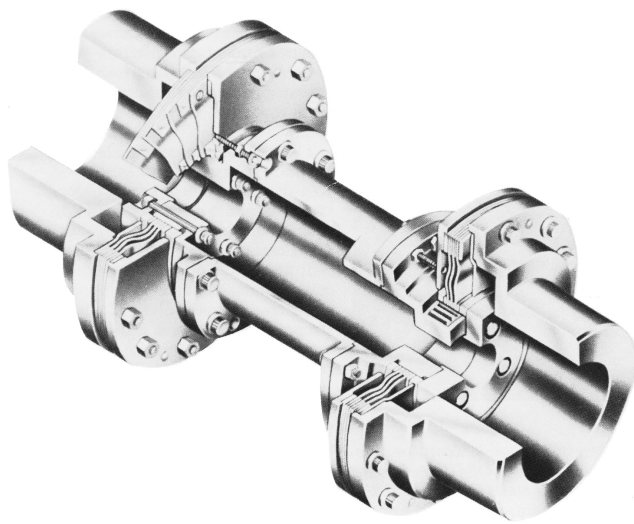


As seen in
Machine Design
July, 1986

Ameridrives Couplings

An Altra Industrial Motion Company

Disc Vs Diaphragm Couplings

Jon R. Mancuso, Manager of Engineering, Zurn Industries Inc.

Although similar, disc and diaphragm couplings are not the same. Using the wrong one can raise havoc with your equipment.

About fifteen years ago, a company that manufactured disc couplings was asked to supply one of their products for a gas turbine application. The design was laboratory tested before installation, and to the engineer's dismay, as the heat load was applied, the axial travel of the drive shaft grew beyond the limit of the disc coupling. It eventually failed and was abandoned in favor of a competing diaphragm design.

The point of this story is that although these couplings appear similar, they are vastly different. Mistaking one for the other can damage your equipment or cause premature coupling failure.

Classified as metallic membrane couplings, disc and diaphragm couplings transmit torque and accommodate the slight misalignment anticipated between most equipment shafts. They were developed to eliminate the problems associated with lubricated couplings, some of which are:

- Maintaining correct lubrication intervals.
- Using the proper lubricant.
- Maintaining a continuous lubrication system.
- Maintaining the coupling seals.
- Ensuring a correct amount of lubricant. Too much or too little may cause the coupling to bind in operation and cause equipment shutdown due to excessive vibration.
- Periodic cleaning and inspection of the coupling.

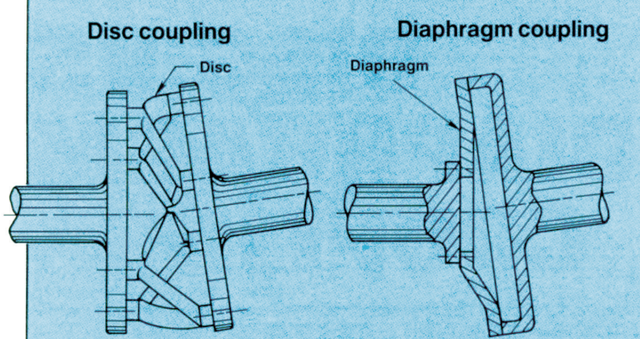
Metallic membrane couplings rely on the flexure of metallic elements to accommodate misalignment and axial movement in shafts. They have been around longer than the other two major types of couplings, mechanically flexible and elastomeric.

The heart of each coupling is a disc or diaphragm. The disc, which is more like a flat ring, usually consists of several flexible metallic layers, called a pack, attached alternately with bolts to opposite flanges. The diaphragm consists of one or more metallic plates attached at the outside diameter of a drive flange. Torque is transferred through the diaphragm in an attachment on the inside diameter.

Most of the confusion in identifying these couplings probably arises when engineers identify diaphragms as discs and vice versa. In terminology this may be true; in couplings it is not.

Disc Couplings

Available in a number of forms, all have the driving and driven bolts on the same bolt circle. The flexibility or misalignment that each type can handle depends upon the length of the material between bolts. Torque is transmitted by driving bolts pulling driven bolts with disc material. More bolts generally provide greater torque capacity but reduce coupling



Disc couplings transmit power through a flexible disc or ring. Driver and driven bolts share the same circle, alternating attaching bolts. The shape and material of the disc determine its power and deflection ratings. Diaphragm couplings transmit power from OD to ID. The diaphragm flexes to accommodate misalignment.

flexibility.

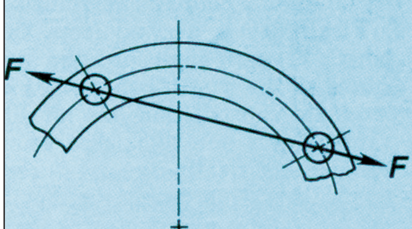
Flexibility is derived from the length between adjacent bolts and varies as the length cubed. A thin laminate construction has an advantage over one thick disc when considering flexibility and forces transmitted due to misalignment. While certain manufacturing considerations make it impractical to use very thin laminations for a disc, thicknesses ranging from 0.005 to 0.025 in. are satisfactory.

The degree of flexibility required and limits of acceptable bearing loads determine the number of driving and driven bolts used. This can be an important factor when selecting a coupling. Choosing a unit with a greater degree of freedom than actually required dictates a diameter, weight, and cost also greater than necessary.

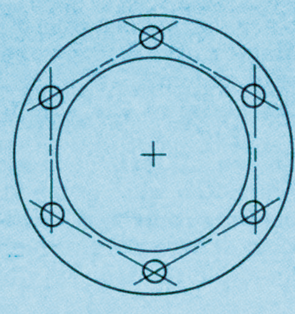
The simplest disc coupling has two driving and two driven bolts and provides the largest degree of flexibility with lowest stresses. However, if the line of action between driving and driven bolts should be outside the material of the lamination, as it would be on a disc with a small OD/ID ratio, the tensile stress could be unacceptably high. To ensure that the line of action falls in an acceptable position, more driving bolts are used than would otherwise be required. The cost in this case is reduced flexibility. To regain some flex, either more laminate material, or a larger OD and bolt circle can be used.

At the other extreme, more bolts allow shorter flex length which reduces flexibility. This is a preferred feature when, for example, the axial movement of a

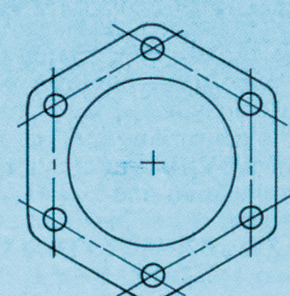
DISC OPTIONS



Disc segment. If too few bolts are used to connect the driving and driven shafts or if the OD/ID ratio is too small, the line of action can fall outside the disc material, producing unacceptable tensile stress.



Circular disc. This type is the most widely used, can accommodate low misalignments, and is easiest to manufacture. However, it develops high compressive stresses at the OD and high tensile stresses at the ID.



Hex disc. This disc reduces tensile stress in the free area over the circular disc. It is also more adaptive than the circular disc to fluctuations in bending stress due to angular misalignment.

Coupling Capacities and Design Differences	Disc		Diaphragm		
	Circular	Misc. shape	Multiple	Convoluted	Tapered
Maximum Continous Torque (X10 lb-in)	4	3	4	6	6
Maximum Speed (rpm)	30,000	30,000	5,000	30,000	30,000
Maximum Bore (in.)	12	12	12	12	12
Maximum Acceptable Misalignment (°)	1/4	1/2	1	1/2	1/2
Maxmium Allowable Axial Travel (± in.)	3/8	3/8	1/8	1	1

rotor needs to be restricted while still allowing for small misalignments.

Disc couplings are used on fractional to 100,000 hp drives. They are categorized into two application groups: general purpose and high speed.

The general purpose flexible disc is made of spring steels. ANSI 1050-1080, or 300 series stainless steels. Other torque transmitting components are made of low to medium-carbon steel. In high-speed couplings, the discs are made of corrosion resistant steels. 300 series stainless, PH stainless, or high strength nickel alloys. Other drive components are made of alloy steels.

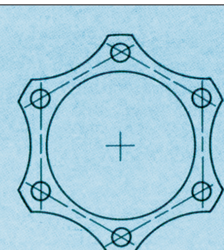
Diaphragm Couplings

Diaphragm couplings have also been used from fractional to 100,000 hp drives and are available in three basic forms:

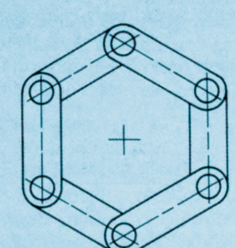
- Tapered contoured
- Multiple straight diaphragm with spokes
- Multiple convoluted diaphragm

The free span between the diaphragm OD and ID provides flexibility. Torque is also transmitted between these diameters. The diaphragm elements can be either uniform or of differing thicknesses, usually with maximum thickness at the smaller diameter. All three shapes have some profile modification to help reduce size, increase flexibility, and control stress concentrations. For example, tapered contoured diaphragms are designed for constant shear stress from ID to OD. This feature tends to reduce overall weight and increase flexibility.

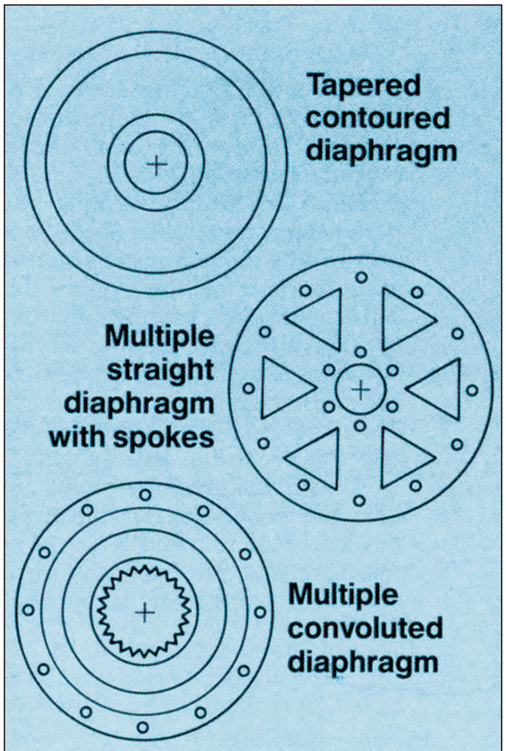
Multiple diaphragm designs, convoluted and straight with spokes, use a number of thin plates rather than a single thick one. This improves flexibility. With thin diaphragms in parallel, stresses are usually lower. Stresses, moments, and forces on a diaphragm increase with the cube of thickness.



Scalloped disc. The least stressed portion of the membrane has been removed. This shape is intended to produce uniform tensile stresses over the driving portion of the blade. Maximum bending stresses in the lamination due to misalignment will occur at the anchor points. This design usually provides the greatest flexibility.



Segmented disc. This form has some advantages in manufacturing, and with larger units, also aids assembly and disassembly of the links into the coupling.



Tapered contoured diaphragms produce constant shear stress from ID to OD. This feature tends to reduce overall weight and increase coupling flexibility. Multiple diaphragm designs, convoluted and straight with spokes, use a number of thin plates rather than one thick plate to improve the flexibility of the coupling and reduce diaphragm stresses.

Tandem disc couplings are typically used on medium power pumps. The length is necessary to reduce angular misalignment of each disc pack from large amounts of offset seen by the equipment.

Close coupled double flex disc coupling are normally used on low torque applications

Multiple convoluted diaphragm couplings are used in high performance applications.

As a result, several thin diaphragms produce lower stress values than a single thick one.

Diaphragm coupling construction: Usually used on high performance equipment, diaphragm couplings require high reliability. Torque transmitting components of these couplings are usually made of high strength alloys with good fatigue properties. Tapered contoured diaphragms are usually made from AISI 4100 or 4300 steels, which are coated for corrosion protection. Multiple diaphragms, straight and convoluted, can be made with cold reduced 300 Series stainless steel ¼ to ½ hard condition, PH stainless steels or high strength nickel alloys.

Selecting a Coupling

Two important considerations for sizing a metallic membrane coupling are operating stresses and safety factor in the flexible membrane. Operating stresses must be held under the endurance limit of the disc or diaphragm material. Endurance limit is an indication of material fatigue life and, hence, coupling operational life.

Before selecting a coupling, the parameters and stresses needed are provided by the rotating equipment manufacturer or the system designer. For the example that follows, a multiple convoluted diaphragm is used, but most flexible membrane couplings experience the same type of

Coupling characteristics	Disc coupling		Diaphragm coupling		
	Circular	Misc. shape	Multiple	Convolute	Tapered
OD/Bore ratio	Small	Small	Large	Medium	Large
Overhung moment	Low	Low	Medium	Med./Low	Medium
Unbalance Force	Medium	Low/Med.	Low/Med.	Low	Med./Low
Bending moment	Medium	Low	Med./Low	Low	Med./Low
Axial force	High	Medium	Medium	Low	Low/Med.
Torsional stiffness	High	Medium	High	Medium	High
Windage losses	Med.	Med./Low	High/Med.	Med./Low	High/Med.

stresses and the selection procedure is very similar.

Membrane stresses can be understood by knowing how the membrane reacts to various types of misalignment. For example, when angular misalignment is imposed on an entire pack, a diaphragm on the centerline of the pack reacts differently than one off the centerline.

Stresses resulting from diaphragm deflection that are continuous during operation are termed steady state. Stresses that completely reverse during each revolution are termed alternating.

Steady state stresses to be considered are:

• Axial stress S_a is a function of the axial shaft deflection imposed on the diaphragm.

• Shear stress S_S occurs when torque is transmitted through the diaphragm pack, it depends on the size, number, and thickness of the diaphragm and is highest at the diaphragm ID.

• Centrifugal stress S_c always result when the coupling rotates. This rotational effect on the diaphragm must be combined with the other steady state stresses.

• Thermal gradient stress S_t applies only where a temperature differential exists across the surface of the diaphragms or where there is a coefficient of expansion difference, in this case, combined thermal stress must also be calculated.

Combining stresses: The stresses described above are calculated at the inside of the diaphragm and for the furthest diaphragm from the centerline. Mean stress S_m is the sum of all but the shear stress; that is:

$$S_m = S_a + S_c + S_t$$

These are combined with shear stress T to give combined steady state stress, S:

$$S = \frac{S_m}{2} + \sqrt{\left(\frac{S_m}{2}\right)^2 + \tau^2}$$

Totals alternating stress S_b is conservatively determined by the simple summation of offset and flexure stresses. Where no cyclic torque is present,

$$S_b = S_o + S_f$$

If cyclic torque is present,

$$S_b = \frac{S_o + S_f}{2} + \sqrt{\left(\frac{S_o + S_f}{2}\right)^2 + \tau^2}$$

Finally, mean stress S_m and alternating stress S_b can be plotted on a Modified Goodman Line to yield various acceptable misalignment values. Safety factor N can then be calculated from

$$\frac{1}{N} = \frac{S}{S_u} + \frac{S_b}{S_e}$$

where, S_u = Ultimate strength of material, psi; and S_e = endurance strength of material, psi.

The safety factor can be compared for the various candidate couplings. Typical values are from l.5 to 2.0. The coupling with the largest safety factor is usually the best selection. If none of the safety factors is sufficient, the operating conditions should be reviewed or an alteration, such as a larger sized coupling, should be considered.

About Altra Industrial Motion

Altra Industrial Motion (NASDAQ:AIMC) is a leading multi-national designer, producer and marketer of a wide range of electromechanical power transmission products. The company brings together strong brands covering over 40 product lines with production facilities in nine countries.

Altra's leading brands include Boston Gear, Warner Electric, TB Wood's, Formsprag Clutch, Wichita Clutch, Industrial Clutch, Ameridrives Couplings, Kilian Manufacturing, Marland Clutch, Nuttall Gear, Bauer Gear Motor, Stieber Clutch, Twiflex Limited, Bibby Turboflex, Matrix International, Inertia Dynamics, Huco Dynatork, Lamiflex Couplings, Ameridrives Power Transmission, Delroyd Worm Gear and Warner Linear. For information on any of these technology leaders, visit www.AltraMotion.com or call 815-389-3771.

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