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High Performance Non-Lubricated Coupling Service Life and Failure Modes

Ameridrives® Couplings

An Altra Industrial Motion Company

High Performance Non-Lubricated Coupling Service Life and Failure Modes

James H. Paluh, Manager-Engineering High Performance Products
Ameridrives International, December 1997

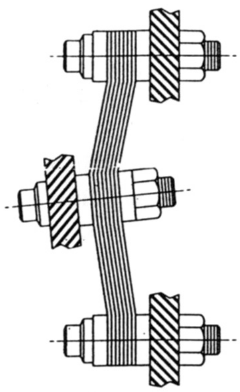

Figure 1

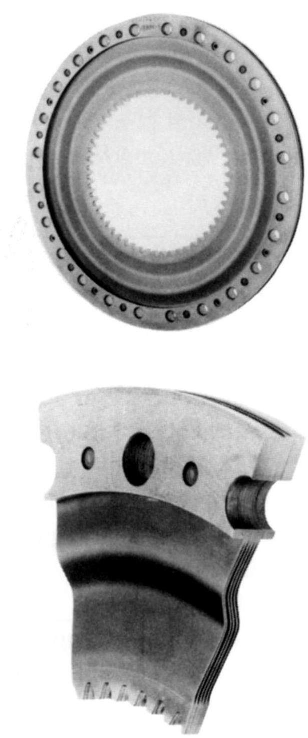

Figure 2

Metallic disc and diaphragm couplings are the two principle types of non-lubricated couplings used in high performance turbomachinery. Both transmit torque and accommodate misalignment between turbo-machinery equipment shafts. These types of couplings rely on the flexure of metallic membranes to accept angular and axial misalignment. In disc couplings, torque is transmitted by the driving bolts pulling the driven bolts with the disc material at a constant bolt circle (Figure 1). The disc elements generally consist of many thin, metallic, identically shaped rings stacked directly on top of one another. The ring shape will vary by design, from circular discs, hex discs, or scalloped discs. The discs are clamped together with washers by bolts that are attached alternately to the driving and driven flanges.

In diaphragm couplings the torque is transmitted radially from the outside diameter of a drive flange through one or more metallic plates to an attachment at the inside diameter. The diaphragms may have either a constant or tapered thickness and may be flat, convoluted, or spoked. The diaphragm outside diameter is usually clamped by bolts while the inside diameter is unitized by electron beam welds, splines, or bolts (Figure 2).

While disc couplings have multiple membranes, the individual discs are typically not separated. When flexing of the disc occurs under misalignment, each disc contacting surface rubs the adjoining disc surface causing some degree of fretting and wear. This fretting can allow corrosion to attack the disc material. When corrosion is combined with fatigue, known as corrosion fatigue, it reduces the endurance limit and may initiate a fatigue failure. The corrosion products can act as a wedge, opening a crack in the fretted area of the disc. Since there is direct contact with the adjoining discs, the crack could propagate quickly. By properly designing the shape (such as scalloping) and the thickness of the discs, fretting corrosion can be reduced, but not eliminated.

Some manufacturers apply coatings to each disc to increase the finite coupling life. However, studies have shown that most coatings have a negative impact on the endurance strength of the base material.

Stress corrosion cracking is defined as the combined action of static stress and corrosion leading to the cracking or embrittlement of metal and must be considered in metallic membrane material selection. Standard disc materials are austenitic stainless steels such as 301 full hard stainless steel. In corrosive environments such as atmospheric sodium chloride, austenitic stainless steels exhibit a high susceptibility to stress corrosion cracking when the temperature exceeds 150° F. Most disc coupling manufacturers offer alternate materials such as inconel which are highly resistant to stress corrosion.

The design and proper installation of the disc coupling bolts is also critical since the inherent design of disc couplings require the bolts to transfer torque through shear and bending. The highest bolt stresses are in bending (Figure 3). This is in contrast to a typical flange to flange connection of a diaphragm coupling where torque subjects the bolts predominately to shear stresses. The proper tension of the disc coupling bolts not only decreases the bolt bending stress to acceptable levels, but affects the fretting and corrosion fatigue characteristics of the disc surface at the washer interface.

Although disc couplings may be extremely long life couplings, they are not infinite life couplings. The life of identical disc coupling designs in the same application at different sites can vary due to the actual misalignment of the equipment, the preload in the individual bolts, and the specific environmental conditions encountered at each location. Adhering to the manufacturer's recommended bolt tightening torque and minimizing the misalignment will assure the longest service life. Experience with the specific turbomachinery equipment must be considered when establishing maintenance and inspection intervals.

The analysis of the disc life is complicated by the fretting of the discs caused by coupling misalignment. Disc coupling manufacturers typically calculate safety factors using the classical fatigue failure theories such as the modified Goodman Diagram, but do not use a reduction in the disc raw material endurance limit caused by corrosion fatigue, wear, or application of coatings. Published raw material endurance limits are not intended to consider wear with fatigue or the effects of coating. Users should exercise caution when reviewing such data and consider the manufacturer's experience and disc life history for similar applications. Either a reduction of endurance properties or higher safety or service factors may be required. Some manufacturers may require a minimum service or application factor. A fatigue analysis of the bolts should be performed in high torque applications due to the high bending stresses. This will assure that the fatigue analysis is performed on the coupling's component with the lowest safety factor. Following these guidelines will help assure long disc coupling service life in typical high performance turbomachinery.

The Ameriflex diaphragm coupling incorporates life and safety factors that are not present in disc coupling designs. The Ameriflex metallic membranes consist of thin, multiple, convoluted and separated diaphragms. Each of these properties provide a benefit to the overall coupling design. The diaphragm life is not dependent on the operating angle within its design rating.

The standard Ameriflex diaphragm material is 15-5 PH in condition H1025. Testing has shown that 15-5 PH age

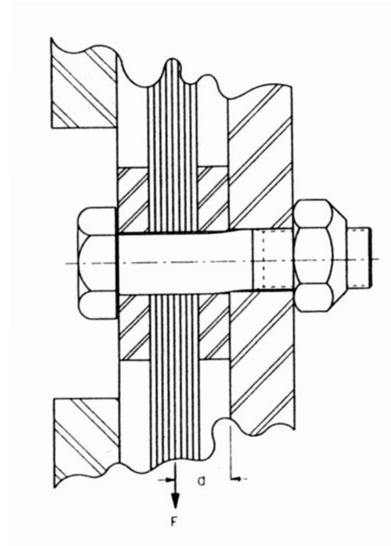

Figure 3

hardened to H1025 is highly resistant to stress corrosion cracking, even at sustained stress levels much greater than Ameriflex diaphragm stresses. In addition, all Ameriflex diaphragms are individually shot peened. Shot peening provides a surface layer of compressive stress on both sides of every diaphragm. Stress corrosion cracking can not occur in an area of compressive stress.

The flex area is separated at the inside and outside diameters (Figure 2) and then rigidly clamped. This separation prevents fretting corrosion from angular and axial misalignment usually associated with the rubbing of the flexing areas of multiple membrane couplings. Since there is no fretting, the designer can legitimately use classical infinite life engineering fatigue analysis for the diaphragm design utilizing the raw material properties. No reduction in the diaphragm material endurance limit or decreased reliability is caused by fretting corrosion or wear of the flex area. In fact, no credit is taken for the added benefit of each diaphragm being individually shot peened. Using the appropriate stresses confirmed by finite element analysis and strain gage testing. Ameridrives can accurately calculate safety factors using any of the fatigue failure theories such as Goodman, modified Goodman, or Constant Life. The Ameriflex coupling is a true infinite life design with diaphragm packs operating in excess of twenty years. In operation this translates into predictable equipment maintenance and inspection intervals regardless of the angular and axial misalignment within the coupling's design rating, environmental conditions and the length of service.

In the event of failure, a disc coupling and a

Figure 4

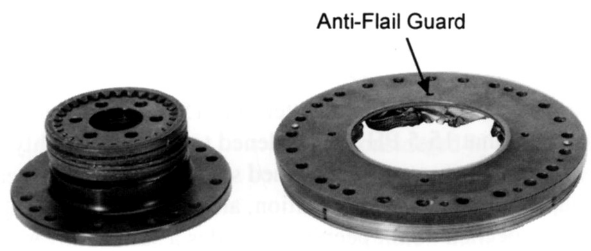

Figure 5

diaphragm coupling affect the system differently. If a failure was to occur in a disc coupling either in fatigue by fretting corrosion or ultimate failure due to a peak torque overload, the driving flange bolts will continue to load the driven flange bolts and drive the equipment. The flailing and high bending loads that occur in this condition may cause significant damage to the adjoining equipment and high vibrations. Adequate vibration monitoring, plus typical overspeed trip devices are critical to prevent further damage to the connected equipment.

Conversely, if an Ameriflex diaphragm coupling was subjected to excessive misalignment which was to initiate a fatigue failure, the crack will propagate gradually due to the separation of the diaphragm flex areas. Eventually, as each diaphragm fails, the remaining diaphragms will shear at their inside diameter due to excessive torque. Most importantly, regardless of the cause of failure, by fatigue or ultimate failure, the diaphragm inside diameter will shear from the spacer or spool preventing the transfer of power from the driving to driven equipment (Figure 4).

The instantaneous loss of load will result in standard turbomachinery overspeed trip. After shear failure, the Ameriflex coupling's anti-flail guards contain the center section for safety and protect the adjoining equipment (Figure 5).

In summary, a disc coupling's service life is finite and significantly effected by the equipment's misalignment, disc configuration, disc coatings, bolt preload and environmental conditions. These factors should be considered in the coupling selection. If a failure was to occur in a disc coupling, more damage may occur to the driven equipment since the bolts will continue to drive the equipment.

The Ameridrives Ameriflex diaphragm is a true infinite life design where the high strength precipitation hardened stainless steel, multiple, convoluted diaphragm flex areas are separated to prevent corrosion fatigue or fretting corrosion. No reduction or change in life occurs up to the maximum ratings of the coupling. The diaphragm material properties such as endurance strength are not compromised by wear, fretting corrosion or coatings. The Ameriflex diaphragms have a built in fail-safe feature of redundancy with separated diaphragms. If a failure occurs, power is no longer supplied to the driven equipment since the diaphragms will completely shear at their inner diameter. This results in an overspeed trip. Finally, the anti-flail capability contains the center section which decreases potential damage to adjoining equipment. These Ameriflex features combined provide a level of reliability and safety unique to other metallic membrane couplings.

Ameridrives® Couplings
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