IDENTIFYING DISC COUPLING FAILURES

COUPLING FUNDAMENTALS

While couplings are designed for infinite life, they must be operated within their intended design limits in order to achieve optimal performance. Due to installation issues and unforeseen events, a coupling may be subjected to loading greater than its rated capacity while in service. These issues can typically be identified through instrumentation or visual inspection, but not all coupling failures can be prevented.

The modified Goodman diagram is created by modeling the theoretical mean and alternating stresses the coupling is subjected to at its maximum allowable ratings. The majority of disc couplings are operated within their recommended range, which has cultivated their reputation of reliability and safety. When a coupling is subjected to a torque and/or misalignment exceeding its rating, the stresses typically cannot be quantified accurately, making it impossible to accurately determine its remaining service life.

Disc couplings are typically passive components compared to the other drivetrain equipment. They do not input any power or provide a process output, but simply connect the driving and driven equipment. The coupling may act as a “litmus test” and provide an early warning to a more significant problem, if the equipment experiences an issue. By understanding and identifying coupling failures, they can be prevented in the future resulting in the increased uptime of your equipment.

MISALIGNMENT

There are a number of reasons why a coupling will operate in a misaligned condition. A few of the most common include:

- Installation & Human Errors
- Thermal Growth
- Worn Bearings
- Dynamic Twist of Skid
- Settling Bases / Foundations
- Pipe strain

The axial alignment, or correct spacing between the flanges, ensures the coupling is being operated in a neutral position rather than under tension or compression. High performance couplings are typically provided with axial thermal growth values, which take into account the thermal expansion of the equipment, allowing the coupling to be installed in a pre-stretched condition. Disc couplings are designed to accommodate this axial misalignment, but incorrect axial alignment or thermal growth values may impart an additional mean stress on the coupling or the equipment, adversely affecting performance.

Key Points

- Disc couplings are designed for infinite life when operated within their recommended limits.
- The primary failure modes of disc couplings are due to excessive misalignment and torque overload.
- The failure mode can be identified through inspection of the disc pack. Future failures may be prevented through the inspection and identification of the root cause.
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Prior to installation, the distance between the coupling flanges and the length of the coupling center section should be measured at four locations at 90° and averaged. Per API 671, Kop-Flex® High Performance couplings are provided with shims in order to adjust the gap between flanges without requiring the equipment to be moved. The equation for determining the proper amount of shim can be seen expressed below where Calculated Separation is defined as the center section length plus thermal growth (Image 1).

\[ \text{Shim Adjust} = \text{Measured Separation} - \text{Calculated Separation} \]

The maximum continuous axial misalignment rating of the coupling is determined from the geometry of the disc pack and listed on the coupling drawing. For optimal service life, it is recommended that the coupling be shimmed and installed to operate within 10% of the maximum axial alignment rating of the coupling.

The angular and parallel offset misalignment rating of a typical disc coupling is specified in degrees per flex half. While a single flex disc coupling can only accommodate angular misalignment, a disc coupling with two flex halves accommodates a combination of both angular (\(\alpha\)) and offset (S) misalignment as seen in Image 2.

The maximum recommended operating misalignment for Kop-Flex couplings is 0.10° per disc pack. This limit is specified “per flex half” because while the angle due to offset misalignment is shared between the disc packs at either end, angular misalignment (\(\alpha\)) results in an additional deflection on one side. While equipment tolerances are typically tighter than the rated coupling misalignment capacity, it can be helpful to determine if the coupling was installed within its designed operating range. It is also recommended that a hot check be performed to confirm the accuracy of the thermal growth offset values.

Typical alignment techniques will report the horizontal and vertical alignment data in either face and rim runout (dial indicator) or angle in/in and offset (laser alignment). In order to determine if the installation is acceptable, trigonometry can be used to calculate the effective angle experienced by the coupling. The total acceptable angle is a combination of both the angular and offset misalignments. The simplified equation is expressed as:

\[ \alpha_{\text{rated}} > \alpha + \tan^{-1}\left(\frac{S}{L}\right) \]

The distance between flex element of the coupling (L) plays a significant role in the determination of the angle. For a smaller (L) dimension due to a close coupled design or shorter DBSE (Distance Between Shaft Ends), the same offset (S) will result in a larger angle when compared to an installation with a longer DBSE (Image 4). Therefore, it is important to set up the alignment device to reflect the equipment being aligned.
When a disc coupling is subjected to angular misalignment, the highest stresses will be found in the outermost discs near the disc pack bolt hole (Image 4). This is the location of the highest bending stresses and therefore where disc couplings typically fail from cyclic fatigue due to high misalignment. Fretting, which can be mitigated by the use of a low friction coating on the discs, may also be present at the failure location due to movement between the discs.

The failure of a disc coupling due to axial misalignment will show similar signs as angular misalignment. The discs may crack on both sides of the disc pack bolt hole, since the coupling is in compression or tension (Image 5).

TORQUE
The torque capacity of the coupling is typically determined during the design and selection phase. Since this is generally a well understood quantity, torque related failures frequently coincide with an atypical event, such as the ingestion of a liquid slug in a compressor or due to a hot shut down following an equipment trip. Torque related failures typically exhibit severe spreading or buckling of the disc pack and may result in the deformation of the flanges due to contact from the disc pack hardware (Image 6).

Failures due to torsional fatigue are becoming more common due to the increased use of variable frequency controlled drives on motors which can excite damaging resonant frequencies. Additionally, synchronous motor driven trains may experience high torsional oscillations during startups, so equipment that is subject to frequent startups is at higher risk. Torsional oscillations act as an additional alternating stress on the disc packs, which will typically fail at highly fretted locations in the center of the link between the disc pack (see Image 7).

CONCLUSION
While designed for infinite life, the issues discussed above influence the effective service life of the coupling. The difficulty in quantifying stresses, either due to shifting equipment or transient torque spikes make it difficult to predict a coupling’s remaining service life. Although technological advances in condition monitoring have decreased unanticipated failures, they may occur without warning or so rapidly that the equipment cannot be shut down in time. Knowing why a coupling fails is the first step to preventing it from occurring again in the future.
### Identifying Disc Coupling Failures

**Coupling Fundamentals**

<table>
<thead>
<tr>
<th>Type of Failure</th>
<th>Symptoms</th>
<th>Typical Causes</th>
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| **Angular Misalignment** | - Fracture near bolt hole  
- Fretting at fracture location  
- Fracture may occur through bolt hole | - Thermal movements  
- Foundation settling  
- Pipe strain  
- Loose anchor bolt/studs  
- Poor initial alignment |
| **Axial Misalignment**   | - Fracture near bolt hole  
- May occur on both sides of bolt hole | - Incorrect thermal growth  
- Equipment not on mag. center  
- Incorrect magnetic center  
- Poor initial alignment |
| **Torque Overload**      | - Buckling of disc pack  
- Severe spreading  
- Spreading in consecutive links  
- Disc pack bolts may contact clearance holes | - Electrical fault  
- Liquid slug in compressor  
- High start up torque  
- Operation/process event |
| **Torsional Oscillation**| - Fracture in center of disc link  
- Fretting at clamping area and in the center of the link | - Oscillations from VFD  
- Torsional issue  
- Frequent startup on sync motor applications |
APPLICATION CONSIDERATIONS

The proper selection and application of power transmission products and components, including the related area of product safety, is the responsibility of the customer. Operating and performance requirements and potential associated issues will vary appreciably depending upon the use and application of such products and components. The scope of the technical and application information included in this publication is necessarily limited. Unusual operating environments and conditions, lubrication requirements, loading supports, and other factors can materially affect the application and operating results of the products and components and the customer should carefully review its requirements. Any technical advice or review furnished by Regal Beloit America, Inc. and/or its affiliates (“Regal”) with respect to the use of products and components is given in good faith and without charge, and Regal assumes no obligation or liability for the advice given, or results obtained, all such advice and review being given and accepted at customer’s risk.

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