Avoiding Coupling Failure - Considerations in Design Selection

Introduction:

Mechanical couplings have a principal use in the connection of rotating shafts for the transfer of rotary motion and torque. As with all mechanical devices, a coupling must match its' intended purpose and application parameters, including many different performance, environmental, use and service factors. All must be satisfied for the coupling to work properly. When selected with these design parameters in mind, and when installed and operating correctly, a coupling should have no failure issues over it's' lifetime. However, when one or more of these is not met a coupling can prematurely fail, resulting in either a small inconvenience or possibly serious financial loss or personal injury. This article provides a view of the primary reasons couplings fail, and the steps that can be taken to minimize the risk of failure.

Typical Errors in Selecting Couplings:

- Selecting the coupling too late in the design process:

  Far too often motion control couplings are selected exceedingly late in the application design process and without meeting the complex requirements of the system. Couplings are a critical component in determining and achieving overall system performance. Early selection will reduce errors along with the potential for premature coupling failure.

- Selecting the wrong type of coupling for the application:

  Coupling selection involves a number of design criteria including: application, torque, misalignment, stiffness, inertia, RPM, shaft mounting, environmental factors, space limitations, service factors, cost and others. All criteria must be considered and addressed in the selection process to ensure that the coupling will work properly without premature failure. This is important both in the initial coupling selection and if conditions change in the application over time.

- Selecting the wrong coupling for the application misalignment conditions:

  To avoid premature coupling failure it is critically important in design selection to match the correct coupling to the misalignment condition or combination of conditions present. Shaft misalignment may be angular, parallel or axial, with further complications when any combination of these occurs (complex misalignment). Flexible couplings are typically designed to compensate for specific application misalignment conditions. An oldham coupling is well suited for handling relatively large amounts of parallel misalignment with low capability to compensate for angular misalignment and axial motion. A single beam coupling, in contrast, easily accommodates angular misalignment and axial motion with a lower capability to compensate for parallel misalignment.

- Failing to correct excessive misalignment:

  Excessive misalignment between joined shafts is one of the most common reasons for coupling failure due to the creation of loads that surpass the coupling specifications. All flexible shaft couplings are designed to allow for misalignment of one or more types and to varying degrees of flex. Understanding the allowable flex for the coupling under consideration is paramount.

  In addition to possible premature coupling failure, keep in mind that any coupling that is designed to bend during misalignment will produce bearing loads. Misalignment beyond coupling specifications introduces the possibility of accelerated wear and the potential for premature failure in other system components such as bearings. When misalignment exists beyond the specifications of the coupling manufacturer it should first be rectified with shaft realignment, followed by the appropriate coupling selection.

- Selecting the wrong coupling for the torque in the application:

  Couplings are frequently under specified when careful consideration is not given to torque in the application. Design selection must take into account not only the steady state torque but also the maximum instantaneous torque, particularly when torque varies as is in starts and stops. In some cases it might be appropriate to also consider a degree of torsional compliance to dampen torque shock loads and peaks.

  Flexible couplings have different static torque ratings depending on the design type. For example, in looking at a specific coupling choice where all other application design factors are within the ratings of two alternatives, a double disc coupling will typically offer a 15-20% higher static torque rating over an identically sized oldham coupling with an acetal disc.

- Consideration for windup:

  All couplings have windup, also known as torsional compliance or torsional rigidity. Windup is the rotational deflection between the driver (e.g. motor) and the load. Think of it as winding up the coupling like a spring. The most significant problem with windup in a servo application is maintaining accuracy of location due to a difference in angular displacement from one end of the coupling to the other. Windup may also introduce resonance in the system and cause the servo to become unstable if improperly tuned.

- Consideration for backlash:

  Backlash refers to play in couplings and is essentially motion that is lost. The effect of backlash is an interruption or uncoupling in the transfer of power between the driver (e.g.: motor) and the load. Backlash is not acceptable in motion control applications, the most significant consequences being lack of control in positioning accuracy and difficulty in tuning the system. In a motion-centric application such as a servo, backlash introduces timing problems that can cause the coupling to be excessively moved forward and backward, introducing stress that can lead to premature failure. For these reasons zero-backlash couplings are ideally suited to servo applications.

- Selecting a coupling with the wrong amount of shock absorption and dampening:

  In a mechanical power transmission application dampening refers to minimizing the transfer of shock and vibration. Dampening is particularly important in motion control and power transmission applications to reduce undesirable vibration which wastes energy and creates harmful stresses on system components. Shock dampening helps reduce the effects of impulse loads, minimizing shock to the motor and other sensitive equipment. Couplings must not contribute to system vibration and may be selected based on the dampening effects desired.

  One type of coupling that dampens well is the zero backlash jaw coupling comprised of an elastomeric "spider" and two hubs. The spider, available in multiple durometers, provides the desired application dampening and can be selected based on the magnitude of the impulse load. The potential for premature coupling failure can be accelerated when the selection of either the overall coupling type or the spider material are incorrect.

- Consideration for inertia:

  Inertia is a body's resistance to change in angular velocity and governs the tendency of the coupling to remain at a constant speed in response to applied external forces (e.g.: torque). In a power transmission system, inertia is determined by mass and distribution about the axis, a factor determining drive torque specification. Selection of a coupling for a servo drive system where couplings start and stop intermittently requires consideration of inertia, in addition to zero backlash and torsional stiffness. Selection also requires an understanding of the driven-system inertia values and their affect on the coupling.

Too much coupling inertia for a given application can seriously degrade the performance of the entire system by introducing resonance and adding to the natural frequency of the system, with possible unintended consequences. A low inertia coupling can allow the system to be tuned to a higher performance level and is a very good choice for precision applications.

- Selecting the wrong coupling for the application shaft speed:

  Application speed is another very important factor in selection. When a coupling's safe operating speed is not addressed in the design criteria it can quickly result in failure, sometimes with tragic consequences. In high speed applications the use of a balanced coupling is essential. It is also important that consideration be given to coupling stiffness since speed also causes deflection.

  Pay particular attention to the manufacturer ratings for speed, never adversely alter the dynamic balance of a coupling before or after installation, and remember that any shaft misalignment can significantly affect a coupling's safe operating speed.

- Selecting the wrong coupling for electrical isolation:

  Electrical isolation is the principle of separating functional components of mechanical systems to prevent the movement of currents while mechanical energy transfer is still maintained. Extraneous electrical currents can be a serious problem in the control of servo systems when passed between drive and driven components. Oldham and jaw couplings are electrically isolating when nonmetallic and polymer inserts are utilized. Other coupling types can also be manufactured in electrically isolating materials.

- Selecting a fuse coupling instead of a fail-safe coupling, or vice-versa:

  A fuse coupling disallows energy transfer upon failure while a fail-safe coupling is designed to stay engaged. Some applications require a fail-safe coupling to protect personnel or equipment. For example, one might use a fail-safe coupling in a material handling application where an interruption in the flow of material might introduce a safety or process issue if the coupling were to fail.

  Jaw couplings are considered fail-safe because, even if the spider fails, the jaws of the two hubs interlock, allowing continued power transmission. In contrast, an oldham coupling with a similar failure mode of it's' center disc will disengage and not allow continued power transmission. Each has its merits depending on the application, operator safety or other factors.

Examples of Coupling Selection for Common Motion Control Problems:

Any recommendation for resolving a motion control or power transmission problem requires a thorough understanding of the application and system design factors, as well as the nature of the problem itself. That said, below are examples of a few reported problems and alternatives to consider.

Example Application Problem	Consider This*
A bellows coupling was incorrectly chosen for an application requiring dampening and shock absorbing capabilities. The bellows coupling failed soon after installation.	Consider a jaw type coupling for applications requiring dampening and shock absorption.
A small stepper motor was installed using a large diameter steel rigid coupling. The performance is sluggish and the positioning accuracy is now difficult to control because the heavy coupling adds too much inertia to the system.	Consider a lighter, appropriately sized aluminium coupling to reduce the mass of the coupling, and hence the inertia it may be adding.

Example Application Problem	Consider This*
A packaging machine cannot be kept in close parallel alignment and the two shafts are transferring excessive forces to other system components. The shafts are connected with a rigid coupling and the motor and gearbox bearings are damaged before the coupling breaks. It is very costly to replace the motor and gearbox, and production time is lost.	Consider an oldham design for handling the parallel misalignment in the shafts. This coupling also produces low bearing loads and acts as a mechanical fuse. A rigid coupling can cause premature bearing failures if used in an application with misalignment.
A machine utilizing a beam coupling is having problems because the encoder feedback system is receiving electrical impulses from other components in the machine. These impulses affect the accuracy of the encoder, resulting in process errors.	Consider an electrically isolating coupling that will protect the encoder from receiving electrical impulses from other parts of the machine.
A curved jaw coupling was selected for an application requiring high torsional stiffness for accuracy. The system is not performing as accurately as it should.	Consider either a bellows or disc coupling with higher torsional stiffness.
A high-speed application has the correctly selected coupling yet has had two successive coupling failures. The coupling manufacturer has assisted the customer in analysis and has found fatigue to be a factor in each instance of failure.	Further research determined that significant dynamic misalignment existed in the application, exposing the coupling to very high levels of stress and forcing it to operate well beyond its specifications. The customer needs to identify the sources of the misalignment and find ways to reduce it, or choose an alternative coupling better suited for the application.

* "Consider This" is based on limited information. All system and application design factors must be considered before making a final or alternative selection.

Minimize the Possibility of Coupling Failure – Ask Questions:

- Does the application require high torsional stiffness?
- What are the accuracy requirements?
- Does the application require dampening or shock absorption?
- How much misalignment is present in the design? Is it angular? Parallel? Axial? Complex?
- Does the coupling need to be the break-first point in the system? Does it need to be fail-safe?
- Is electrical isolation a requirement?
- What is the maximum torque applied to the coupling?
- At what speed or speeds will the coupling be operating?
- In what temperature will the coupling operate?
- Are there other environmental factors for the application (e.g.: chemicals, wash down, vacuum)?

The Importance of Proper Coupling Installation

You can prepare the most elaborate meal imaginable yet failing to serve it properly will send your guests home disgruntled. The best design effort and attention when selecting a shaft coupling is essentially meaningless if the coupling is installed improperly or if the actual application parameters are outside of original design criteria. Far too many times a coupling is installed hastily or without regard for the manufacturer specifications, leading to premature failure. Follow coupling installation instructions to the letter as this is where common mistakes typically occur.

Basic coupling installation instructions might include:

- Prepare the coupling and shafts prior to installation; clean mating parts; oil shafts lightly.
- Check to ensure that any misalignment between the shafts is within the coupling's ratings.
- Follow all instructions for fasteners, specifically the tightening sequence and torque requirements.
- Don’t install the coupling too far left or right of the center line. Center any misalignment along the length of the coupling.
- Don’t install shafts too deep or too shallow in the hubs for the specific coupling in use. Some couplings require a minimum gap between shafts. In most cases the shaft depth within the hub is specified by the manufacturer based on the coupling design.
- Don’t introduce additional stress on the coupling by compressing or stretching it upon installation. Couplings must always be installed in their free-state.

These basic guidelines are intended to reinforce the importance of proper coupling installation, thus reducing the possibility of premature failure. Always refer to the specific manufacturers instructions when performing a coupling installation.

The Importance of Proper System Maintenance

Motion control couplings are, with specific exceptions, essentially maintenance free. The matter of regular and diligent “system” maintenance is important, however, for the entire system in which the coupling is an integral component. System maintenance requirements and schedules are generally a function of the specific application, duty cycles, operating parameters, environment and other factors. Any maintenance or service plan for the system as a whole is intended to avoid component failure anywhere within the system, including shafts, couplings, motors, bearings, etc. The coupling may be adversely affected if other component operating characteristics force operation outside of design specifications.

Basic system maintenance requirements might include:

- Check for abnormal operating characteristics such as unusual noise or excessive system component temperatures.
- Check for excessive vibration or other indicators of a change in alignment within the system.
- Check for any signs of wear or looseness in fasteners; re-torque where necessary.
- When using an oldham coupling or jaw type coupling, consideration should be given to the duty-cycle of the center disc or spider. Wear on this component may result in backlash, thus introducing system performance issues. Replace center discs and spiders with the vendor specified part and material when the duty cycle has been exceeded or when excessive wear is noted. The discs are low-cost items, easily replaced, and will restore the coupling’s original capabilities.
- In the event a coupling fails it is important to determine and document the conditions within the system in which the failure occurred. This will allow for appropriate corrective action, including specification of a different coupling to address any changes in the application.

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Summary

The keys to avoiding coupling failure are correct coupling selection utilizing all application design criteria, proper Installation and periodic system maintenance. Consider all of the application requirements early in design as this will reduce the risk of selecting the wrong type of coupling. Install the coupling properly, verifying that design considerations were correct. For example, is there a greater degree of misalignment than originally specified? Last, regularly maintain the system to ensure that design parameters have been consistently maintained and that no wear, contamination or other detrimental factors have been introduced to any system components. If a problem does arise after the application is in operation gather and document all possible details. This will uncover the problem and a corrective solution can be implemented.

Pictures:

Picture# DSCN1285

This beam coupling has failed near the center and represents what may occur in a torque overload condition. A torque in excess of the coupling design limits was applied to illustrate this example. Beam coupling failure may also occur in applications with parallel misalignment because the single beam must bend in two different directions simultaneously, creating larger stresses in the coupling that could cause premature failure.

Picture # DSCN1277

This bellows coupling has failed in a deep convolution closer to one hub than the other and represents what may occur in a misalignment situation. This type of failure can occur with an excessive degree of misalignment exceeding coupling design limits, or when the coupling is improperly installed and the misalignment (again within specifications) is not uniformly distributed across the bellows.

Picture # DSCN1284

This oldham coupling has experienced a failure in the center disc and represents what may occur in a torque overload condition. A torque in excess of the coupling design limits was applied to illustrate this example.