HIGH SPEED COUPLING FAILURE ANALYSIS

by

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ABSTRACT

This paper deals with the design functions and case histories of gear couplings. A brief discussion of the various basic design features of gear couplings and their lubrication systems is presented. This is followed by various case histories and the probable cause of their failures. The diagnostic analysis may help the reader reduce or recognize his own coupling problems.

INTRODUCTION

Thousands of high speed couplings are in service all over the world. More recently, the trend to upgrade older applications and demand higher horsepower on new turbo-machinery brings the coupling of the power train into sharper focus. This report is a concise discussion of actual gear coupling experiences within the past ten years. A few case histories which most graphically depict the failures have been chosen.

In the analysis of high speed coupling failure it is necessary first to understand the design and functional limitations of the coupling and, secondly, to be familiar with the connected equipment.

DESIGN CRITERIA

Flexible Couplings

To better understand the design and functional limitations of the coupling a thorough understanding of the basics is desired. The following are the three major functions performed by a flexible coupling:

1. Efficiently transmit mechanical power from one shaft to another, directly and with constant velocity.
2. Compensate for all types of misalignment between the two shafts without inducing abnormal stresses and leads on connected equipment and without tangible loss of power.
3. Allow axial float or movement of shafts, preventing either shaft from exerting excessive thrust on the other and allowing each to rotate in its normal position.

Misalignment

The various types of misalignment which may be encountered by such a coupling are:

1. Parallel offset — Here the axes of connected shafts are parallel, but not in the same straight line.
2. Angular misalignment — In this case the axes of the shaft intersect at the center point of the coupling but not in the same straight line.
3. Combined angular and offset misalignment — For this case the axes of the shafts do not intersect at the point of coupling and are not parallel.

Lubrication

There are two major types of lubrication techniques employed in the design of gear couplings. The continuous lubrication technique utilizes an oil spray from the nozzles into the coupling gear teeth. This is usually turbine oil. Continuous lubrication systems usually employ either a partial or complete oil retaining dam. In all cases the oil is recirculated back through the machine lubrication system. The major advantages of this type of system is that it helps dissipate heat generated in the coupling thus maintaining a relatively constant temperature. It also eliminates the necessity of sealing the coupling and in some cases may also eliminate seals in connected equipment. The disadvantages of such a system is the oil piping and the sealing of the coupling guard or cover. Other disadvantages are the centrifuging of contaminants into the gear teeth, thus requiring an adequate filtering of the turbine oil. This system disallows the use of a lubricant tailored specifically for gearing since the lubricant is common to other elements in the compressor and/or turbine.

The batch, packed, or sealed lubrication system is used where a recommended grease or oil is sealed in the coupling and is changed as necessary or during scheduled shut down. It's major advantages are that the lubrication used is the best available for the application and that the lubrication does not get very contaminated. The system also does not require oil piping and the sealing of the coupling guard. It's disadvantages are that it requires sealed of connected equipment, there
seals tend to wear and deteriorate with age. Improper selection of lubricants may cause the loss of lubricity due to a centrifuge effect. High temperatures may also cause a loss in lubricity.

Fasteners

Fastening fasteners are special precision components and should be treated as such. These fasteners require special heat treating to be able to withstand the large forces they experience in high speed coupling applications. The quality control and inspection of these fasteners must be very exacting in nature. Figure 1 shows various fasteners used in high speed couplings. Three ordinary bolts which should not be used as fasteners are also included so that the reader may note the difference.

Installation of fasteners should be done using a torque wrench. After four to six disassemblies they should be replaced with new weight matched sets. If these bolts are not replaced, the nut may bottom out on the threads before the coupling flanges are tight. This would cause the coupling to transmit the torque through the bolts rather than through the flange faces and thus may cause the bolts to fail in shear. Bolt shear or bolt hole elongation may result in a major coupling failure.

Diagnosis

To properly diagnose the problem, the cause and effect must be well understood. Table 1 shows some of the problems and their probable effects on the gear coupling. Table 2 shows the most common failures encountered in the field.

CASE HISTORIES

To better understand the failures mentioned in the text, an examination of various case histories is required. Figures 2 and 3 show the cracking of the teeth on the same coupling. The probable cause of this was excessive misalignment. Figure 4 shows a coupling whose hub is broken and keys sheared. The probable causes of this failure is too much of a shrink on the shaft, the bore too large for coupling size thus exceeding the bursting stress, and the lack of a radius on the Keyway causing high stresses at the corner of the keyways. Another probable cause may have been the upgrading of the system thus causing an overloading of the original coupling design.

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<tr>
<th>TABLE 1</th>
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<td>Diagnistic Analysis of Gear Couplings</td>
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<td><strong>PROBLEM</strong></td>
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<td>2. Low oil viscosity</td>
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<td>5. High ambient temperature</td>
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<td>6. High misalignment angle</td>
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<th>TABLE 2</th>
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<tr>
<td>Types of Typical Gear Coupling Failures</td>
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<td><strong>CONTINUOUS LUBE</strong></td>
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<td>1. Wear</td>
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<td>2. Corrosive wear</td>
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<td>5. Worm tracking</td>
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Figures 5, 6, 7 and 8 show a gear coupling, utilizing a packed lubrication system, which locked up causing worn and broken teeth. The probable cause of this failure could be attributed to a wrong and/or contaminated lubricant causing a centrifuge action. A system upgrade causing an overloading of the original coupling design and excessive misalignment may also have contributed to its failure. Figures 9, 10 and 11 show a gear coupling, utilizing a continuous lubrication system, which has been worn and fretted at two places on the face and the ends of the teeth. The probable cause of this failure may be attributed to a dirty lubricant, excessive vibration and improper alignment. Another cause may be the improper lapping or polishing of the taper shaft. For example a shaft with 1/2 inch taper per foot if reduced in diameter by 13 thousands of an inch will cause the hub to move 1/32 of an inch up the shaft.

Figures 12, 13, 14 and 15 show an example of the classic "worm tracking" failure of a gear coupling. There are a number of theories as to the cause and/or sources of worm tracking. Several of the references at the end of this paper delve into "worm tracking" very deeply and each coupling manufacturer appears to differ as to cause or source.

Figure 16 shows a coupling with a broken end or seal ring. The probable causes of his failure is too much shaft to shaft spacing along with misalignment.
Figure 9. Worn and fretted teeth of a coupling using a continuous lubrication system.

Figure 10. A top view of worn teeth of a coupling using a continuous lubrication system.

Figure 12. Severe cracks in the teeth of the inner gear due to worm tracking.

Figure 13. A top view of the inner gear showing severe damage due to worm tracking.

Figure 11. Face damage to teeth of a coupling using a continuous lubrication system.

Figure 14. A view of a tooth which has undergone severe damage due to worm tracking.
Figures 15 and 18 show the gauled bores of a geared coupling. This may be due to improper removal methods, i.e., too much pull, insufficient heat, or heat in the wrong place, failure of "O" ring for hydraulic fits, etc. It also could result from tapers or finishes which are not good enough, i.e., 75-90% blue, finish approximately 16-32 micro-inch or better.

Figure 19 shows a discolored bore of a gear coupling. The probable causes for this are: improper stand off, allowing contamination between the shaft and the hub, an improper hydraulic fit or contaminated hydraulic oil used during assembly. Another cause could be an egg shaped bore causing an improper key fit or incorrect key-way machining.

Figure 20 shows a bore gauled due to an excessive interference fit or improper hydraulic hub removal.

The above case histories were chosen since they span a large number of different failures. These case histories should be helpful to the reader in determining his problem.
Figure 20. A close up of a gauled bore in a coupling.

CONCLUSION

By properly understanding and implementing the design criteria and limitations, longer coupling life will be achieved. The case histories described here should be a major help in the diagnostic analysis of coupling failure.

The American Gear Manufacturers Association created a Technical Committee on Flexible Couplings. Their publications are very beneficial and may prove to be a continued source of information for the users library. AGMA coupling standards are available on request. Table 3 is a listing of particular AGMA standards which may be of interest to the reader.

TABLE 3
AGMA Standards

510.02  Nomenclature for Flexible Coupling
512.03  Keyways for Flexible Couplings
511.02  Bore and Keyway for Flexible Couplings
513.01  Taper Bores for Flexible Couplings
514.02  Load classification and Service Factors for Flexible Couplings (Preliminary)
515.01  Balance Classifications for Flexible Coupling

REFERENCES


3. Decker, John L. (Manager-Engineer, Zurn Industries, Erie) "Introduction to Gear Couplings.” Paper presented at ASTM/AGMA Coupling Lubrication Symposium, Atlanta, Georgia (December 11, 1974).

4. Decker, John L. (Manager-Engineer, Zurn Industries, Erie) "Discussion on Keyless Fits.” (November 22, 1974).


