RCFA – High Speed Compressor Motor Bearing Failure
(Summary only – not a complete report)

Purpose:
Determine the root cause(s) of the bearing failure and prevent recurrence by implementing effective solutions.

Equipment:
The bearing failure occurred on a 12,000HP, high-speed adjustable frequency drive, induction motor. The motor serves as the driver for a single-stage, centrifugal, natural gas pipeline compressor at a natural gas compressor station.

The compressor train is installed within an enclosed compressor building that is classified as a Class I, Division II location per NFPA 70 (The National Electrical Code). Based on the electrical area classification, an Emergency Shutdown System (ESD) is installed as a part of the compressor building controls, which requires that all electrical power to the compressor building be de-energized along with isolating and blowing down the compressor case and unit piping. The compressor building ESD system is activated by several conditions including building fire detection.

The motor bearings are forced-lubricated sleeve bearings using AC powered, electric motors to drive the lube oil system pumps with DC powered electric motor driven pumps as auxiliary backup units. Motor bearing lube oil is supplied via an elevated lube oil tank during compressor building ESD's. The tank was designed to provide sufficient oil flow to the bearings for 60 seconds.

Summary of Failure:
The initial reading of the compressor train distributed control system (DCS) indicated that the compressor was running at approximately 6,800 rpm, and the bearing temperatures were reading a steady state value of 138°F. At the same time, the DCS alarm log indicated that an ESD was activated by the building fire detection system.

The DCS event log recorded the unit and blowdown valves operating in response to the ESD activation. Motor bearing temperature readings remained at the steady state 138°F value for approximately 68 seconds, followed by the inboard bearing (coupling end) ramping to 230°F then off scale. The outboard bearing ramped to a final value of approximately 190°F for the remainder of the motor coast down period. Trending the motor speed indicated a coast down from 6,800 to 2,200 rpm over the first 68 seconds, and it ultimately took 5 minutes to come to rest. The bearing was removed, the failure was confirmed, and the damage was consistent with lube oil starvation.

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Because of the cost of unplanned down time and the potential for motor rotor and stator damage, a team of personnel was assembled to perform a root cause failure analysis for the bearing failure. The team consisted of a subject matter expert, an engineer from the compressor train manufacturer as well as a facilitator and operations and maintenance technicians.

The primary effect that was analyzed was the motor bearing failure. A detailed cause and effect chart was developed in order to identify root causes and provide effective solutions to prevent recurrence.

The initial compressor train assessment included a review of the ESD system, the lube oil system, train alignment and the bearing technology. After a review of the compressor train design manual and discussions with the manufacturer it was found that the lube oil rundown system was designed for a 60 second run down time, and the design did not consider compressor train rundown times with the compressor blown down.

Cause and Effect Summary and Root Causes

A summary of the cause and effect chart of the bearing failure is provided by the following sequence of events:

1. Failure to identify correct compressor train rundown conditions during ESD activation.
2. Lube oil starvation was caused by the improperly designed gravity lube oil rundown system.
3. Lube oil starvation led to bearing failure.

Solutions:

Several solutions were considered which include:

1. Relocating the lube oil reservoir and pumps; however, this solution was much too expensive and not as reliable as a gravity system.
2. Modifying ESD protocol, but this is not acceptable due to safety and regulatory concerns.
3. Using pneumatic powered backup lube oil pumps, which introduces additional complexity and reliability concerns.
4. Modifying the gravity fed lube oil rundown system for an 8 to 10 minute rundown.

   This solution was fairly complex and expensive, but provided the most reliable method for eliminating not only repeat occurrences but also, and more importantly, the potential for motor rotor and stator damage due to bearing failures.

Results:

The true root cause of the bearing failure was identified, and a cost effective, reliable solution was implemented to prevent recurrence of this same issue. The finalized system was tested in a simulated manner and found to be an effective solution.

Comments:

Many times RCFA's identify the incorrect root causes because of the wrong problem solving mindset. RCFA's that are conducted without adequate discipline to find the correct root causes often provide solutions that simply cover up the true root causes. In this case, if a disciplined methodology had not been implemented, the ESD or fire detection system may have been incorrectly blamed and possibly modified without solving the real deficiency. Additionally, other non-related issues such as the small coupling misalignment that was discovered may have been incorrectly labeled as the root cause of this failure, leaving the true root cause unidentified.