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INVESTIGATION INTO MAGNETIC DRIVE SEALLESS PUMP FAILURE 3 FLARE GAS RECOVERY UNIT (FGRU)

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ABSTRACT

Failure investigation was conducted on magnetic drive centrifugal sealless pumps that had only been operating for six months and were already struggling to rotate. It was discovered that hydrocarbon sludge and other debris had blocked the lubricating channel, which was meant to provide pathways for cooling and lubricating the pump's inner magnetic and containment shell. Further investigation revealed that service water had contaminated the process fluid, precipitating calcium carbonate upon contact with the amine solution and clogging the flushing line. An additional duplex strainer was installed on the repaired pumps, and adequate precautions were taken to prevent water contamination.

Keywords: *cleanliness, internal flushing, contamination, clogging, duplex strainer*

INTRODUCTION

Conventional centrifugal pumps used to deliver fluid in the process refinery plant are normally susceptible to mechanical seal leak failure, accounting for 43% of pump failure modes [1]. This caused product loss and created environmental issues due to hydrocarbon spillage. Even under normal operation, the pump mechanical seal is subjected to the minimum permitted leakage rate allowed under international standards [2]. In order to completely avoid hydrocarbon leakages that contribute to fugitive emissions into the environment, some refinery plants have switched to using magnetic drive centrifugal pumps or sealless pumps.

In constructing a sealless pump, the process fluid is completely contained within the pump containment shell, preventing product leakage. However, the flushing line uses the process fluid as an internal lubricant and cooling medium to remove the generated heat and provide lubrication. Consequently, any restriction to the lubrication flow paths will jeopardise the pump's internal components and result in catastrophic pump failure as a result of lubricant starvation [2]. Additionally, the fluid runs between the inner magnet, the containment shell and through the shaft holes to the rear of the pump shaft, where it returns to the pump’s suction through the thrust balance hole in the impeller. The magnetic flux circuit between the inner and outer magnet rotates the pump shaft connected to the inner magnet. The outer magnet is coupled to the drive motor through another shaft to transmit the rotation to the inner magnet [3].

While a sealless pump will eliminate leakages, it has very limited solids handling capability. Particles will accumulate in the passages surrounding the magnet and in the close tolerances of bearings, such as between the bush and sleeves. This will hinder the pump's performance, resulting in issues and sometimes even failure. In addition, solids will wear out the bearings and other internal pump components [4].

Under the implementation of Plant Change projects, seven sealless pumps (API685) were installed in one of the Malaysia oil refinery plants in the west coast peninsular. The design of sealless pumps was aimed to prevent hydrocarbon product leaks into the atmosphere, which otherwise would contribute to fugitive emission and, when the product leakage worsens, could escalate to a Health, Safety and Environment (HSE) incident of loss of primary containment. It would also reduce costly periodic pump maintenance due to mechanical seal leaks. However, four of the seven installed pumps experienced significant failure following the project commissioning. One of the pumps installed under the Fuel Gas Recovery System was found hard to rotate after seven days of running, and the standby pump experienced low discharge pressure and performance after five days of running. The process flow and the location of the pumps are depicted in Figure 1.

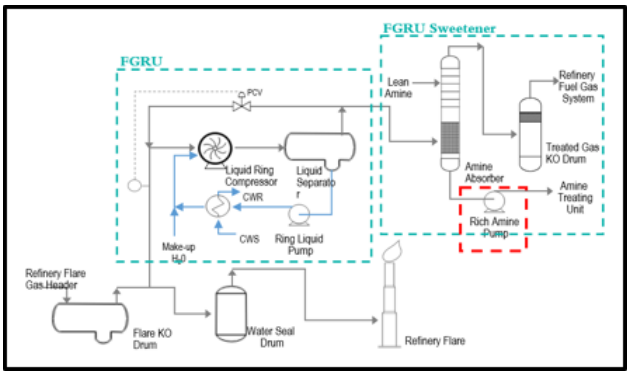

Figure 1 Process flow diagram of Flare Gas Recovery Unit (FGRU)

METHODOLOGY

The magnetic drive pump's internal components were dismantled and examined for the purpose of investigation into the failures. This would give a clear picture of the extent of damage to the internal component of the pumps. Secondly, the pump suction strainers were examined, and the particles collected inside the pump and at the strainer were sent to an outside lab for further examination. The particles would give clear evidence of the sources of the clogging. Thirdly, X-ray diffraction elemental analysis of the particles collected at the strainer was carried out. Similarly, the particle sample test determined the clogged particle's material to ascertain the particles' origin. In conclusion, the 5-Why method was used to conduct a Root Cause Analysis (RCA) to identify the failure's underlying causes and offer suggestions for preventing another one of its kind.

RESULT AND DISCUSSION

The investigation found that the internal flushing or internal lubrication flow line was clogged with process solid particles. This caused lubricant starvation and loss of cooling to the pump's internal parts. The absence of lubrication had increased friction which caused the mating surfaces to seize. The pump containment shell showed external burnt marks and rubbing, and the bushings were found damaged. In fact, it was supported by the temperature records on the containment shell, which displayed an increase of normal temperature of 60°C to a high of 103°C. Figure 2 shows the extent of damage to the pump's internal parts.

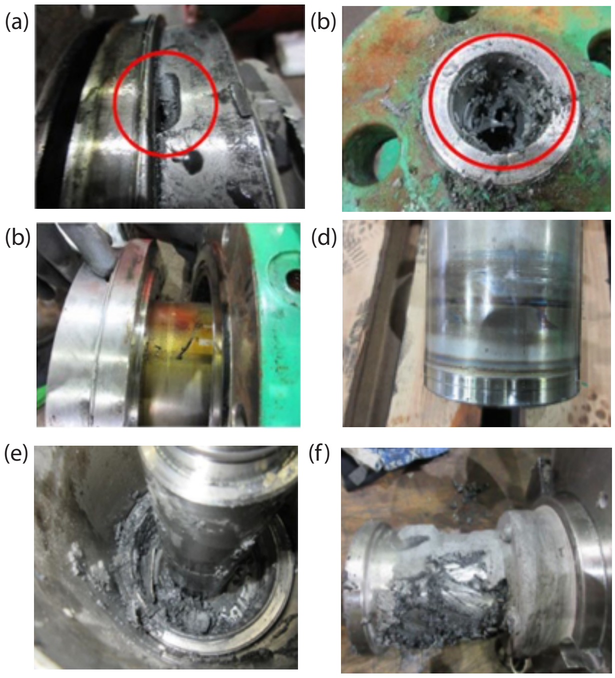

Figure 2 (a) Clogged flushing line (b) Process particles (c),(d) Burn mark on containment shell (e),(f) bushing damages

The damage was enhanced with the expanded Outer Magnetic Ring (OMR). The bearing housing could not be removed because the OMR expanded and seized with the bearing expanded & seized with bearing housing and shell containment. Figure 3 shows the expanded OMR.

Figure 3 Expanded Outer Magnetic Ring (OMR)

In addition, further analysis of the filtered particles found a few types of particles that caused the clogging of the flush line. Figures 4a and 4b shows images of particles collected at the pump's strainer. The debris consisted of moist dark and light brownish lumps and had an alkaline pH of 9.5. It contained mainly carbon, oxygen, sulphur and calcium, with other elements such as aluminium, manganese, iron and strontium. The compounds detected contained mainly calcium carbonate (aragonite) with a small amount of calcium carbonate (calcite), iron sulphate hydrate (rozenite) and iron oxide (maghemite).

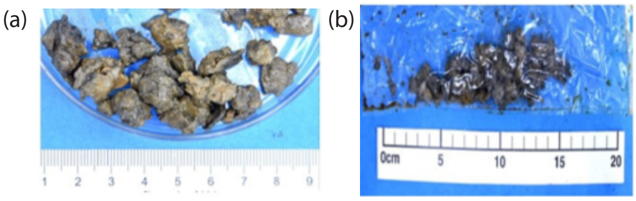

Figure 4 Particles collected at the pump internal and filter

Table 1 X-Ray Diffraction (XRD) analysis result of the particles, approximate element content (wt%)

Element	Wt%
C	32.71
O	35.11
Al	0.10
S	6.04
Ca	23.99
Mn	0.29
Ge	0.36
Sr	1.40

Based on X-Ray Diffraction analysis, as shown in Table 1, the deposited solid particle found at the damaged sealless pump was rich in calcium carbonate. The process theory at the upstream FGRU Amine Absorber demonstrated the governing bicarbonate reaction for tertiary amines (MDEA) on the CO_2 absorption reaction:

$$C0_2+H_20+(HOCHCH_3)_2NCH_3 \leftrightarrow (HOCHCH_3)_2N(CH_3) H^+ + HCO^- \ldots\ldots(1)$$

The solvent lean amine (MDEA) within the operating pH range of 10 – 11 further dissociated and converted the bicarbonate ion to carbonate ion.

$$HCO_3^- \leftrightarrow H_2 + CO_3^{2-} \ldots\ldots(2)$$

The origin of calcium ions could only be identified in the service water stream from the upstream process. In this case, the stream acted as a liquid ring at the upstream Liquid Ring Compressor and make-up water at 3-Phase Separator Vessel. It was found that the 3-Phase Separator Vessel level had reached a high level (100%), consequently showing high-level build-up (91%) at the downstream Amine column. This indicated a high potential for service water-carryover to the Amine Column. The liquid in the column was then pumped by the two FGRU mentioned above, Rich Amine Pumps, with one pump operating continuously and one on standby. Therefore, by examining these facts, the contamination of the water that resulted in the calcium carbonate-rich solid particle generation that clogged the magnetic drive pump's flushing and cooling line might have been the true cause of the failures.

CONCLUSION

Although sealless pumps are the way to prevent mechanical seal leaks and lower emissions of greenhouse gases (GHGs) into the environment, they have some drawbacks. The following lessons learned should be considered when selecting a sealless pump for the refinery hydrocarbon application during the project design phase to prevent similar failures in the future. The selection of a sealless pump should only be considered for clean processes and liquid services, such as exporting the final HC product and the base oil plant. During the design stages, the pump datasheet must specify the size and concentration of allowed solid particles in the pumping liquid. To ascertain the solid's size and concentration, a sample of the process liquid must be taken and analysed at a defined interval. The sealless pump should be designed to accommodate a duplex filter for the internal flush system to reduce the risk of particle contamination further. Additionally, a differential pressure gauge or indicator must be designed and installed across the duplex filter for routine field operator monitoring. The operator will be notified when particles begin to build up inside the duplex strainer due to this increase in differential pressure. A temperature sensor must be installed in the pump isolation or containment shell for high alarm and high-high trip protection. The pump will trip whenever the temperature exceeds the normal range, preventing further damage. After the investigation and major pump repair were finished, these suggestions were incorporated and implemented in the Fuel Gas Recovery system. The pumps have normally been operating thus far, with neither a single nor any failures recorded.

REFERENCES

[1] P.B. Heinz and R.B. Allan, "Pump User's Handbook: Life Extension," *3rd Edition*, 2010.

[2] American Petroleum Institute (API) Standard 682, "Pumps – Shaft Sealing Systems for Centrifugal and Rotary Pumps, 2014.

[3] F.A. Dossary and D.A. Dossary, "Case Study: Sealless Caustic Circulation Pump Failure", *Pump & System*, 2022.

[4] O. Zimmermann, "Common Causes for Magnetic Drive Centrifugal Pump Failure", *March Pumps, 2020*. [Online] Available: https://www.marchpump.com/blog/mag-drive-pump-failure-common-causes/