Mechanical Seal Failure in the oil flooded compressor
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Introduction

We consistently experienced mechanical seal failure of the oil-flooded screw compressor in the refrigeration system. The first seal failure happened on July, 2015, which is a year passed since start-up. This seal failure was repeated 4 times every 3 months. All the seal failures were caused by the oil carbonization. These phenomena happened on the outboard seal only and all seal failures’ phenomena were almost same. We finally solved this problem by adjusting the seal face flatness.
Introduction

- System Scheme & Trouble

M/Seal Trouble

Compressor Spec. 1750 kW / 3550 rpm
Refrigerant Propane (R-290)
1) Jul. ‘2014 – The refrigeration system start-up

2) Jul. ‘2015 – 1st Mechanical Seal Trouble : Emergency shut down
   Mechanical seal replacement without any modification
   Mechanical seal replacement without any modification
4) Jan. ‘2016 – 3rd Mechanical Seal Trouble : Planned shutdown
   Mechanical Seal was modified to change the roughness from 30 um to 60 um and additional flushing line was installed → Failed
   Mechanical seal was modified to face flatness. The light band on seal face was adjusted as 7 L.B. → Performed well
Trouble

Oil Leakage

- 13. Jan. '16
  - 53.3 cc/day

- 5. Feb. '16
  - 55.9 cc/day

- 11. Feb. '16
  - 43.2 cc/day

- 17. Feb. '16
  - 19.2 cc/day

Dark !!
Trouble

- Type: Dual Pressurized Seal / Face to Face
- Oil Injection Rate = 21 LPM
- Seal Face Material (Stationary / Rotating) = Carbon / TC
Trouble

- The carbonization happened at the inner dia. of outboard seal
- Sealing Face looks good, not bad except for carbonization
- There is no carbonization on Inboard side and the Mating Ring was clean

Possible cause for Seal Trouble
- **Oil Carbonization** on the Stationary Ring by the Heat
- Carbonization deposit makes the seal faces opened
Trouble

< Inboard seal >

< Seal Sleeve >

Discolored by Burning

< Outboard seal >

Mating Ring

Seal Face looks good

Oil Carbonization
Cause Analysis

1) Why did Carbonization happen?
   - Carbonization
   - Heating
   - Lube Oil Viscosity
     - Low Viscosity Oil Replacement
     - No-try
   - Flushing flow rate
     - Additional Flushing Line
     - Fail
   - Seal Face Design
     - Seal Face Roughness
     - Fail
     - Adjust the Seal flatness
     - Success
   - Contact with Air
     - Oil Circulation / N2 Quenching
     - No-try
     - The rotor shall be replaced to retain the dimension for quenching or circulating → No-try
   - High diff. Pressure across Seal Faces
     - Reduce barrier fluid pressure / Multi-stage
     - Unrealizable!!

2) Why did the Carbonization happen on Outboard only?
   - Contact with Air
     - Oil Circulation / N2 Quenching
     - No-try
   - High diff. Pressure across Seal Faces
     - Reduce barrier fluid pressure / Multi-stage
     - Unrealizable!!
   - Wavy Face
     - No-try
   - UNCD Face
     - No-try
Troubleshooting

Lubricant: Gargoyle Arctic SHE 230
- Viscosity: 220 cSt @ 40 °C

* Proper Vis. Range: 10 ~ 40 cSt

Pure Lube Oil Viscosity is 220 cSt at 40 degC. But the propane is soluble in lube oil through the compressor and separator and the lube oil is injected to the bearing and seal as approx. 18 cSt.

The lube oil viscosity is not a problem!!
Troubleshooting

At a 3rd shutdown - planned

1) Adjustment the roughness
   - Matte finish (higher roughness) on the seal faces was applied to provide full fluid’s film and improve lubrication.

2) Installation of the additional flushing line
   - In the oil-flooded screw compressor, the seal was located at the end of the main rotor’s shaft.
   - There is no oil injection line for mechanical seal only.
   - Oil was injected through the radial and thrust bearing.
   - The new flushing line was added to increase the oil injection flow.

But these trials did not help and the carbonization happened again in 3 months.
Troubleshooting

New flushing line

Flow might be less than the designed value due to narrow oil path

New Flushing Line was added
Troubleshooting

▶ At a 4th shutdown - planned

To adjust the seal flatness
- We considered the reduction of contacting area on seal faces to decrease heat generated at seal faces
- The flatness of seal faces were adjusted as 7 convex L.B.

♫ Finally the carbonization didn’t emerge anymore

Seal Face Flatness
2 L.B. → 7 L.B. (0.29 um × 7 L.B. ≈ 2 um)

√ 1 L.B. = Wave length of the Helium Monochromatic Light x ½ = 2900 Å = 0.29 um

* Mechanical Seal Band
  - Test Method to verify the face flatness
  - Manufacturer’s general standards
    : within 3 L.B.
Troubleshooting

Effect - adjustment of the seal faces flatness (Assume)

1) Increase the area which is fully lubricated with the flushing oil

2) Increase the flushing flow rate
Troubleshooting

Effect - adjustment of the seal flatness (Assume)

3) Decrease the heat generation

Heat Generation

\[ H = P_f \times V \times A_f \times f \]

Total Pressure

\[ P_f = \Delta P \times (b - k) + P_{sp} \]

For convex seal faces (converging fluid film), K is greater than 0.5
- For flat faces, K is 0.5

K-factor is changed by the seal faces flatness’s adjustment as well as sealing fluid.
Summary

The seal failure was caused by the oil carbonization and all seal failures’ phenomena were almost same. These phenomena happened on the outboard seal only. According to our analysis, the carbonization came from the high lube oil viscosity, low flushing flow rate, contact with air, and high differential pressure on the seal faces. We finally solved this problem by optimizing the seal faces flatness under the current operating condition. This action may not be common solutions. But it is one of easy approaches to sort out carbonization issue under an urgent situation.
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[Back-up] Mechanical Seal Failure

- Oil Circulation type
Mechanical Seal Failure

- N2 quenching type
[Back-up] Mechanical Seal Failure

- Wavy Face

Diagram showing a sealing dam with annotations for tilt and amplitude.