Compressor rotor failure due to fouling at Qatargas condensate refinery

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KHT Process Overview

Wash Water
(Stripped Sour Water)
Hydrogen Recycle Compressor

- The compressor train is equipped with BN 3500 system
- The compressors are of barrel type construction
The Problem

- About six months after commissioning in September 2009, LP compressor performance degradation was observed.
- Degradation was slow initially and accelerated with time.
- Compressor efficiency dropped from 65% (new) to 35% (failure).
Performance Trends

- **Efficiency [%]**
- **Power [KW]**

Graph showing the trends of efficiency and power over time from May 2010 to July 2011.
LP Compressor Failure

- July 2011, after about 20 months in service, a sudden increase of LP compressor vibration from 10 mic to 75 mic at DE
- BN ADRE was installed on machine vibration rack to analyze the data
- However, meanwhile vibration quickly increased to danger levels (beyond 1000 mic) at DE
- Machine was manually shutdown because vibration trip did not function
Internal Inspection

- First stage impeller found broken
- Heavy deposits / fouling of impellers and diffusers
- Damaged Journal bearings, DE was severe

Note:
HP Compressor was not dismantled based on vibration, bearings temperatures and thermodynamic performance data analysis
Internal Inspection
Broken 1\textsuperscript{st} stage impeller
Internal Inspection

Fouling

Fouling was most severe on 1\textsuperscript{st} impeller and was progressively less to the 4\textsuperscript{th} impeller.

Almost no fouling of 4\textsuperscript{th} & 5\textsuperscript{th} impellers
Internal Inspection
Fouling
Journal bearings were subjected to very high cyclic load due to unbalance rotor after impeller breakage. Max bearing temperature recorded was 130°C.
The deposits were mainly Ammonium Chloride per laboratory analysis.

Ammonium Chloride is produced in traces in the reactor due to the presence of $\text{N}_2$, $\text{H}_2$ and chlorides in feed.
Investigation
EDS Analysis

EDS Analysis of foulant on 1st Stage Impeller showing high Chlorides & Iron
Investigation
Metallurgical Analysis

“The fracture surface is smooth, relatively featureless, and contains some evidence of beachmarks and thumbnails which are all characteristics of a fatigue failure”.

[Images of metallic components and fracture surfaces]
Modal analysis were carried out with the OEM to know if the impellers natural frequencies are close to the operating range and could be responsible for broken impeller. Sufficient margin was found.
Investigation
Root Cause of Failure

- Under deposits pitting corrosion of 17-4 PH SS impeller by chlorides
- The impeller failure was attributed to stress corrosion cracking and possibly combined with high cycle fatigue resulting from flow irregularities caused by excessive fouling of the gas flow passages and pitting.
Investigation
Contributory Causes of Failure

- Lack of understanding of fouling service and its harmful nature
- Insufficient process controls to prevent deposits formation
- Incomplete execution of vibration trip function by project team. BN3500 not connected to compressor ESD for trip on high vibration or journal bearings temperature
Resolution

- Compressor reassembled with spare rotor
- Vibration and bearing temp trip function commissioned per OEM guidelines
- Water injection upstream of compressor started on alternate days
- Compressor efficiency was closely monitored to see the effectiveness ...........
  remained steady at 65%
- After 3 years of service,
  - max 2% efficiency dropped, indicating water injection was working very good
  - Compressor was opened for inspection in a planned outage and the internals were in excellent condition which was in line with the efficiency trends
  - Rotor NDT revealed no defects
Resolution

81-K1601 (Kerojet H₂ Recycle Compressor)
Combined LP & HP Performance
Efficiency & Gas Power

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Lessons Learned

• In addition to reducing throughput of centrifugal compressors, fouling can result in serious damage to vital components and cost heavy production loss
• Thorough understanding of process stream constituents and impact on equipment is very important for reliable plant operation
• Equipment surveillance for performance and mechanical health parameters can help in early detection of problem and preventing failures
• Process and Rotating engineers collaboration is important
• Gaps in project QA/QC
Q&A