Ethylene Unit Cracked Gas Compressor
Case Studies on Fouling

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Outlines

- Overview of Equipment and Setup
- CGC Fouling Experiences
- Identification of Turbine Fouling
- Impacts of Compressor-Turbine fouling
- Turnaround Inspections
- Countermeasures for Fouling Control
- Future Improvements
- Conclusions
Overview of Equipment & Setup

- CGC is a five stages centrifugal compressor
- Caustic wash and drying are facilitated between 4th and 5th stage
- 5th stage is a heat pump for DeC3 system where C4 and heavier are removed
- CGC is driven by a SHP steam turbine
- Turbine extracts HP steam while condensing is controlled by CGC power demand
Compressor System Flow Diagram

Wash Oils

Stage 1

Stage 2

Stage 3

Stage 4

Cracked Gas

Caustic & Dryers

Stage 5

Acetylene Converters

HP DeC3

To Recovery Section
Compressor Overview

- Diffusers
- Inlet Vanes
- Wheels
- Balance Line
Fouling Phenomenon - What, Why and How

- Organic: Free radical mechanism catalyzed by peroxides, transition metals and heat
- Inorganic: Quench water carryover
- Organic or inorganic deposits dehydrogenate over time leaving behind

\[ \text{Initiate} \quad \Delta \text{heat} \]
\[ \text{Propagate} \quad \text{R-H} \]
\[ \text{ROOH} + \cdot R \]
\[ \cdot R + \cdot R \]

\[ \text{Terminate} \]
CGC Fouling Experiences

- Polytropic efficiencies dropped
- Discharge temperatures increased
- Inter-cooler pressure drops increased
- Governor valve opening maximum
- Turbine steam rate increased
- Max continuous speed not sustainable
Compressor Delta T

AFTER TURNAROUND 96

AFTER TURNAROUND 99

TURNAROUND 2001

Stage 1 delta T  Stage 2 delta T  Stage 3 delta T  Stage 4 delta T
Identification of Turbine Fouling

- Unable to maintain speed at max steam flow
- HP and LP valve fully open
- Backpressure from LP turbine
Causes of Turbine Fouling

- BFW quality upset
  - High Sodium / Silica due to capacity overrun or improper regeneration of demin train
- Water Carry-over
  - Steam drum level control high
- Steam contamination
  - Attemporating water high in sodium or silica
Impacts of Compressor-Turbine Fouling

- Throughput limited due to maximum driver governor valve opening
- Increased suction pressure
- Energy inefficient due to higher steam rate
- Short run length, 3 years down for cleaning
Turnaround Inspections

- Inspection done during TA99 and TA 2001
- 1st and 5th stage - relatively clean
- 2nd, 3rd & 4th stage - heavily fouled
- Polymer deposits and most samples were organic component
- Inter-coolers fouled with polymers and tars
- Discharge piping layered with polymer
Summary of the Inspection Findings

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1st to 4th Stage Discharge Condition during Turnaround 2000/01

1st Discharge 2nd Discharge 3rd Discharge 4th Discharge
2nd stage intercooler bundle

Bundle entrance

Polymer laced inlet pipeline

Inlet to intercooler
Turnaround inspections - CGC Turbine
Countermeasures for Fouling Control

- Compressor wash oil review
  - Feed points available at the suction piping
  - Injection spray atomizers enhance distribution
  - Increased wash oil injection rate to 3-4% vol.
  - Quality monitoring - existent gums
  - Quantity monitoring - dP

- Antifoulant Injection
  - Trial run at the 4th stage - worst case

- Improved BFW quality
  - Proper Demin regeneration and lower steam drum level
Compressor Wash Oil Review

- 1st to 3rd stage: HPG + C5
- 4th stage: HPG
- Specific gravity: 0.77-0.80
- Aromatic content: 65%
- Existent gums: < 5mg/100ml
- Distillation D-86
  - IBP: 70 °C
  - End point: 185 °C
Anti-foulant Injection

- Trail run at 4th stage
- Start of run - 9 May 02
- Co-injection with the existing wash oil
- Injection rate at 2-5 ppm by weight
- Monitoring parameters:
  - Polytropic Efficiency
  - Suction / Discharge Temperatures
  - Pressure Drop Across Inter-cooler
  - Steam Consumption
  - Vibrations
Antifoulant Trial Run

Antifoulant: 2-5 ppm wt based on the 4th stage charge rate.
Antifoulant Trial Run Findings

- Polytropic efficiency improved - 4-5%
- Comp discharge temperature reduced - 3-4°C
- Delta T reduced
- Pressure drop across inter-cooler maintained
- Vibration normal
4th Stage Polytropic Efficiency and Delta T

Dosage 2ppm
Dosage 3-4 ppm

4th Stage Polytropic Efficiency, %
Compressor Delta T, degC

Efficiency (%)  DT
4th Stage Polytropic Efficiency and Delta T

C-300 Efficiency

- 2nd stage
- 4th stage
- Ave eff = 1st to 3rd stage

Eff, %

Efficiency over time from 20th April 2002 to 24th June 2002.
Future Improvements

Wash oil quality
- C8+ High aromatics, low gums & higher FBP
- Intermittent or Continuous - 0.5% wg
- High volume flush - 2% wg

Wash oil and Antifoulant injection to casing
- Revamp or TA modification

Wash water injection
- max 1% throughput to minimize rotor erosion

Inter-coolers
- Antifoulant injection facilities for online cleaning

High efficiency 3D impeller blades (new service)
- More efficient and larger gas passage
Conclusions

? A review of equipment and maintenance records are essential to each producer

? Part of this review should include turbine and compressor fouling

? Adequate wash oil selection and antifoulant injection enables cracker extension of cracked gas compressor run lengths by reducing the amount of polymer fouling.

? Any review should also include future optimizations
Thank You

Q & A