Case studies
Tiaan Vosloo
19 September 2013
Case Studies

• Contents
  - Background
  - Material
  - Operation
  - Conclusion
• Failure
  – Understanding the underlying mechanism can assist in preventing a re-occurrence.
  – A failure is very often a result of some inefficiency somewhere in the ‘system’.
  – Understanding the mechanisms causing the failures can reduce future failures and increase operating efficiencies and operating costs.
Background

• Failure
  – Material
  – Operation
Material

• Material Selection
  – Operating within the material limitations?
  – Correct material for the application?
  – Understanding the material?
  – Cost of the material?
Material

- Material Limitations
  - Temperature
  - Environment
  - Applied Stresses
Material Limitations

- **Temperature**

<table>
<thead>
<tr>
<th>Material</th>
<th>Max Temperature (ASM) °C</th>
<th>Excessive scaling (NALCO) °C</th>
<th>Max T based on strength (ASM) °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steels</td>
<td>425</td>
<td>550</td>
<td>425</td>
</tr>
<tr>
<td>0.5% Mo</td>
<td>540</td>
<td>570</td>
<td>510</td>
</tr>
<tr>
<td>1.0%Cr 0.5%Mo</td>
<td>565</td>
<td>600</td>
<td>560</td>
</tr>
<tr>
<td>2.25%Cr 1%Mo</td>
<td>580</td>
<td>600</td>
<td>595</td>
</tr>
<tr>
<td>T91, 9%Cr1%Mo</td>
<td>650</td>
<td>770</td>
<td>560</td>
</tr>
<tr>
<td>304, 19%Cr10%Ni</td>
<td>760</td>
<td>870</td>
<td>595</td>
</tr>
</tbody>
</table>

Guideline temperatures
Material - Temperature

- Material Limitations
  - Temperature
    - Heat transfer inhibited due to scale
    - Excessive heat exposure
    - Rate and extent of degradation is time and temperature dependant
    - Degradation, deterioration ultimately failure
    - Degradation mechanism is a Function of the material
    - Physical distortion, swelling, blistering etc…
Material - Temperature

• Steel degradation mechanisms
  – Oxidation (scale formation)
  – Graphitising
  – Spheroidising
  – Creep
Material - Temperature

• Oxidation (scaling)
  – Over-heated steel in its simplest form ‘burns’ the steel
  – Weakens the steel structure
  – Forms Iron Oxide scale
    • Fe₂O₃ haematite
    • Fe₃O₄ magnetite
  – Can sometimes cause cracking
Material - Temperature
Material - Temperature

- Graphitising vs Spheroidising
  - Basic microstructure of Carbon steel
  - Ferrite Matrix (White)
  - Pearlite (Dark)
    - Ferrite
    - Iron Carbide Fe$_3$C
Material - Temperature

- Graphitising vs Spheroidising
  - Driving force for Carbon to reach a more stable phase
  - Competing degradation mechanisms [Chem, Temp]
  - Elevated temperature required for activation energy

*ASM Handbook Vol. 1
Material - Temperature

• Graphitising
  – Atomic carbon migrates from steel constituents (decomposition of Iron Carbide)
  – Forms graphite nuclei
  – Nuclei increase in size leaving pure iron or ferrite matrix
  – Time and temperature dependant
  – Very soft, weak microstructure which ruptures along the graphite nodules
Material - Temperature

- Graphitising
Material - Temperature

- Spheroidising
  - Breakdown of lamellar pearlite
  - Carbides form within ferrite crystals
  - Precipitation of grain boundary carbides
  - Grain boundary voids
  - Time and temperature dependant
  - Very soft, weak microstructure which ruptures along the voids
Material - Temperature

- Spheroidising
  - Progression of Spheroidisation
Material - Temperature

- Spheroidising
Material - Temperature

- Creep
  - Time, Temperature & applied stress required
  - Coalescence of voids
  - Ultimately fails due to lack of grain boundary cohesion
Material - Temperature

Creep damage correlation

Strain (%)

Time (h)
Material - Temperature

• Creep Classification
  – A, as received
  – B, Observe and take note
  – C, Regular monitoring
  – D, Repair
  – E, Immediate repair
Material - Environment

• Material Limitations
  – Environment (Chemical)
    • Accelerate general corrosive attack
    • Promote stress corrosion cracking (SCC)
    • Promote corrosion fatigue
    • Severity is a function of the type of corrosion
  – Environment (Mechanical)
    • Erosion
    • Mechanical wear
Material - Environment

- Corrosion

<table>
<thead>
<tr>
<th>Type</th>
<th>Culprit</th>
<th>Area</th>
<th>Severity</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Oxygen Moisture</td>
<td>Internal</td>
<td>F[Time]</td>
<td>Eliminate source</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCC</td>
<td>Stress Catalyst (NaOH)</td>
<td>Internal</td>
<td>F[NaOH]</td>
<td>Repair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Welds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrosion Fatigue</td>
<td>Residual Stress Cyclic load Catalyst</td>
<td>Internal</td>
<td>F[Cycle Amplitude]</td>
<td>Repair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Welds</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Material - Environment

• General Corrosion
Material - Environment

• Stress Corrosion Cracking
Material - Environment

- Corrosion Fatigue
Corrosion fatigue susceptible areas
Thermal fatigue areas
Material

• Material Limitations
  – Applied stress
    • Steady constant loading
      – Material degradation predictable
  
  • Cyclic loading
    – Thermal fatigue
    – Corrosion fatigue
    – Material degradation UNpredictable
Operation

• Boiler operating philosophy
  – Throughput vs Design parameters
  – Direct impact on boiler condition and efficiency

• Lack of knowledge
  – Realising the importance of each component in the system
    • Water treatment, Firing procedures etc…
  – Preventing unnecessary degradation
    • Maintaining the boiler
Operation

- Elevated Temperatures – Long term
Operation

• Elevated Temperatures – Short term
Operation

- Rapid start-ups
Operation

- Water treatment
Operation

- Water treatment
Operation

- Water treatment
Operation

- Water treatment & Cyclic loading
Operation

- Insufficient water level
Operation

• Neglecting water system
Operation

- Neglecting water system

Glutamic Acid and Monosodium Glutamate

All methods for the industrial production of (S)-monosodium glutamate first produce either (S)-glutamic acid hydrochloride or (S)-glutamic acid.

The crude, crystalline glutamic acid is first suspended in water and then dissolved, neutralized and converted to the monosodium salt by the addition of sodium hydroxide. The solution is decolorized using activated carbon, if necessary, and concentrated under vacuum at 60°C before cooling for crystallization. The crystals are isolated by centrifugation and then dried.
Operation

• Neglecting water system
Operation

- Incorrect storage
Operation

- “Chameleon” material
Operation

• “Chameleon” material
Operation

• “Chameleon” material
Conclusion

• Failures
  – Result of operating deficiencies
  – Direct reflection on operating efficiency and productivity
Conclusion

• Actions
  – Establish, Understand and Eliminate the root cause
  – Pro-actively monitor and manage
    • Statutory inspections
    • Metallurgical assessments
  – Adjust and optimise operation practices
    • Reduction in down time and maintenance cost
Questions?

www.johnthompson.co.za