Refinery Pre-heat Train Monitoring and Cleaning Tool

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Agenda

• Saudi Aramco

• Drivers for application and overall design.

• Overview of design.

• Challenges
Saudi Aramco Company Profile

- National oil company of Saudi Arabia.
- Almost 56,000 employees.
- One of the World’s largest oil companies.
- A fully-integrated oil and gas company with affiliates, joint ventures and subsidiaries around the world.
- Owns and operates one of the largest oil tanker fleets.
Crude Unit Overview

Crude preheat train

CDU

Naphtha Section

VDU
Operation Objectives

- Crude preheat exchanger fouling
  - Increased heater fuel load
  - Increased pressure drop
- Operating costs depend on fuel source
Operation Objectives

- Monitor heat exchanger performance.
- Identify which exchangers to clean and when.
- Demonstrate that overall cost of cleaning recovered
Modeling Objectives

• Utilize existing simulation technologies
• Evaluate technologies and methodology
  – Detailed exchanger models
  – Hysys EO

• Cautious approach to automation until benefits well understood.
Steps to Evaluate HX Network Scenarios

Establish Operating Conditions
- Eliminate individual energy imbalance:
  - Average data.
  - Reconcile data.
  - Improve measurements.

Estimate Exchanger Performance
- Individual exchangers (U values, Fouling factors).
- Preheat exchanger network (normalized furnace inlet temperature).

Predict Future Performance
- Different operating scenarios (bypass, clean, etc.).
- Consider key time effects on unit performance.
1. Establish Operating Conditions

- Using HYSYS EO
  - Easy interaction with performance, prediction models
  - Faster performance <1 min avg. solving time
1. Establish Operating Conditions

- EO: Available/missing instrumentation ...
1. Establish Operating Conditions

- Reconciliation Improves results and helps identify trends
  - Smoothes the trends.
  - Regression of fouling trends easier.
  - Helps automation of the tasks.
2. Estimate Exchanger Performance

- **U** \( U = \frac{Q}{(A \times \text{LMTD} \times \text{Ft})} \)
  - FAST: Direct calculation from measurable variables.
  - INDIRECT: Varies with flows and properties.

- Fouling factor \( r_o + r_i \left( \frac{d_o}{d_i} \right) \)

\[
\frac{1}{U} = \frac{1}{h_o} + r_o + \frac{e}{K\left(\frac{d_o}{d_w}\right)} + \left(\frac{1}{h_i} + r_i\right) \frac{d_o}{d_i}
\]
  - SLOW: Traditionally iterative.
  - DIRECT: Only dependent on amount of fouling.
  - Requires individual coefficient correlations.
2. Estimate Exchanger Performance

- New EDR utility in HYSYS
  - FAST: Directly calculates fouling factor - no iterations.
  - ACCURATE: dependent on fouling, not on process variables.
2. Estimate Exchanger Performance

- Using EDR to estimate fouling factor KPI is realizable objective.
- Beneficial for historical fouling trends analysis.
  - Two years of weekly datasets (7 exchangers / dataset).
  - Trial and error
    - 30 to 60 seconds per heat exchanger per dataset.
    - 6 - 12 hours for all datasets
  - EDR
    - 10 - 20 minutes for all datasets.
3. Predict Future Performance

- Fractionators in pumparound rating mode.
- EDR to calculate the performance of heat exchangers.
- Include effect of online time on unit performance.
  - Fouling factor trends extrapolated as desired.

- Decision and adjust variables:

<table>
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<th>Decision</th>
<th>Adjust</th>
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<tr>
<td>Fractionator heat balance</td>
<td>Heat exchanger cleaning</td>
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<td>Furnace preheat temperature</td>
<td>Bypasses</td>
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<td>Furnace fuel consumption</td>
<td>Pumparound flows</td>
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</table>
3. Predict Future Performance

Crude preheat train

Heat exchangers in EDR rating mode.

CDU

PA duties calculated by heat exchanger performance.

Naphtha Thermosiphon Reboilers

VDU

EDR Furnace models to calculate Fuel Consumption as predicted by the network KPI.
Architecture Overview

• **Two (2) simulation-based applications.**
  – Performance – Historical & Current
  – Predictive

• **Three (3) simulation blocks.**
Two Model User Interface(s)

1: Performance Monitoring

- Data validation & reconciliation.
- Calculation of fouling factors.
- Fouling trend calculation from reconciled historical plant data.
- Current fouling from reconciled plant data.
Two Model User Interface(s)

- 2 : Prediction/Scenarios
  - forecasting operation to assess changes.
  - using fouling from historical analysis.
Challenges

• Variable vs. constant Fluid properties
  – For changing crude slate it may be necessary to run distillation columns.

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<th>PHYSICAL COMPARISON TABLE</th>
<th>Std Id</th>
<th>Mass Dens Kg/m3</th>
<th>Mass Heat Capacity Kj/kgC</th>
<th>Thermal Cond W/mK</th>
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Challenges

• Pressure drop (dP) as a fouling indicator.
  – Fouling factor calculations seem to be more stable and reliable as a source for identifying fouling than a difference between measured and model (theoretical) pressure drop.
Challenges

• Simple UA/A as indicator.
  – Again, fouling factor calculated results are more stable and reliable in predicting exchanger fouling.
Challenges

• Model scope in reconciliation.
  – A decision was made to use a reduced scope model, fixing some relationships between fluids instead of modeling the actual dependence.
  – The decision was made based on the model of a splitter with a pre-heater reusing some heat from the bottoms stream.
Conclusion

• Using EDR to estimate fouling factor KPI is a realizable objective.

• Data reconciliation benefits limited by missing process data.

• Improved Hysys EO desired
  – EDR not linked to EO exchangers: extra SM model required
  – Direct EO automation not available: ASW & EO synchronization issues

• Work in progress
  – Main benefit expected from fouling trends
Thank you