Let’s **Redefine** the Possibilities:
It’s Not Always the Catalyst's Fault
(and sometimes it’s the catalyst’s fault!)

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Audience Poll

What was the root cause of the last major problem on your FCCU?

- Poor choice of technology
- Hardware failure / reliability
- Change in feed or refinery configuration
- Catalyst selection
- Other / Not sure
Catalyst Affects More Than The Reactor!

Common catalyst considerations
• Yield, selectivity, coke make, metals passivation, etc.

Less common catalyst considerations
• How is the catalyst affected outside the reactor?
• If there are problems, is it due to the catalyst?

Assessing FCC performance through simulation
• Determine root cause of underperformance
• Reduce risk of changes through virtual testing
• Identify additional optimization opportunities

This presentation looks at how the catalyst affects performance beyond the reactor
• Results for both case studies were created using Barracuda Virtual Reactor®
Example 1: Why Is My Combustion Promotor Ineffective?

Full-burn FCC emissions problems following turnaround (TAR):
- NOx: 10% over 365 day rolling average
- CO: 43% over 365 day rolling average
- Particulate emissions: frequent high loss episodes
- Significant afterburn

Combustion promotor (COP) had minimal effect on afterburn and CO. Why?
- Poor COP?
- Bad choice of modifications?
- Damage?
- Other?
Formation of Team and Initial Finding

Shutdown scheduled to repair expected damage
- Someone asked, “What if there’s no damage?”

The simulation predicted significant gas channeling (without air grid damage)
- The spent catalyst distributor exacerbates the maldistribution

Team formed to propose options if no damage was found
- Refinery engineers, corporate staff, cyclone vendor, two independent consultants, simulation expertise
Primary Cause – Spent Catalyst Distributor

Spent catalyst distributor effectiveness

- Spent catalyst initially biased to south side
- Same side as gas channeling
- But no distributor changes were made at the TAR!

Major changes not feasible before shutdown
What Could be Modified if No Damage Found?

During shutdown could alter:

- Air grid orientation
- Dipleg discharge direction
- Shortening secondary dipleg lengths

<table>
<thead>
<tr>
<th>Case</th>
<th>Air Grid Orientation</th>
<th>Dipleg Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 0</td>
<td>Offset</td>
<td>Current</td>
</tr>
<tr>
<td>Current</td>
<td>Aligned</td>
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<tr>
<td>Case 1</td>
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</tr>
<tr>
<td>Case 2</td>
<td>Aligned</td>
<td>Option 1</td>
</tr>
<tr>
<td>Case 3</td>
<td>Offset</td>
<td>Option 2</td>
</tr>
</tbody>
</table>
Virtual Testing Results

No case addresses root cause

Can incremental improvements be obtained?

- Regions with highest time-averaged gas bypass shown
- Cases 2 and 3 dissipate gas jets at a lower elevation
Gas Uniformity Index

Quantification of time-averaged gas flow shown (Uniformity Index*)

\[ U = \frac{\text{Cross-sectional area being used for gas flow}}{\text{Total cross-sectional area}} \]

Poor utilization of regenerator cross-section in all cases

- Gas stream coalescence and bypassing influenced by internal structures

Cases 2 & 3 have the highest uniformity of gas flow.

Thermal and Gas Composition Profiles

Regenerator temperature profiles dominated by maldistribution

High O₂ reaching dilute phase

Afterburn due to O2 and CO mixing in the dilute phase

Cases 2 and 3 show better mixing and less maldistribution
Catalyst Losses and Secondary Dipleg Plugging

Catalyst losses may be correlated with secondary dipleg plugging

Lower bed densities at secondary dipleg outlets were observed before the 2015 turn-around

• Dipleg 3B in the current configuration shows a high likelihood of plugging
• Case 3 appears to have a greater likelihood of dipleg plugging based on overall density gradients
• Raising the Case 2 dipleg discharge elevation by 1.5 feet reduces the concern
Outcome

During shutdown
- The air grid wasn’t broken
- Simulation gave the refiner confidence to implement the change
- The refiner opted for Case 2 with the secondary dipleg heights shortened by 1.5 ft

Post-shutdown:
- NOx & CO maintained below 365 day rolling average
  - Dropped significantly after start-up
  - Air rate optimization and positive response to CO promotor
- Catalyst losses: complete elimination of the catalyst loss events

LESSONS LEARNED

- Catalysts/additives cannot fully overcome all design deficiencies
- Simulation helps identify root cause / virtual testing of changes
- Improvements are possible even if root cause cannot be addressed
Example 2: Why Don’t I Have Stable Catalyst Circulation?

A US gulf coast refiner experienced erratic stripper/standpipe catalyst circulation following a revamp

• Stable operation required over-aeration
• Low standpipe dP as a result

What was the root cause?

• Stripper / standpipe redesign?
• Fluffing and aeration rates?
• Coarse Ecalt due to excessive losses through regen cyclones
• Other?
CPFD Model Constructed

Simulations performed to identify root cause
- Model domain included bottom of stripper to top portion of standpipe

Base case simulations
- Case 1 – Typical Ecat PSD
- Case 2 – Coarse Ecat PSD

![Graph showing particle size distribution](image)
Model Calibration From Ecat Fluidization Test Data

Typical $u_{mf}$, $u_{mb}$ and de-aeration testing was performed on two catalysts:

- Ecat fines content has a minimal effect on minimum fluidization velocity.
- Ecat fines content has a significant effect on bed expansion / de-aeration times.
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Empirical model settings were extracted through simple experiments and included in the simulations
Simulation Results

Longer de-aeration time of typical Ecat allows for smoother transition and well fluidized catalyst at the inlet of the SCSP.

Large de-fluidized catalyst zone apparent in elliptical head extending to the main stripping steam ring.

Fluffing steam ring has poor penetration into the de-fluidized zone.
Can Catalyst Help Here?

The refiner is looking at hardware changes or other options for maintaining fines in their circulating Ecat inventory.

- Other refiners have observed significant changes in fluidization and improved operations through catalyst changes alone

Talk to BASF regarding your specific situation
LESSONS LEARNED

- Catalysts/additives cannot fully overcome all design deficiencies
- Simulation helps identify root cause / virtual testing of changes
- Improvements are possible even if root cause cannot be addressed
- Ecat fines content affects fluidization and catalyst circulation stability!
- Work closely with your catalyst supplier and make sure they understand your FCCU!
Conclusions

Catalyst and additive particles affect all parts of the FCCU

- Not just used for their catalytic function in the reactor

Catalysts are often blamed for problems actually caused by hardware, configuration, damage, or other root causes

Simulation is an effective tool to:

- Identify root cause of underperformance
- Provide independent and objective virtual testing of potential changes

The best solutions are obtained by maintaining open communication with all stakeholders, including the knowledgeable team at BASF
Questions

We welcome your questions

For additional FCC-related resources please visit:

http://cpfd-software.com/industries/refining-and-petrochemical/fcc-resources