FLUIDIZATION FUNDAMENTALS OF FCC REACTORS AND PRACTICAL EXPERIENCES

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Fluidization fundamentals of FCC reactors and practical experiences

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FCC-unit introduction

• Fluidised Catalytic Cracker; fine (but carefully sized catalyst) is circulated continuously: from reactor to regenerator @ 1000 ton/hr
• Conversion directly related to catalyst circulation rate
• Feedstock is converted to:
  – Dry gas ~ 4wt% (H₂, H₂S, CH₄, C₂’s and non-condensables CO, CO₂, N₂, O₂, used in RFG)
  – Mixed olefins ~ 25vol% (C₃ & C₄’s, workup to alkylate, HOC)
  – Gasoline ~ 50vol% (~93RON petrol blending component)
  – LCO ~ 20vol% (Blend component for fuel oil and upgraded to diesel)
  – Slurry ~ 10vol% (Blend component for fuel oil)
Catalyst circulation is controlled via 3 slide valves:
- Flue-gas slide valve
- Spent catalyst slide valve
- Regenerated catalyst slide valve

The allowable pressure drop through a valve is determined by the following:
- the static head of catalyst upstream of the valve
- the pressure loss due to friction in the valve stand pipe (a function of catalyst circulation rate)
- the pressure drop in between the regenerator and the reactor ($P_{\text{regenerator}} > P_{\text{reactor}}$)
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Fluidization

• FCC’s uniqueness is circulating catalyst
• Standpipes are designed to create static head
• As move down a standpipe, static head ↑
• If the entrained gas is compressed too much, the catalyst will become de-aerated
• De-aerated catalyst = catalyst circulation problems
• Steam, air, N₂ is used to keep catalyst fluidized
Fluidization cont’d

- 2 scenarios can cause catalyst circulation problems (low dP)

Pressure Drop Across a Fluidized Bed

- Increasing Pressure Drop across the Bed
- Increasing Gas Velocity

\[ \Delta P = \rho g h \left( \frac{u^2}{2g} + \frac{u_{mix}^2}{2g} \right) \]

\( \rho \) = Density, \( h \) = Height, \( u \) = Gas Velocity

\( \Delta P \) = Pressure Drop, \( g \) = Gravitational acceleration

\( u_{mix} \) = Minimum fluidizing velocity

\( u_{opt} \) = Minimum bubbling velocity
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Critical fluidization measurements

- Real-time density measurements (dP cells)
- Cyclone velocities, Rx-Rg levels & Pressure
- Slide-valve dP vs. valve opening
- Superficial gas velocities
- Pressure surveys
- Equilibrium catalyst PSD
- Radioactive scans
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Troubleshooting example

- Problem occurred after an unit upset, ~ power failure
- RCSV-dP was erratic and low after unit upset
Problem investigation

• All attempts failed to restore the pressure balance;
  – increased regen P;
  – increased catalyst level;
  – increased riser steam, etc.

Problem investigation cont’d

• A pressure survey indicated that the apparent density in the standpipe was less than previous survey results.
The fluidization problem was caused by either over-fluidisation or under-fluidisation.

Tested the theory with motive steam rate.

The RCSV-dP recovered when the motive steam rate was reduced.
Problem investigation cont’d

- Regenerator was much more sensitive for after-burn
- Main reason for after-burn is due to poor air and catalyst distribution

Problem investigation cont’d

- Concluded that the problem originated in the regenerator
- Possible “de-fluidised” area underneath the grid and over-fluidised catalyst entered the standpipe
- A radio-active scan was proposed to confirm the theory
Radioactive scan

- Density profile was measured along the regen standpipe, using radioactive sealed source & detector
- The scan was performed during 2 different operating conditions; i.e. stable and unstable

Radioactive scan cont’d

![Graphs showing transmission intensity over distance for high and low motive steam rates in two portions of the stand pipe.](image)

**Fig. 1:** Responses obtained on first 1/4 portion of RCSV stand pipe (top half)

**Fig. 2:** Responses obtained on second 1/4 portion of RCSV stand pipe (top half)
Conclusions

- The unit upset resulted in fluidization problems in the RCSV standpipe and an increase in regenerator after-burn.

- Although RCSV-dP problem could be managed by the motive steam rate, after-burn remained a concern. The after-burn problem was the consequence of air maldistribution in the regenerator.

- The air maldistribution / after-burn constraint resulted in loss of ~R400k/year due to the loss in catalyst circulation/conversion.

- Unit tripped 4 times up to planned shutdown, with no improvement of RCSV-dP.
Conclusions cont’d

- The reason for the dP problem became apparent when the regenerator was inspected during the shutdown

- The inlet to the RCSV standpipe was partially obstructed by the coke catcher that became detached

THANK YOU