Impact of Column Geometry and Internals on Gas and Particle Flows in a Fluidized Bed with Downward Solids Circulation

Yohann Cochet, Cedric Briens, Franco Berruti, Francisco J. Sanchez Careaga, Jennifer McMillan

May 28th, 2019

ycochet@uwo.ca
Introduction
Fluid Coking™ Technology

Fluid Cokers in Canada:
- 400,000 bbl/day
- 15-20% of Canada’s oil sands production

Objective: ↓ liquid losses & fouling by changing the solids residence time distribution

(Modified from Murray R. Gray, 2014)
Agglomerate bypassing should be reduced. Example: 1 cm agglomerate with initial liquid content of 12 wt%.

\[ \tau = \frac{\text{bed mass}}{\text{solid recirculation flowrate}} \]

- Increase \( t_{10} \): time for the fastest 10% of the agglomerates
- Less liquid reaches stripper
- Agglomerate fully dried
- Agglomerate formation

\( \% \) of liquid from initial agglomerate reaching the stripper in BYPASSING agglomerate
Objectives
Explore possible solutions in a pilot unit

How to reduce hydrocarbons reaching the stripper in industrial Fluid Cokers?

Change bitumen feeding profile (e.g.)

Use ring baffle

Combine ring baffles & bitumen feeding profile

(ExxonMobil, 11th International BBTC Conference, 2013)
Equipment
Cold pilot-scale unit

Fluid Coke:
- \(d_{pm} = 140 \, \mu m\)
- \(\rho_{part} = 1480 \, kg/m^3\)

Air:
- as simulated injections
- as fluidisation gas

Mean residence time: 2 min

Injection level, top view

Bed height: 1.25m

\(D_{high} = 25 \, cm\)

\(D_{low} = 20 \, cm\)
Formation-to-stripper time

• Measured using **Radioactive Particle Tracking** (single $^{46}\text{Sc}$ tracer & 12 scintillation detectors) with CARPT method

• One time distribution for each agglomerates formation zone

\[
t'_{10} = t_{10}/\tau
\]

\[
\tau = \frac{\text{bed mass}}{\text{solid recirculation flowrate}}
\]

Tracer encapsulated to adjust density, to match:
- **Wet agglomerates** (1080-1240 kg/m$^3$)
- **Solids & micro-agglomerates** (880-970 kg/m$^3$)
Results
Best alternative configurations

Adding ring baffles
Changing bitumen feeding profile
Adding ring baffle(s) & changing bitumen feeding profile

Baseline

0.87 m.s\(^{-1}\)

Larger is better

Logarithmic scale

\(t'_{10}/(t'_{10})_{BASELINE}\)

LIGHT Tracer

HEAVY Tracer

Adding ring baffles
Changing bitumen feeding profile
Adding ring baffle(s) & changing bitumen feeding profile

0.87 m.s\(^{-1}\)

0.87 m.s\(^{-1}\)

0.87 m.s\(^{-1}\)
Adding ring baffle(s)

<table>
<thead>
<tr>
<th>1 baffle (flux tubes)</th>
<th>1 baffle (no flux tubes)</th>
<th>4 baffles (no flux tubes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIGHT Tracer</td>
<td>HEAVY Tracer</td>
<td>Not industrially suitable</td>
</tr>
</tbody>
</table>

Baseline

0.87 m.s⁻¹
Uneven bitumen feeding redistribution using baffle with flux tubes and 4 banks

Baseline

Uneven redistribution
Top > Bottom

Uneven redistribution
Bottom > Top

- LIGHT Tracer
- HEAVY Tracer

Even redistribution
Liquid content reaching the stripper (1)

Measured formation-to-stripper time distribution

Heat & Mass transfer model (shrinking core)

\[ f(d_{Agg}, L/S) \]
Proportion of liquid trapped reaching the stripper (2)

By combing the 2 previous charts

Agglomerate (L/S)₀ = 0.3

Baffle positive
Baffle detrimental

Baffle + redistribution positive
Baffle + redistribution detrimental

Redistribution positive
Redistribution + baffle
Basecase

Agglomerate diameter (mm)
Change of bitumen feeding profile
Distance vs. hydrodynamics

Only effect of distance to stripper?

NO

All active agglomerate formation zones

Only common active agglomerate formation zones

Consider only common active agglomerate formation zones

Stripper zone
Change of bitumen feeding profile
Heavy agglomerate motion pattern

From RPT

5 banks of injection

Video

No baffle

Variation of axial velocity

No baffle

Variation of axial velocity

Video

No baffle

Variation of axial velocity
Change of bitumen feeding profile

Heavy agglomerate motion pattern

4 banks of injection (same total gas flowrate)

Video

No baffle

Variation of axial velocity
Change of bitumen feeding profile - Comparison
Variation of axial velocity

Stronger upward (related to bubbles) flow after the modification
Conclusion

Two possible solutions to reduce liquid reaching the stripper:

1. Redirect bitumen feed from lowest injection bank to higher banks – For any agglomerate size

Or,

2. Add ring baffle with flux tube – Only for small agglomerates (< 5 mm)

The combination of both is in-between

Improvements connected to hydrodynamics changes
Acknowledgments

NSERC/Syncrude/ExxonMobil
Industrial Research Chair
in Fluid Coking Technologies