Fluidized Bed Reactor Application for Catalytic Pyrolysis of Waste Plastic

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Overview

Encina’s Technology Process

- Utilizing material recycling technologies to achieve reactor specifications
- Integrated existing material recycling technologies into advanced processes
- Optimized material handing process to meet the specification of the reactor
- Designed for Encina’s mixed stream sources

Front

- Proprietary Plastic Fluid Catalytic Cracking (PFCC) reactor unit
- Employs conventional FCC concepts found in current petrochemical facilities
- Reactor design and catalysts configurated for handing waste plastic streams instead of oil and NGLs from a traditional refinery process

Middle

- Conventional chemical processing technologies from the reactor effluent
- Utilizes configurations used in chemical facilities globally
- Circular basic chemicals and hydrocarbon liquid products from renewable sources
- Products prepared for existing commodity market use and acceptance

Back
Scale-Up Process

• **Bench scale units**: Fixed and fluidized beds
  - Assess the catalyst performance
  - Build fluidization curve - Calibrate the CFD model

• **Larger Fluidized Bed**:
  - Study the effect of feeding rate, operating T, and catalyst formulations on the yield of the products - Validation of the kinetic model

• **Demonstration unit**:
  - Demonstrate plastic preparation, conversion, and products separation processes
  - Establish the full catalyst circulation loop
  - Explore the effect of operation conditions on yield
  - Study feed material dispersion, temperature profile, and entrainment at different operation conditions

• **Large-scale cold flow test**:
  - Study the effect of Encina IP design on hydrodynamic at different flow regimes
  - Better understanding of the separation technology
  - Evaluate the effect of internals on hydrodynamic
  - Finding optimal operation conditions for Encina’s separation technology

• **Commercialization**:
  - Optimizing existing designs
  - Mitigate commercialization risks
Drag Calibration: 6-inch fluidized bed

Pressure BC

Flow BC

Particle inventory

6-inch fluidized bed: velocity increasing

6-inch fluidized bed: velocity decreasing
**Drag Calibration**: 8-inch fluidized bed

- The error is within 10%
- CFD predictions match the experimental results well for the mid-range velocities
- It’s difficult to match the experimental curve slope
Grid validation:

- Number of grid cells: 0.25M vs 1M
- Number of real cells: 148,390 vs 587,217
- Grid cell size: 0.0967m vs 0.06m
- Number of clouds: 10.6M vs 19M
- Computational time: 18hr/100s vs 60hr/50s
Grid validation:

Superficial velocity, ft/s

Time, s

Elevation-1

Elevation-2

Bed Density, lb/ft³

Time, s

Elevation-1

Elevation-2

Effluent mass fraction

X direction location

4th flux plane

Cell num: 0.25M

Cell num: 1M

mf-effluent

0.9

0.8

0.7

0.6

0.5

0.4

0.3

0.2

0.1
Encina Reactor IP perspectives

No Encina IP:
- Channeling fluidized bed observed
- Poor particles and gases mixedness

Encina IP configurations:
- More uniform particles and gases mixedness
Encina Reactor IP perspectives

Encina IP configurations:
- Better particles and gases mixedness
- More stable fluidized bed
- Less particle entrainment
- Temperature maldistribution in the lower bed
Particle mixedness

- Tracer mixing: Weight% of tracer at a selected elevation
- Ideal mixing: Assuming tracer particles were evenly distributed across the entire fluidized bed
- It takes about 20s for achieving good particle mixedness
Higher elevation fluidized bed showed consistent temperature for both axial and radial mixing.

- Lower temperature observed in lower elevations and need to be eliminated
  - Critical temperature ensures the effective operation

- Larger temperature variation noticed in the lower bed
  - Indicating a poor radial mixedness
Design improvement

Original design

DI_1

DI_2

DI_3

DI_4

Operation improvement

Original design

OI_1

OI_2/DI_4
Design/Operation improvement

Critical Temperature, K

Temperature, K

Original design

DI_1  DI_2  DI_3  DI_4  DI_5  OI_1  OI_2/DI_4
Conclusion:

• Different sizes of fluidized bed reactor were modeled with CPFD Barracuda
  
  o Velocity and bed density well predicted by adjusting the existing drag model
  
  o It is challenging to match the experimental pressure fluctuation and particle entrainment results at the high velocity range
  
  o The CFD codes showed difficulties in detecting particle-particle interactions

• CPFD Barracuda is an effective and useful tool for the scale-up process
  
  o Optimizing the operation conditions
  
  o Building engineering correlations