APPLICATION OF CIRCULATING FLUIDIZED BED REACTORS FOR PRODUCING CLEAN FOSSIL FUELS AND BIOFUELS

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Abstract

The use of fluidized bed systems in the petroleum industry has greatly contributed in the production of transportation fuels, especially after the discovery and wide application of zeolites and the Circulating Fluid Bed (CFB)-Riser reactor in Fluid Catalytic Cracking (FCC). A real commercial case of using the riser pilot plant to rank two new catalysts, which were subsequently used in a commercial unit, is presented. The results showed that the pilot plant correctly predicted the ranking of the two catalysts. In this paper in addition to FCC, Biomass Catalytic Pyrolysis (BCP) is considered as an important application for the use of CFB for converting biomass to bio oil.

Keywords

FCC, Biomass, Pyrolysis.

Introduction

In a Fluid Catalytic Cracking Unit (FCCU), a feedstock made of carbon, hydrogen, sulfur, nitrogen and sometimes small amounts of nickel and vanadium, enters the bottom of the riser. The preheated feed mixed with a hot catalyst up to 732°C, is vaporized and the zeolite containing particles initiate a series of endothermic reactions, producing on the one hand useful products such as gasoline bound naphtha, diesel bound light cycle oil and light olefins such as propylene and butylenes. At the same time, however, parallel reactions take place: coke deposits on the catalyst particles and deactivates the zeolite particles. The combustion of coke in the regenerator restores the catalyst activity and provides the energy required for the endothermic cracking reactions in the reactor side.

Typical commercial feedstocks used in the petroleum industry have a density (15°C) in the range of 0.8097 to 1.0079 g/ml and a carbon residue in the range of 0.00 to 6.5 wt.% on feed. In a commercial Fluid Cracking Unit (FCU), there is a frequent need to consider a change in the catalyst, because of improvements in the catalyst technology.

In a previous publication (Lappas et al., 2015), we consider laboratory techniques used to rank a priori new FCC cracking catalysts. It was concluded that for the prediction of absolute yields in commercial scale, a pilot plant riser reactor is the most reliable unit. Although the scale up factor of the pilot plant to a commercial unit is close to 500,000, this paper will present data which show that laboratory simulation of a commercial size reactor is possible provided that the pilot plant reactor zeros in the following design characteristics: (a) a mixing zone in the bottom of the riser for good distribution and vaporization of feed with hot catalyst particles, (b) a riser design of variable geometry in order to match the catalyst residence time of a commercial unit, (c) a design of disengagement zone separation zone at the exit of the riser for the separation of vapors from solid particles.

FCC Data Comparisons

The FCCU design characteristics, the feedstock and catalyst properties determine the feedstock conversion and the product yields and qualities. In the present paper we consider a real commercial case of using the riser pilot plant to rank two new catalysts, which were subsequently used in a commercial unit (Joyal et al., 2008). In Fig. 1 pilot plant data are used to plot the wt.% of feed converted to heavy oil (slurry) versus wt.% feed conversion. For a

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refiner it is important to find catalysts to minimize the yield of slurry. After commercial trial of the two catalysts, as shown in Fig. 2, it was found that the pilot plant correctly predicted the ranking of the two catalysts.

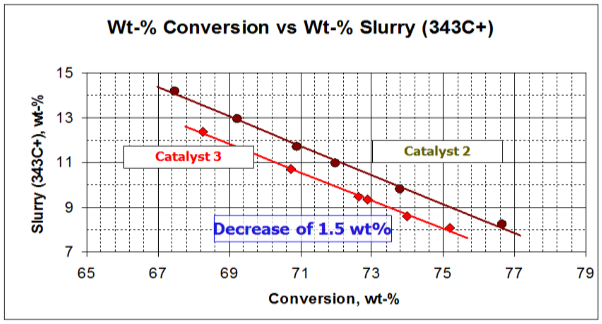

Figure 1. Pilot plant slurry yield comparison

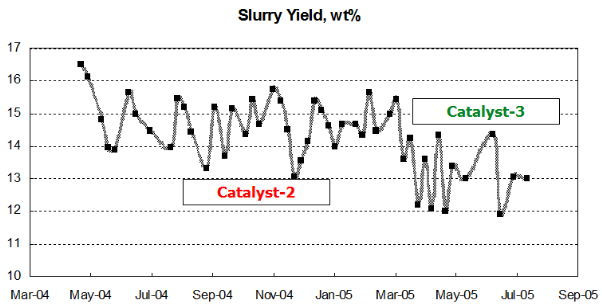

Figure 2. FCC commercial slurry yield

Biomass Catalytic Pyrolysis (BCP)

Following the positive feedback on the design of the FCC pilot plant, a new reactor design was undertaken for Biomass Catalytic Pyrolysis (BCP). The difference between the FCC and the BCP pilot plant was the geometry of the mixing zone at the entrance of the riser. The exact dimensions of the mixing zone were established from a reactor model based on the kinetic data (Kaushal and Abedi, 2010) and fluidization data obtained in a cold flow unit. From this analysis, it became evident that small biomass particles (300 to 500 μm) were required. In addition, the particle residence time in the mixing zone should be in the range of 15 to 45 seconds dependent on the pyrolysis temperature. A schematic diagram of the BCP pilot plant is shown in Fig. 3.

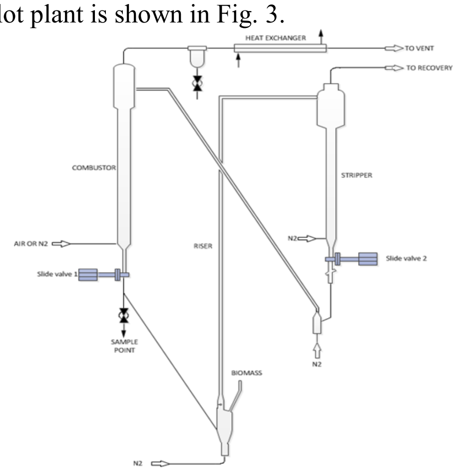

Figure 3. CFB Biomass Pyrolysis Pilot Plant Unit

In BCP a catalyst is used as heat carrier instead of silica sand. The pyrolysis vapors produced from pyrolysis reactions, undergo a series of dehydration, decarbonylation and decarboxylation reactions inside the catalyst pores. Extensive work (Iliopoulou et al., 2014) has shown that ZSM-5 is a preferred catalyst to produce low coke yields and bio oil with lower oxygen content than other catalysts such as Y zeolites. A typical yield curve is shown in Fig. 4. The bio oil carbon efficiency of the BCP process and ZSM-5 for producing bio oil with 20 wt.% oxygen is about 43%. A commercial process design will be discussed in the meeting.

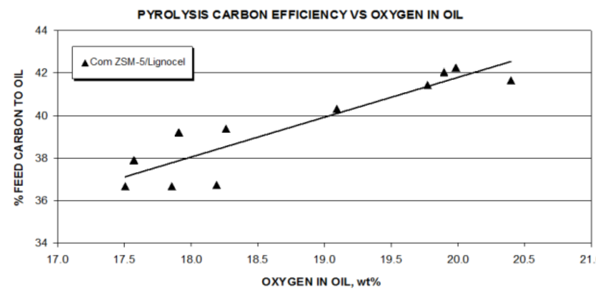

Figure 4. Pyrolysis Carbon Efficiency

Conclusions

In this study we will demonstrate that a CFB reactor is a valuable unit for producing clean fuels either in FCC or BCP. We will also focus on the differences in the design characteristics that should exist in order to optimize FCC and BCP operation. Finally, the needs for future work will be discussed in the presentation.

Acknowledgments

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