FLUID CATALYTIC CRACKING UNIT: A PRIMARY CONVERSION PROCESS OF PETROLEUM REFINERIES

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ABSTRACT

With the increase in population, the demand of useful refinery products is also increasing. Therefore it is becoming necessary to convert low value feedstock into more valuable products. Cracking is one such operation. Cracking is a process in which high molecular weight hydrocarbon are dissociated into smaller ones either by heating or by the use of catalyst. Fluid Catalytic Cracking (FCC) is a primary conversion process in petroleum refineries. It is widely used for theupgradation of low value feedstock into more valuable products. In this operation all types of feed from naphtha to Deasphalted oils can be formed easily from low value feedstock.

Keywords: Cracking, Deasphalted Oil, Naphtha Upgradation,

I. INTRODUCTION

Fluid catalytic cracking (FCC) is one of the most important conversion processes used in petroleum refineries. It is the primary conversion process. Common objective is to upgrade low value feedstock to more valuable products. It is widely used to convert the high-boiling, high-molecular weight hydrocarbon fractions of petroleum crude oils to more valuable gasoline, olefinic gases, and other products.[1][2][3][4] Cracking of petroleum hydrocarbons was originally done by thermal cracking, which has been almost completely replaced by catalytic cracking because it produces more gasoline with a higher octane rating. It also produces byproduct gases that are more olefinic, and hence more valuable, than those produced by thermal cracking.

II. PROCESS DESCRIPTION

The feedstock to an FCC is usually that portion of the crude oil that has an initial boiling point of 340 °C or higher at atmospheric pressure and an average molecular weight ranging from about 200 to 600 or higher. This portion of crude oil is often referred to as heavy gas oil or vacuum gas oil (HVGO). The FCC process vaporizes and breaks the long-chain molecules of the high-boiling hydrocarbon liquids into much shorter molecules by contacting the feedstock, at high temperature and moderate pressure, with a fluidized powdered catalyst.

In effect, refineries use fluid catalytic cracking to correct the imbalance between the market demand for gasoline and the excess of heavy, high boiling range products resulting from the distillation of crude oil.

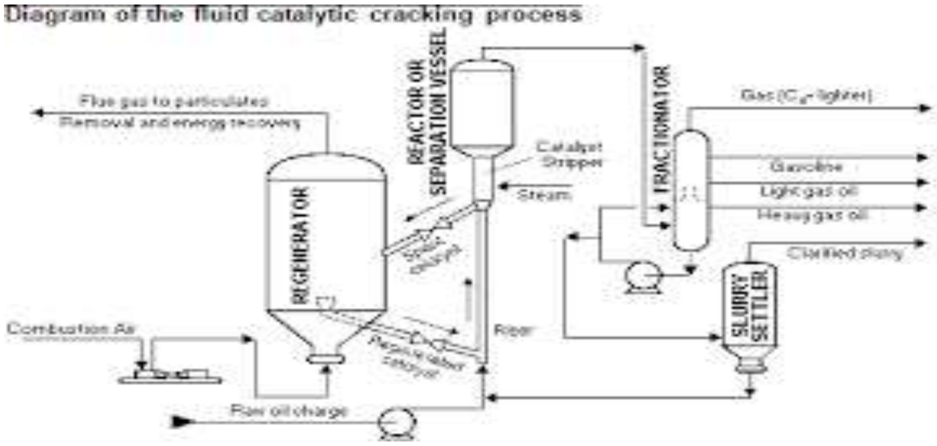

Fig. 1. Fluid Catalytic Cracking Unit

2.1 Riser and Reactor

The reactor and regenerator are considered to be the heart of the fluid catalytic cracking unit. The schematic flow diagram of a typical modern FCC unit in Figure 1 below is based upon the "side-by-side" configuration. The preheated high-boiling petroleum feedstock (at about 315 to 430 °C) consisting of long-chain hydrocarbon molecules is combined with recycle slurry oil from the bottom of the distillation column and injected into the catalyst riser where it is vaporized and cracked into smaller molecules of vapor by contact and mixing with the very hot powdered catalyst from the regenerator. All of the cracking reactions take place in the catalyst riser within a period of 2–4 seconds. The hydrocarbon vapors "fluidize" the powdered catalyst and the mixture of hydrocarbon vapors and catalyst flows upward to enter the reactor at a temperature of about 535 °C and a pressure of about 1.72 bar.

The reactor is a vessel in which the cracked product vapors are: (a) separated from the so-called spent catalyst by flowing through a set of two-stage cyclones within the reactor and (b) the spent catalyst flows downward through a steam stripping section to remove any hydrocarbon vapors before the spent catalyst returns to the catalyst regenerator. The flow of spent catalyst to the regenerator is regulated by a slide valve in the spent catalyst line.

Since the cracking reactions produce some carbonaceous material (catalyst coke) that deposits on the catalyst and very quickly reduces the catalyst reactivity, the catalyst is regenerated by burning off the deposited coke with air blown into the regenerator. The regenerator operates at a temperature of about 715 °C and a pressure of about 2.41 bar. The combustion of the coke is exothermic and it produces a large amount of heat that is partially absorbed by the regenerated catalyst and provides the heat required for the vaporization of the feedstock and the endothermic cracking reactions that take place in the catalyst riser. For that reason, FCC units are often referred to as being 'heat balanced'.

The hot catalyst (at about 715 °C) leaving the regenerator flows into a catalyst withdrawal well where any entrained combustion flue gases are allowed to escape and flow back into the upper part to the regenerator. The flow of regenerated catalyst to the feedstock injection point below the catalyst riser is regulated by a slide valve in the regenerated catalyst line. The hot flue gas exits the regenerator after passing through multiple sets of two-stage cyclones that remove entrained catalyst from the flue gas.

The diameter Riser diameter varies from 60-180cms.Height varies from 25-30 meters. It consists of thick refractory lining for insulation (10-13cms). Reaction occurs in 1.5 to 3.0 seconds before the catalyst and products are separated .Ratio of catalyst to oil ratio is normally 4:1 to 9:1 by weight.

2.2 Regenerator Flue Gas

Regenerator has two main functions.

i. Restores catalyst activity and supplies heat to crack feed.

ii. Spent catalyst contains 0.4 to 0.5 wt% coke.

Depending on the choice of FCC design, the combustion in the regenerator of the coke on the spent catalyst may or may not be complete combustion to carbon dioxide CO_2. The combustion air flow is controlled so as to provide the desired ratio of carbon monoxide (CO) to carbon dioxide for each specific FCC design.[1][5]

$$C + \frac{1}{2} O_2 \longrightarrow CO$$

$$CO + \frac{1}{2} O_2 \longrightarrow CO_2$$

The coke has only been partially combusted to CO_2. The combustion flue gas (containing CO and CO_2) at 715 °C and at a pressure of 2.41 bar is routed through a secondary catalyst separator containing swirl tubes designed to remove 70 to 90 percent of the particulates in the flue gas leaving the regenerator.

III. CATALYST USED

Modern FCC catalysts are fine powders with a bulk density of 0.80 to 0.96 g/cm3 and having a particle size distribution ranging from 10 to 150 µm and an average particle size of 60 to 100 µm.[5][6] The design and operation of an FCC unit is largely dependent upon the chemical and physical properties of the catalyst. The desirable properties of an FCC catalyst are:

i. Good stability to high temperature and to steam

ii. High activity

iii. Large pore sizes

iv. Good resistance to attrition

v. Low coke production

A modern FCC catalyst has four major components: crystalline zeolite, matrix, binder, and filler. Zeolite is the primary active component and can range from about 15 to 50 weight percent of the catalyst. The zeolite used in FCC catalysts is referred to as faujasite or as Type Y and is composed of silica and alumina tetrahedra with each tetrahedron having either an aluminum or a silicon atom at the center and four oxygen atoms at the corners. It is a molecular sieve with a distinctive lattice structure that allows only a certain size range of hydrocarbon molecules to enter the lattice. In general, the zeolite does not allow molecules larger than 8 to 10 nm (i.e., 80 to 90 ångströms[contradiction]) to enter the lattice.[6][7]

IV. CONCLUSION

In terms of both industry-wide throughput capacity and its overall effect on refining economics and operationsFCC is the single most important refining process downstream of crude distillation . FCC offers (1) high yields of gasoline and distillatematerial (in the range of 60–75 vol% on FCC feed), (2) high reliability and low operating costs, and (3) operating flexibility to adapt to changes in crude oil quality and refined product requirements. Also it produces significant volumes quantities of light gases (C1 to C4), including olefins. Light olefins are highly reactive chemicals that are valuable either as petrochemical feedstocks or as feedstocks to the refinery's upgrading processes (which produce high-octane, low-sulfur gasoline blendstocks). With suitable catalyst selection, FCC units can be designed to maximize production of gasoline blendstock (FCC naphtha), distillate blendstock (light cycle oil), or petrochemical feedstocks.

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