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Agglomerate behavior in a recirculating fluidized bed with sheds: Effect of agglomerate properties

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ABSTRACT

A radioactive particle tracking (RPT) technique was used to study the effect of the size and density of an agglomerate on its interactions with internal baffles in a fluidized bed, mimicking the stripper sheds of a Fluid Coker™. Dense agglomerates (mimicking Fluid Coker agglomerates with a high liquid concentration) have a lower residence time in the stripper section of the reactor than light agglomerates (mimicking Fluid Coker agglomerates with a low liquid concentration) and small dense agglomerates spend more time in the stripper section than large dense agglomerates. A simple thermal drying model is proposed that uses the particle tracking results to determine the rate of release of hydrocarbons vapors in and below the shed zone, vapors which are responsible for stripper shed fouling. The model predicts that small dense agglomerates dry quickly while large dense agglomerates retain up to 50% of their original liquid when they leave the bed. Up to 18% of the original liquid contained in large dense agglomerates is evaporated and released in and below the shed zone, and thus contributes to shed fouling.

1. Introduction

Fluid Coking™ (Fig. 1) is a process used to upgrade heavy oils through thermal cracking. Oil is injected in a downward-flowing fluid bed of hot coke particles, where it heats up and cracks into smaller vapor molecules. The down-flowing coke particles are then conveyed to a fluidized bed burner where they are reheated. Most of the oil must first crack in the liquid phase before it can vaporize at the reactor temperature.

Valuable oil vapors trapped between the coke particles are recovered through steam stripping before the coke particles are sent to the burner. The stripper section of the Fluid Coker consists of a system of baffles (sheds) that enhance the removal of hydrocarbon vapors from fluidized coke particles, and reduce gas back-mixing through the shed zone.

Although the coking reactions are relatively rapid [8] at the reactor temperature, most of the injected liquid is trapped [5] within wet agglomerates ranging from 1 to 20 mm in volume-equivalent diameter, where the temperature is significantly lower [1,7,21]. Because thermal cracking is endothermic, the effective reaction rate of the trapped liquid is dramatically reduced due to heat transfer limitations through the agglomerates [8,9]. Some of the agglomerates survive and reach the stripper region, where their liquid continues to react and release product hydrocarbon vapors.

Most of the hydrocarbon vapors released within and below the stripper shed regions flow up through the sheds, where they may crack and form solid deposits that foul their surfaces. Extensive fouling changes the shapes of the sheds, makes them thicker and reduces the free space between adjacent sheds through which coke flows (Fig. 2); this decreases the stripping efficiency and causes premature shutdown of the reactor. Experience with commercial Fluid Cokers has shown that the top shed row is the most heavily fouled. Stripper fouling can be slowed by raising the coker temperature and thus accelerating the reactions of the trapped liquid, but this reduces the yield of the valuable liquid product by also accelerating cracking of the vapors and increasing the yield of permanent gases.

It is, therefore, essential to study the motion of agglomerates within the stripper zone and, in particular, their residence time below the top stripper shed row, since the vapors released below this row are responsible for its fouling.

The radioactive particle tracking (RPT) technique allows the immediate determination of a radioactive tracer-agglomerate location within a certain space or measurement zone. As shown by Sanchez and Granovskiy [16], the RPT technique can be used to measure the degree of fouling of a shed and provide important information about the hydrodynamics of the fluidized bed where the shed is installed. In this study,

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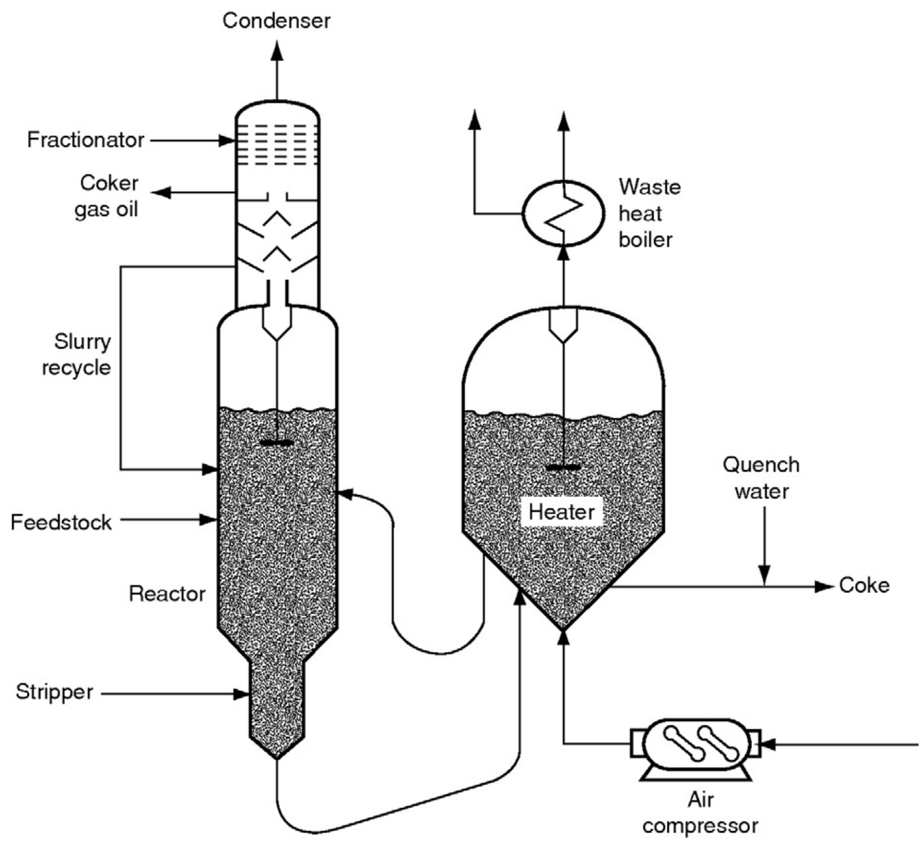

Fig. 1. Schematic diagram of a fluid coke system [17].

RPT is used to track agglomerates inside a recirculating fluidized bed focusing on a measurement zone that would correspond to the stripper region of a Fluid Coker.

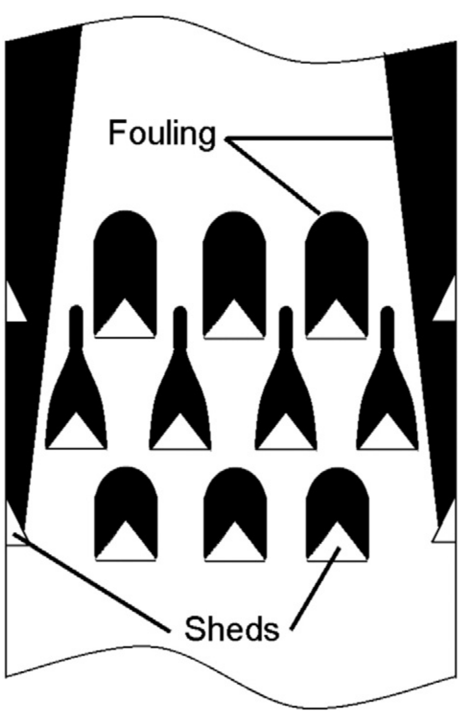

Fig. 2. Schematic of unwanted coke deposition (fouling) in the sheds and walls of the stripper section of a Fluid Coker.

Preliminary experiments have shown that the agglomerate motion is affected by agglomerate size and density, shed configuration, gas velocity and solids recirculation rate. In commercial Fluid Cokers, it would be very difficult to change fluidization velocity, shed geometry and solids recirculation rate, since they have already been optimized for the process. On the other hand, agglomerate properties could be changed by modifying the spray and attrition nozzles [5,10].

The objectives of this study were to:

- Determine how agglomerate properties, such as size and density, affect the motion of agglomerates in the stripper section of a cold flow recirculating fluidized bed.
- Predict the flow of hydrocarbon vapors reaching the top stripper shed row from the measured agglomerate motion characteristics in the stripper section.

2. Material and methods

Fluid coke, provided by Syncrude Canada Limited, was used as the fluidized material. Its particle density was 1450 kg/m^3 and its Sauter-mean diameter was 140 μm. A coke mass of 19 kg was utilized in the laboratory scale fluid bed system.

An epoxy/gold tracer-agglomerate prepared as suggested by Godfroy [6] was selected as the radioactive source. When gold is radiated in a nuclear reactor (for this research, the Material Test eactor at McMaster University in Canada), some of it transforms into Au^{198} isotope with a half-life of 2.69 days [2]. In this study, the tracer-agglomerate radiation decreased gradually from 166 to 70 μCi (over a week). The simulated agglomerates were constructed using epoxy resin (West System, Inc. Bay City, MI) and, gold powder (Stream Chemicals, Inc. Newburyport, MA). For simulated