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Original Research Paper

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

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ABSTRACT

A Radioactive Particle Tracking (RPT) technique was used to study the effects of the internal baffles in the stripping section of the Fluid Coker™, called sheds, have on the behavior of wet agglomerates that are formed when residual oil is injected into the Coker. Vapor emitted by reacting wet agglomerates below the sheds rises and causes shed fouling. The release of vapor from agglomerates can be estimated by combining the RPT results with a coking reaction model. The study found that the sheds reduce the time agglomerates spend in the shed zone, which in turn reduces the amount of organic vapor that reaches the sheds, but at the same time increase the wetness of the agglomerates that exit to the recirculation line, which results in the loss of valuable liquid. The research also found that the best type of shed, from the point of view of agglomerate motion, is the mesh-shed. Finally, experimental data indicate that reducing the cross sectional area of the sheds from 50% to 30% increases the time that the agglomerates spend above the shed zone, and thus reduces the flow of vapor emitted below the sheds.

1. Introduction

Fluid Coking™, as shown in Fig. 1 [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 fluid bed burner where they are reheated.

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 Coker™ consists of a system of baffles or sheds that enhance the removal of hydrocarbon vapors from fluidized coke particles, and prevent gas back-mixing through the sheds.

Although the coking reactions are relatively rapid [2], the liquid needs to reach the reactor temperature, and most of the injected liquid is trapped [3] within wet agglomerates ranging from 1 to 20 mm [4–6]. Because thermal cracking is endothermic, the effective reaction rate of the liquid trapped is dramatically reduced due to heat transfer limitations through the agglomerates [2,7,8]. Some of these agglomerates survive and reach the stripper region, where their liquid continues to react and release product hydrocarbon vapors.

Most of the hydrocarbon vapors released below the top stripper shed rowflow up through the sheds, where they may crack and form solid deposits that foul the shed surfaces. Extensive fouling changes the shapes of the sheds, makes them thicker and reduces the free space between adjacent sheds through which coke flows, as shown in Fig. 2; this decreases the stripping efficiency and can cause premature shutdown of the reactor. Experience with commercial Cokers has shown that the top shed row is the most heavily fouled. Stripper fouling can be slowed by raising the Coker temperature, but this reduces the yield of the valuable liquid product.

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

A Radioactive Particle Tracking (RPT) technique allows the immediate determination of a radioactive tracer-agglomerate location within a fluidized bed: as an example, Upadhyay and Roy [9] used radioactive particle tracking with tracers of different densities to study particle segregation in non-recirculating fluidized beds. Sanchez et al. [10] showed that RPT can be used to track model agglomerates in a cold model of the Fluid Coker stripper. As

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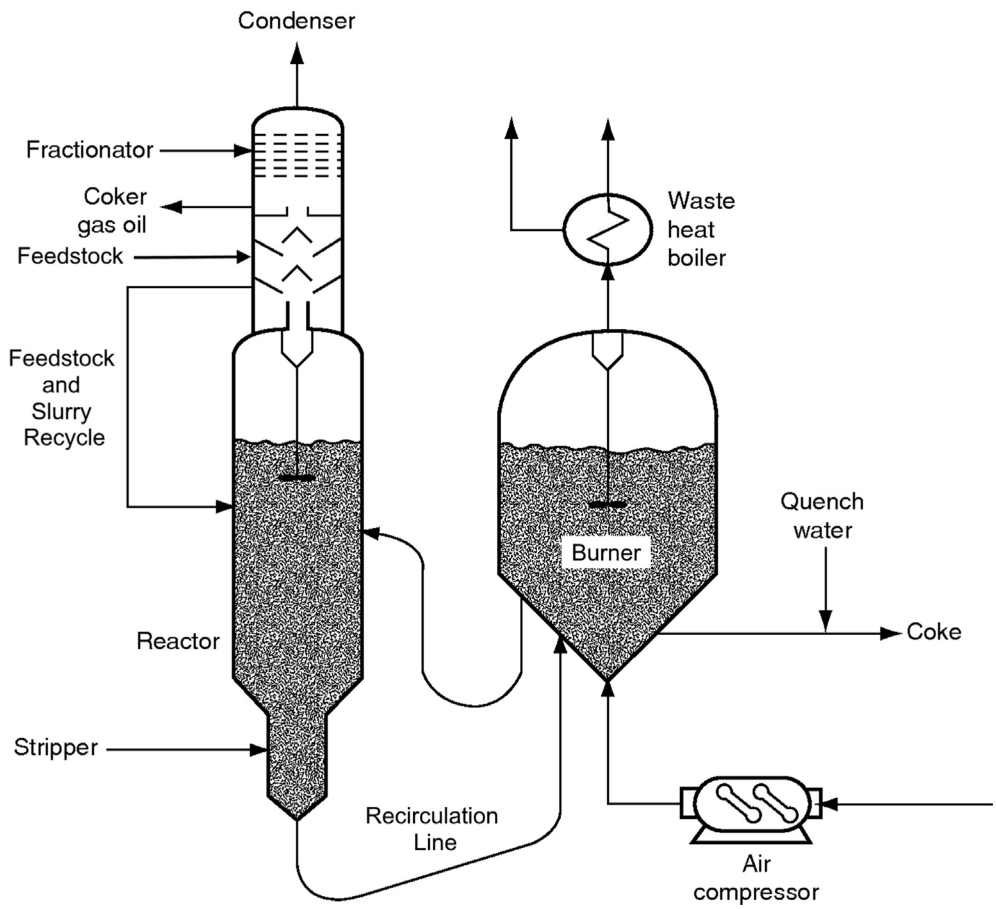

Fig. 1. Schematic diagram of a fluid coke system.

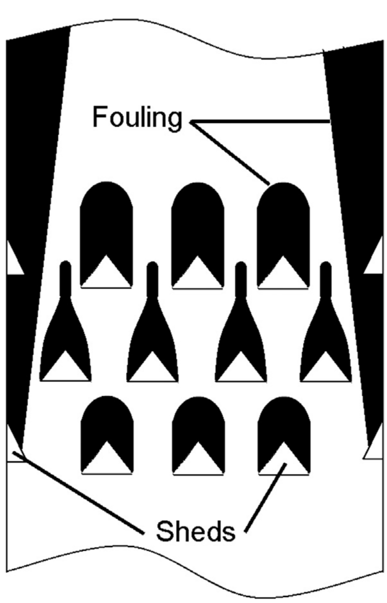

Fig. 2. Schematic of unwanted coke deposition (fouling) on the sheds and walls of the stripper section of a Fluid Coker.

showed by Sanchez and Granovskiy [11], the RPT technique could also be used to measure the degree of fouling on a shed.

The objectives of this study were to use RPT in a cold flow recirculating fluidized bed simulating the stripper section of a Fluid Coker™ to determine how the motion of agglomerates is affected by:

- Determining how agglomerate properties, such as size and density, affect the motion of agglomerates in the absence or presence of sheds.
- Testing different types of sheds, shed configurations and sizes to determine their effect on the motion of agglomerates in the stripper section.

The release of vapors from agglomerates can, then, be estimated by combining the RPT results with a coking reaction model.

2. Materials and methods

Fluid coke, provided by Syncrude Canada Limited, was used as the fluidized material. Its particle density is 1450 kg/m^3 and its Sauter-mean diameter is 140 μm. A bed mass of 19 kg was utilized in the laboratory scale fluid bed, giving a defluidized bed height of 0.75 m. The minimum fluidization velocity was 0.010 m/s.

An epoxy/gold tracer-agglomerate prepared as suggested by Godfroy [12] was selected as the radioactive source. When gold is irradiated in a nuclear reactor such as the Material Test Reactor at McMaster University in Canada, some of it transforms into Au^{198} isotope with a half-life of 2.69 days [13]. In this study, the tracer-agglomerate radiation decreased gradually from 166 to 27 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 agglomerates of lower densities, the carrier was created using epoxy resin mixed with glass bubbles (Freeman Manufacturing and Supply Company, Avon, OH). For larger simulated agglomerates with high densities, a nylon ball (McMaster-Carr, Aurora, OH) was selected as the carrier