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Modeling the thermo-hydraulic performance of direct fired heaters for crude processing

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ABSTRACT

Although fouling in heat exchangers for crude processing has received much attention in recent years, the problem still remains unsolved and the economic losses associated to it are significant. Development and application of fouling models due to coke deposition on the heat transfer surface have been achieved with a high degree of certainty for situations where single phase occurs. Fouling rates in systems where two phase flow takes place, as in fired heaters, have been yet studied little. In this work a fouling rate model is adapted to the case of two phase flow conditions and used to predict the thermo-hydraulic behavior of fired heaters. The model is used to predict how fuel consumption is increased as the thermal resistance builds up on the heat transfer surface; additionally, production losses as a consequence of increased pressure drop are determined.

1. Introduction

A crude preheat train consists of a series of heat exchangers where energy is recovered and used to condition the temperature of the crude oil for the separation of its components in a distillation column. Due to the high temperature required, a fired heater is used to provide the energy required before entering the separation unit. During normal operation, fouling builds up on the heat transfer surface of the heat exchangers causing pressure drop to increase to the extent that plant throughput falls; the usual practice to avoid a drop in production rate is to bypass the fouled units. Although throughput is maintained, the thermal duty must be compensated for by increasing the heat load on the fired heater. Fired heaters are not exempt from fouling and when it occurs it becomes an important bottleneck that commonly leads to plant shut down.

Fouling in fired heaters occurs as a consequence of the chemical transformation of crude oil components into coke; the mechanism under which this process is likely to occur was presented by Watkinson and Wilson [1]. Other studies have focused on the simulation of the chemical transformation known as ageing [2–4] when it takes place in single phase flow. As described above, the higher thermal resistance caused by the deposition of coke on the heat transfer surfaces results in higher energy consumption which apart from increasing production costs, also increases the amount of green house gases discharged into the atmosphere. Higher thermal resistance also brings about higher flow resistance; thus if no additional pumping power is available, plant throughput is reduced. Furthermore, the fouled surfaces yield higher wall temperatures which might, eventually cause tube rupture. The estimated losses due to the combined effects of fouling in the oil refining industry are of billions of dollars per year [5].

The mitigation of fouling by means of the manipulation of operating variables such as temperature and velocity has been studied by several researches [6–8]. The use of tube inserts to mitigate fouling has also been observed [9,10]. Klaren et al. [11] proposed the use of fluidized solid particles which constantly remove the sediment and break up the boundary layer improving the heat transfer coefficient. Fouling in heat exchanger networks can be mitigated reducing wall temperature by properly choosing the network structure [12].

Significant advances on the modeling of fouling rates in shell and tube heat exchangers have been achieved since Ebert and Panchal [13] first introduced the concept of the threshold curve [7,14]. Modeling the fouling rates on the crude side in fired heaters is complicated since temperature and wall shear stress that controls fouling are affected by local pressure and phase flow; a generalized model that accounts for these effects was developed by Polley [15].

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