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ANALYSIS OF THE ENVIRONMENTAL AND ECONOMIC IMPACT OF FOULING IN CRUDE PREHEAT TRAINS FOR PETROLEUM DISTILLATION

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ABSTRACT

In general, the first main step of petroleum refining consists in the distillation of the crude oil stream. In order to reduce the energy consumption, the hot product streams and pumparounds from the distillation column are used to preheat the crude oil in a series of heat exchangers called crude preheat train. However, during the refinery operation, there is an increase of energy consumption due to accumulation of deposits over the thermal surface of the crude prehat train. In this context, the objective of this paper is to present an analysis of the fouling impact associated to the petroleum distillation. Based on data from three Brazilian refineries, the economical losses and the additional CO_2 emissions due to fouling are quantified. This analysis is conducted comparing the behavior of the fouled crude preheat train with the corresponding performance of the equipment in a clean condition. These results are important to quantify the environmental and economical driving forces for fouling management activities.

INTRODUCTION

Fouling is a chronic operational effect that is considered the major unsolved problem in heat transfer technology. This problem can affect the industrial performance in relation to economical and environmental aspects.

In petroleum refineries, the crude stream must be heated to a required temperature in a distillation column which separates the crude oil in its main fractions (naphtha, kerosene, diesel, etc.). This step explores the different volatilities of the petroleum components, and involves considerable energy consumption.

So, in order to reduce this energy consumption, the crude preheat train heats the crude oil stream using the hot product streams and pumparounds from the distillation column. This energy integration scheme corresponds to about 60-70% of the total heat load of crude heating in the atmospheric distillation (Panchal and Huangfu, 2000).

During the operation, fouling reduces the thermal effectiveness of the preheat train. This phenomenon brings an increase in fuel burning in the furnaces, which generates significant economical losses.

Another consequence due to fouling is related to the environmental penalties, mainly due to CO_2 emissions. Considering that there are currently 750 refineries worldwide, the total amount of emitted CO_2 due to fouling is approximately 88 million tons per annum (Müller-Steinhagen et al., 2009).

In this context, this paper presents an analysis of the economical and environmental impact of fouling in the crude preheat train for three Brazilian refineries.

METHODOLOGY

The Petrobras R&D Center (Leopoldo Américo Miguez de Mello Research & Development Center - CENPES) has developed an on-line heat exchanger performance evaluation system called Fouling^{TR}. Nowadays, this system is installed for monitoring the thermal performance of crude preheat trains in four Brazilian refineries.

Fouling^{TR} can evaluate the performance of the entire train including or excluding the presence of fouling. The simulation of the crude preheat without fouling is conducted through the integration of a process flowsheet simulator (Petrox from Petrobras) together with a commercial code for heat exchanger rating (Xist from HTRI). The behavior of the fouled crude preheat is evaluated based on measured values of mass flow rates and temperatures obtained from process sensors. Therefore, it is possible to determine the heat load absorbed by the heat exchanger at the current operational conditions and the corresponding value at clean conditions. The difference between these values is the additional heat load which must be supplied due to the fouling problem. A more detailed description of the system can be found in Liporace and Oliveira (2007).

RESULTS

The proposed analysis is explored using crude preheat trains of three Brazilian refineries, called 1, 2 and 3, with the following throughputs: 190,000 bpd, 105,000 bpd and 308,000 bpd, respectively. The set of data collected contains the total heat load of the crude preheat trains in the clean and dirty conditions. The time series data of the refineries encompass 2076 days for refinery A, 1250 days for refinery B, and 1574 days for refinery C.

Based on these data, it is possible to evaluate the reduction of the energy absorbed in the crude preheat train due to fouling. Figures 1, 2 and 3 show typical profiles of this reduction in the three refineries investigated in determined periods. It can be observed that the energy penalty increases during the process operation, because there is a continuous reduction of the thermal effectiveness of the thermal equipment.

Considering the entire set of data, the average reductions of the energy absorbed in the crude preheat trains, in relation to the clean condition, were 10.5%, 16.2% and 6.9%.

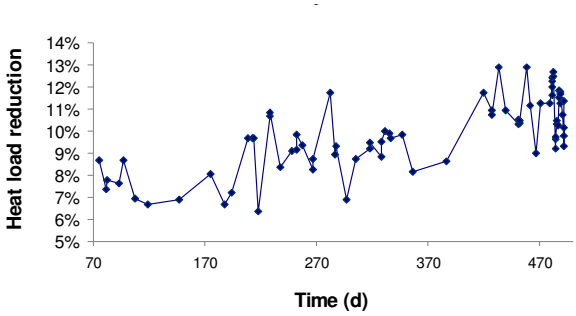

Fig.1. Reduction of the heat load of the crude preheat train in relation to the clean condition – Refinery 1.

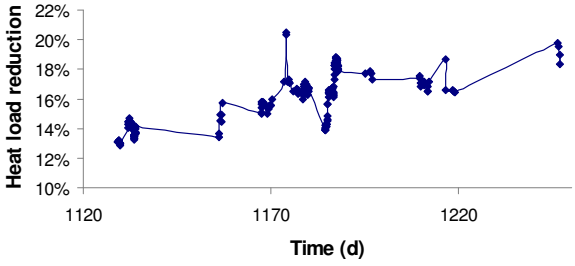

Fig.2. Reduction of the heat load of the crude preheat train in relation to the clean condition – Refinery 2.

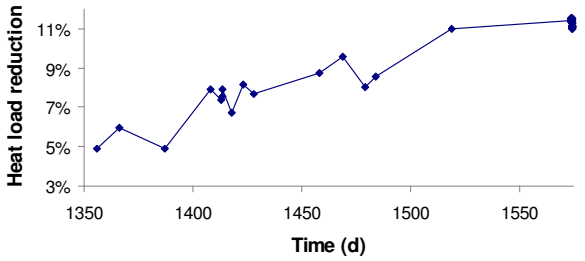

Fig.1. Reduction of the heat load of the crude preheat train in relation to the clean condition – Refinery 3.

Economical impact

The collected data of the three crude preheat trains allows an assessment of the economical impact of the additional energy consumption due to fouling. Considering a fuel oil with a LHV equal to 44.3 GJ/t and a price equivalent to 300 US$/t (Jan/2010), the average fouling costs per crude barrel are presented in Figure 4.

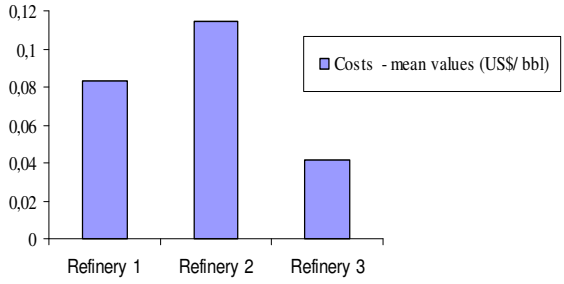

Fig.4. Fuel costs due to fouling

Environmental impact

Considering the same fuel oil in this analysis, with an estimated carbon percentage of 85.6% (Smith, 2005), the average carbon emissions due to fouling in each refinery are shown in Figure 5.

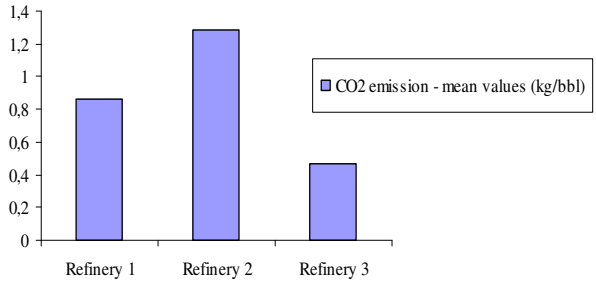

Fig.5. Emissions due to fouling

Analysis applied for a typical refinery

Based on the results of Refinery 1, it can be estimated that, for a typical 200,000 bpd refinery, the crude preheat train fouling would be responsible for about US$ 6 millions/year of extra energy costs and 62500 metric tons/year of CO_2 emissions. Considering an estimate of the total emissions equivalent to about 0,16 t CO_2 / t oil processed (Chan, 2007), these additional emissions would correspond to 3.9% of the total carbon footprint of the refinery.

CONCLUSIONS

This paper presented an analysis of the economic and environmental impacts of fouling in crude preheat trains of three Brazilian refineries.

During the period considered for each refinery, the average reductions of the energy absorbed in the investigated crude preheat trains ranged from about 7% to 16%. As a consequence, the average economical impact of fouling per barrel processed in the crude preheat trains ranged from 0.04 US$ to 0.11 US$ and the environmental impact related to carbon emissions ranged from 0.46 kg to 1.28 kg.

In this context, these values indicate considerable economical and environmental driving forces in the effort to mitigate fouling in crude preheat trains.

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