THE FOULING PHENOMENOM IN THE SHELL-TUBE HEAT EXCHANGERS OF ALGIERS REFINERY

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ABSTRACT

Crude oil fouling in refinery preheat exchangers is a chronic operating problem that compromises energy recovery in these systems. Progress is hindered by the lack of quantitative knowledge of the dynamic effects of fouling on heat exchanger transfer. Generally, crude oil flows through the tube side while various other hot streams and pump-around streams flow through the shell side in the heat exchangers. Fouling in heat exchangers has been the subject of intensive research by several groups of investigators. For that, in this study, we will consider the fouling phenomenon of the heat exchangers tubes for the preheat circuit of the Algiers refinery E101 CBA and FED, which are used for the heating of the crude oil before its division, are exposed to the problem of fouling at the tube side of heat exchangers.

Keywords: *Fouling, Crude oil, Heat exchanger, Fouling resistance, Heat transfer, Fluid temperature*

NOMENCLATURE

Symbols :

Rd	Fouling resistance, m². °C/kW
U_S	Total coefficients of surface heat transfer at the dirty state, kW/m². °C
U_p	Total coefficients of surface heat transfer at the clean state, kW/m². °C
M	The flow mass of the cold fluid (the crude oil), m^3/h
Cp	The heat-storage capacity, kJ/kg. °C
t_e , t_s	Output and input temperatures of the crude oil, respectively, °C
T_e , T_s	Output and input temperatures of the ebb of head respectively , °C
P_e, P_s	Inlet and outlet pressure of the crude oil respectively , bar
A	The external surface of heat transfer, m²
F ΔTm	The difference in the logarithmic temperature, °C
d_4^{15}	Density
h_0	Heat transfert coefficient of external film, kW/m². °C
hi_0	Heat transfert coefficient of internal film brought back to external surface, kW/m². °C.

1. INTRODUCTION

Development and research on thermal transfer in compact heat exchangers became significant during the last years. Although the number of compact heat exchangers applied to the industrial plants increases, such as the tube and calenders exchangers, there is always a lack of information about the heat exchange phenomenon along the heat-transferring surface. The manufacturers reserve increasingly significant budgets in the search of a maximum capacity exchange and a high compactness [1].

One of the major problems with which the heat exchangers are confronted, intended for the chemical, oil, food industries is accumulation, on the heat-transferring surfaces of substance organics or of dissolved matters or present in suspension in the food fluid [2].

This phenomenon, called fouling, with correct operation of industrial plants and, in particular, of heat exchangers. It constitutes, so a major problem in the design and the operation of this equipment and that, since the beginning of century. As an example, the Algiers Refinery always suffers from problem of stopping tubes of heat exchanger. For that, an experimental study of this phenomenon has been undertaken in site on the cell of heat exchangers E101 CBA and E101 FED intended for crude heating before its fractionation, which are exposed to the fouling problem with dimensions tube of heat exchangers.

Many works were devoted to study the effect of the one thermophysical properties on the coefficient of transfer and the pressure loss. Indeed, R.M. Manglik and A.E. Bergles (2002) are interested in the study of the influence of the mass throughput on the temperatures of the two fluids and the coefficient of heat transfer along the heat-transferring surface [2]. The coefficient of heat transfer according to the quality of vapor to various heat fluxes.

Chagny et al. (2000) studied the influence of liquids properties on the thermal transfer for various values of Prandtl and a broad range of Reynolds number [3]. Sarma et al..(2002, 2003, 2005) presented a new approach to envisage the coefficient of heat transfer of convection in a tube for various tubular distributions, they proposed the correlations generalized for factors of forecast of friction and coefficients of heat transfer [4-5-6]. Naphon who studied the characteristics of thermal transfer and the loss of pressure in the horizontal of heat exchanger [7]. Manglik and Bergles devoted their studies to the correlations of thermal transfer and fall of pressure for streamline flows and turbulent [8-9]. Haraburda described a method of calculation of thermal transfer coefficient on the side calendre.

2. EXPERIMENTAL PROCEDURE

The study was made on the level of three cells of heat exchangers of the circuit preheats of the Algiers refinery (Fig.1). Vat of storage, the crude oil leaves at the ambient temperature, one of the three centrifugal pumps P 101, drives back it towards the atmospheric unit of distillation U101, while crossing the two circuits of the E101 battery: E101 CBA and E101 EFD, which is of type shell-tube with floating head. The crude crosses the battery with dimensions tube where it is heated using the backward flow head, which is a mixture of light products coming from the top of the fractionating column C101 on the level of the plate N46. Oil passes then by the electrostatic desalter by the addition of treated water and caustic soda. Treated water is injected at the entry of the E101 exchanger and the entry of the desalter, with an aim of washing the crude and of involved with it salts which are present there.

Each cell is made up of three heat exchangers of the type tube-calenders, laid out in series.

2.1 ASSUMPTION SIMPLIFYING

Being given the non existence of average adequate measurement techniques to separately treat each exchanger constituting the cells, the three exchangers in series were regarded as being only one exchanger.

Our experimental study is based on the following assumptions.

1. The same crude oil flow crosses the tube side for each exchanger,
2. The same backward flow crosses the calenders side for each exchanger,

3. The number of total tubes is the sum of the each heat exchanger tube,
4. The total number of tube side master keys is equal to three times of the number of tube side master keys for each heat exchanger,
5. The output and input temperatures of the two fluids are taken at the ends of the cell.

Fig. 1 Picture of the E101 CBA heat exchanger

3. CALCULATION METHOD

In the present study, the evolution according to the time of the fouling resistance of the crude oil passer by tubes was studied by considering each cell, consisted of three exchangers in series, as being only one exchanger with three master keys and twelve master keys with tube for each cell E101 CBA and E101 EDF.

The calculation of the fouling resistance was made by using the following relation:

$$Rd = \left(\frac{1}{U_S}\right) - \left(\frac{1}{U_P}\right) \qquad (1)$$

U_S and U_P are the total coefficients of heat transfer of surface at the dirty state and the clean state, respectively. The total coefficient of heat transfer of surface at the dirty state was given in the course of time, via the expression:

$$U_S = \frac{m.C_P.(ts-te)}{A.F.\Delta Tm} \qquad (2)$$

m is the flow mass of the cold fluid (the crude oil), C_P is the heat-storage capacity, te and ts are the exit and inlet temperatures respectively, A the external surface of heat transfer, (F ΔTm) the difference in the logarithmic temperature and U_S is the total coefficient of heat transfer brought back to external surface.
This relation is drawn from the assessment of energy on the heat exchanger by supposing the isolated system and the physical properties of the two fluids, as well as, the coefficient of heat transfer remain constant along the exchanger.

3.1 Calculation of Up

In the Algiers refinery, the operating conditions at the boundaries of the E101 exchanger are variable, it is necessary to revalue the total coefficient of heat exchange in the proper conditions Up.

$$\mathrm{Up} = \mathrm{h_0 h_{i0}}/(\mathrm{h_0} + \mathrm{h_{i0}}) \qquad (3)$$

With:
h_0: The heat transfer coefficient of external film.
h_{i0}: The heat transfer coefficient of internal film brought back to the external surface.

4. RESULTS AND INTERPRETATION

The heat exchangers used in the Algiers refinery tend to support the chemical reaction fouling, much more than any other type of the fouling.

This is proven, in the present study, through the analyses carried out in laboratory. It showed that:

- The chemical reaction fouling is prevailing it, because of the strong presence of hydrocarbons in the deposits.
- The particulate fouling is negligible because of the weak presence of the sediments.
- The participation fouling: according to the analyses, the quantity of salts is very weak in the crude.
- The corrosion fouling: the weak presencein the crude of the corrosive elements: Cl^-, NaCl, mgCl....
- The Biological fouling: according to the analyses carried out on the water of washing used in the refinery, it was noted that there is a weak presence of bacteria in this water, from where a very light bacteriological development.

4.1 TEMPORAL EVOLUTION OF THE FOULING RESISTANCE

Fig. 2 shows the width of the damage caused by the fouling in Algiers Refinery.

Fig 2 Example of a fouling exchanger

All the results for the fouling resistance for both series are presented in the form of curves on Fig.3 and Fig. 4

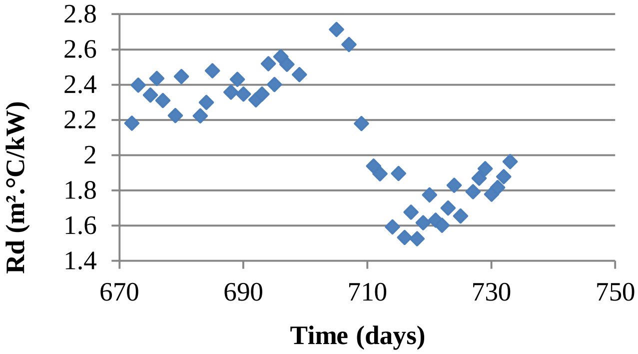

Figure 3. Temporal evolution of the fouling resistance for the E 101 CBA series

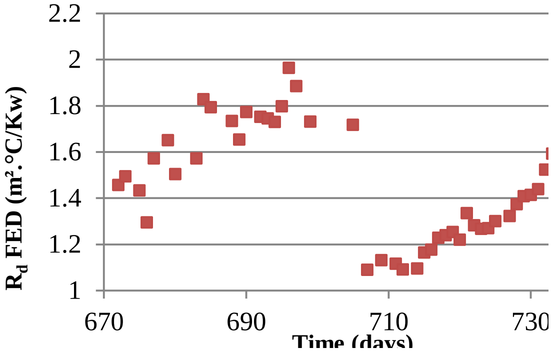

Figure 4. Temporal evolution of the fouling resistance for the E 101 FED series

According to the values of these resistances, which are the majority higher than zero, these series present a state of fouling.This is obvious since, as mentioned before, these exchangers were in service since more than one year, and according to the studies carried out on the same series by Dr. Oufer in the year 2000 [10], fouling starts with apparaitre after approximately 160 days of its startup.

The curves presented show that the temporal evolution of the fouling resistance, seems to follow an asymptotic evolution which conforms to the model of Kern and Seaton [11], with the absence of the induction period. That can be explained by the delay recorded between the last cleaning which corresponds to t=0, and the beginning of experiments. As it appears clearly as the fouling resistance represents increases with the time until reaching a maximum value about 2,7 m² °C/kW for the battery E 101 CBA and about 2 m² °C/kW for the serie E 101 FED; this in the first part of the curve which varies at the time from 670 to 705 days, beyond, one observes a reduction in the fouling resistance, compared to the first part of study. It attack the value of 1,9 m² °C/kW for the battery E101 CBA and about 1,6 m² °C/kW for the cell E 101 FED.

The reduction of the fouling resistance in the two curves of Fig. 3 and Fig. 4 is due to the need for a stop emergency for one exchanger of the series E101 CBA, and of the same with the variations of the operating conditions in the Algiers refinery, which are:

- Increase in the flow which is twice higher than that of the last year, from where increase the fluid speed (crud oil);
- The good quality of the crude oil: a very low content salts and sediments;
- The washing water of the crude oil is well water treated and does not pose a problem of tartar and corrosion.

The maximum values of the fouling resistance represent an asymptotic resistance, since the series functioned since more than one year, a sufficient period so that the resistance asymptotic value is reached. The fluctuations observed on these curves are due with the variation of flow which, while acting on the shear stress to the wall, causes réentrainement particles of the deposit or their deposition according to the sent flow value.

In the same way, according to the curve of Fig. 5, it appears clearly which the fouling resistance is higher in battery E 101 CBA than in battery E 101 FED; and this is right because of the position of the one batteries compared to the other (the first battery undergoes a higher flow of curde oil and the more fouling).

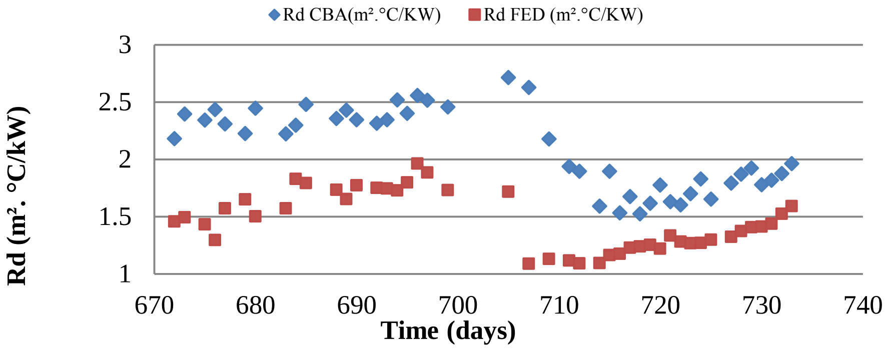

Figure 5. Temporal evolution of the fouling resistance for the two series of exchangers [12]

4. CONCLUSION

This study was devoted to the fouling phenomenon of three cells of exchangers of heat circuit preheats of crude of the Algiers refinery

The curves illustrating the evolution of the fouling resistance in the course of time followed an exponential pattern in conformity with the model of Kern & Seaton. The absence of the induction period was mainly the consequence of a bad cleaning, or shifts between the present study and the beginning of operation of the exchangers after the last stop.

The chemical analyses of the deposit showed that chemical reaction fouling is prevailing, because of the strong presence of hydrocarbons in the deposits.

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