Proceedings of International Conference on Heat Exchanger Fouling and Cleaning - 2013 (Peer-reviewed)
June 09 - 14, 2013, Budapest, Hungary
Editors: M.R. Malayeri, H. Müller-Steinhagen and A.P. Watkinson
Published online
www.heatexchanger-fouling.com

FOULING MONITORING IN CRUDE OIL PREHEAT TRAINS

H. Erdener Akınç[1], M. Becer[2] , M. Bakır[1] , Y. Özçelik[3] and F. Balkan[3]

[1] TÜPRAŞ, Turkish Petroleum Refineries Corporation Head Office, Kocaeli/TURKEY
[2] TÜPRAŞ, Turkish Petroleum Refineries Corporation İzmir Refinery, Kocaeli/TURKEY
(Corresponding Author: metin.becer@tupras.com.tr)
[3]Ege University, Chemical Engineering Department, İzmir/TURKEY

ABSTRACT

Fouling in heat exchangers is one of the major problems in chemical process industries, especially in refineries and considered as the main source for energy loss, reaching up to 2% of the refinery's total energy consumption. In the recent years, due to the challenging refinery margins, there is a profound interest in minimizing the energy consumptions in all oil refinery applications. As fouling formation occurs, the heat transfer capacity of the exchangers decrease; thus higher heat load is required in the furnace which leads more fuel gas/ fuel oil consumption in the furnace. Also, the amount of greenhouse gas emissions increase. This paper aims proper fouling management, which is based on heat exchanger simulation, data monitoring and fouling prediction. For this purpose, a method for monitoring the exchanger fouling factor, R_f, is developed by simulating the crude oil unit preheat train. By considering the effects of physical and chemical properties such as temperature, pressure, composition, etc. of both tube and shell flows of each exchanger, the clean heat transfer conditions are being simulated. The fouling factor (or fouling resistance), R_f, is monitored using this clean heat transfer coefficient and the actual heat transfer coefficient obtained from real time data. The simulation results (clean case), were found to be consistent with real time data taken after the cleaning period from refinery crude oil distillation unit.

INTRODUCTION

In a refinery, crude oil is first introduced to the atmospheric crude oil distillation unit; where it is being separated into its fractions such as LPG, naphtha, kerosene, diesel and atmospheric residue due to their different boiling points. Crude distillation is an energy intensive process reaching up to 14% of the total refinery energy consumption. In the current process, the crude oil is being heated via products (light, heavy distillates and atmospheric residue) and pump-around streams in first and second pre-heat exchanger trains prior to the crude oil distillation furnace. In order to reduce the energy consumption in the furnace, the efficiency of the heat exchangers in the preheat trains is very crucial. However, as the process goes on, due to the chemical and physical nature of the streams, fouling formation occurs on heat exchange surfaces and affects the heat exchangers' thermal and hydraulic performance negatively. Fouling is mainly defined as the formation of deposits on heat exchange surfaces due to sedimentation, crystallization, biological growth, chemical reactions, corrosion products, freezing or their combination [1,2]. The deposit formation due to chemical reactions may be complex in nature, and will include several mechanisms such as autoxidation, polymerization, cracking or coke formation. If there is ambient oxygen, it will catalyze the gum formation which is usually seen in hydro-processing units. Gum-like material will also be observed in jet fuel, gas oil and similar products upon heating due to the precipitation of paraffinic hydrocarbon mixtures [3]. Thus, temperature, pressure and flow rate are important operating parameters which affect the fouling formation. Usually, the temperature increase will lead to an exponential increase in the chemical reaction rates; pressure increases the solubility of the oxygen thus will increase the gum formation rate. Flow rates, however, will have a reverse effect such that higher velocities make it difficult for deposits to attach to the surface.

Fouling in the crude oil preheat trains is considered as ~20% of all heat exchanger fouling [4]. Therefore, there is a profound interest in cutting down the energy losses due to fouling by proper monitoring and prevention methods. The fouling of a heat exchanger can be monitored via the overall fouling resistance, R_f . R_f, is defined as the difference between dirty and clean overall heat transfer resistances and shown as;

$$R_f = 1/U_d - 1/U_c \qquad (1)$$

It might be easier just to follow the dirty heat transfer resistances through real time data of the refinery, however in order to monitor fouling, one will need the clean heat transfer resistances for the same flow and operation conditions of that heat exchanger. Thus, simulating the exchanger is inevitable.

Monitoring is of vital importance in both observing the actual fouling resistances and modeling fouling rates. Polley et al. [5] monitored the crude oil fouling to extract fouling model parameters. They proposed a short-cut approach by assuming linear variations of the temperature (wall or film) and showed that Ebert and Panchal equation gives better results than ESDU model. Liporace et al. [6] described an online heat exchanger performance evaluation system based on rigorous simulation of the equipment to predict both the dirty and clean overall heat transfer coefficient. A real-time comparison between these two values was a measure of the actual performance of the heat exchanger and/or that of the preheat train.

METHODOLOGY

This paper gives an insight on the methodology driven in order to monitor fouling in a refinery crude oil plant via overall fouling resistance, R_f. In this respect, a software is developed in order to calculate the clean and dirty heat transfer resistances by using real time refinery data, such as temperature, pressure, flow, distillation data of each stream and heat exchanger design specifications'. For this purpose, the crude oil plant first (upstream of desalter) and second (downstream of desalter) preheat heat exchanger trains are chosen as pilot; and temperature indicators are placed in all inlet and outlet streams of both shell and tube sides of the exchangers. The schematic view of the process is given in Figure 1 and 2.

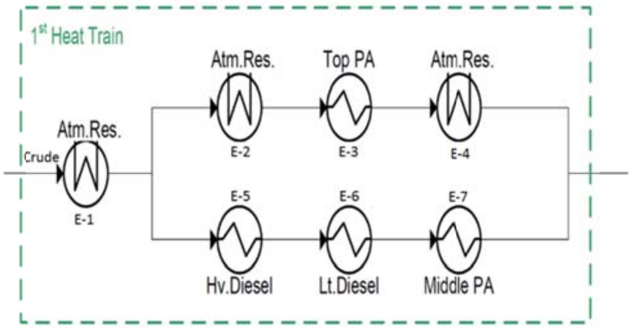

Figure 1: First Preheat Train (upstream of desalter)

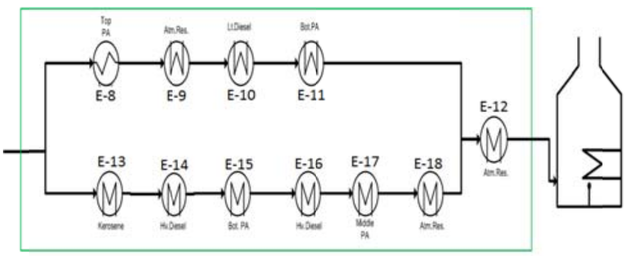

Figure 2: Second Preheat Train (downstream of desalter)

The real time data obtained from these indicators is processed in the developed software. The general algorithm is given in Figure 3. First of all, both tube and shell side inlet and outlet temperature differences are assumed. By using the inlet temperatures and these assumed temperature differences, it computes outlet temperature, iteratively. From inlet and iterative outlet temperature, the average temperature is found and all physical properties of streams are evaluated at this temperature with the usage of the API Data book relevant correlations [7]. Afterwards, Kern and Bell-Delaware approach is followed for clean heat transfer coefficient's calculations. The iterations continue until the assumed outlet temperatures are close to the calculated outlet temperatures in the predetermined confidence interval. These outlet temperatures are, then the clean outlet temperatures of the heat exchanger and represent the maximum performance of the heat exchanger. By using the operational outlet temperatures the dirty heat transfer coefficient can be calculated. The difference between dirty and clean heat transfer resistances gives the overall fouling resistance, R_f. By following this procedure for real time data, R_f, can be monitored.

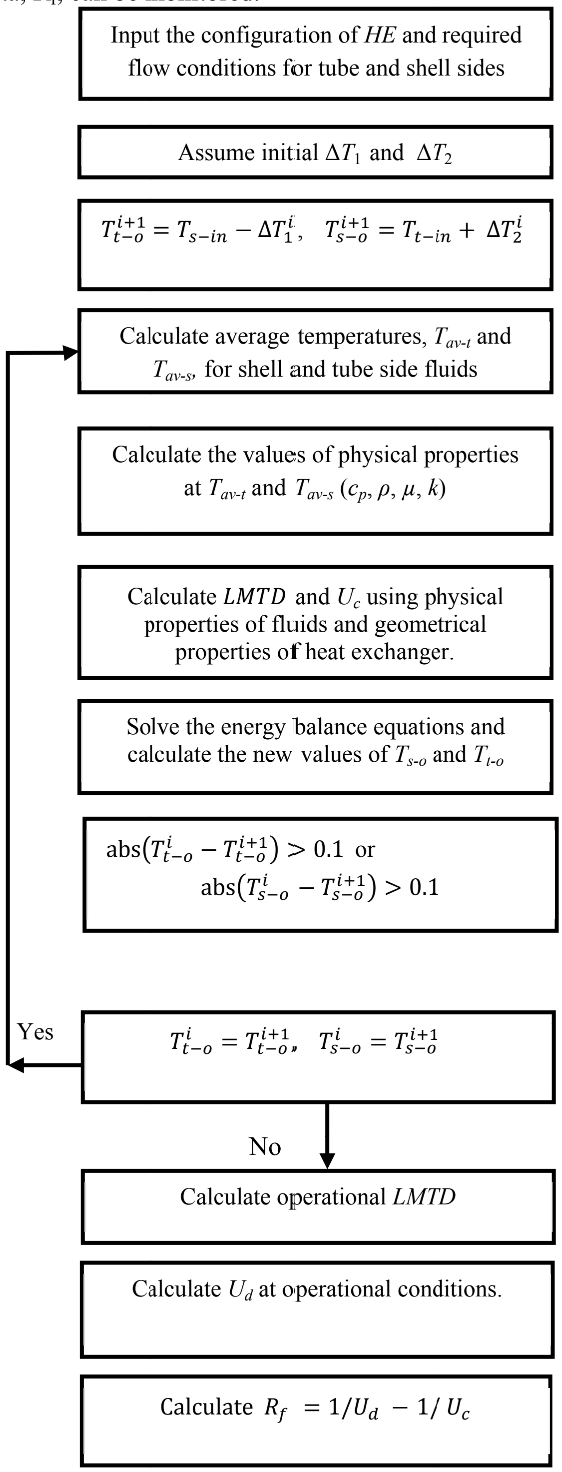

Figure 3: General Algorithm

RESULTS & DISCUSSION

The developed software was used to monitor the fouling in crude distillation unit first and second preheat exchangers. As discussed before, temperature indicators were placed on the inlet and outlet streams in order to obtain real time process data. During the installation, the heat exchangers were also cleaned mechanically. The average cleaning period for a crude oil unit heat exchanger is around 3-4 years. Thus, during a couple of months after the cleaning, it is expected to observe operational temperatures to be close to the clean outlet temperatures computed via the software; thus R_f is around zero. Figure 4 shows operational and simulated tube outlet temperatures for the first preheat exchangers. Heat exchanger simulations were also performed with commercial software. For the second preheat exchangers (at furnace inlet), the simulated tube outlet temperatures calculated via the commercial software and the software developed in this project, were compared with the real process data and they are shown in Figure 5 (E 12 heat exchanger).

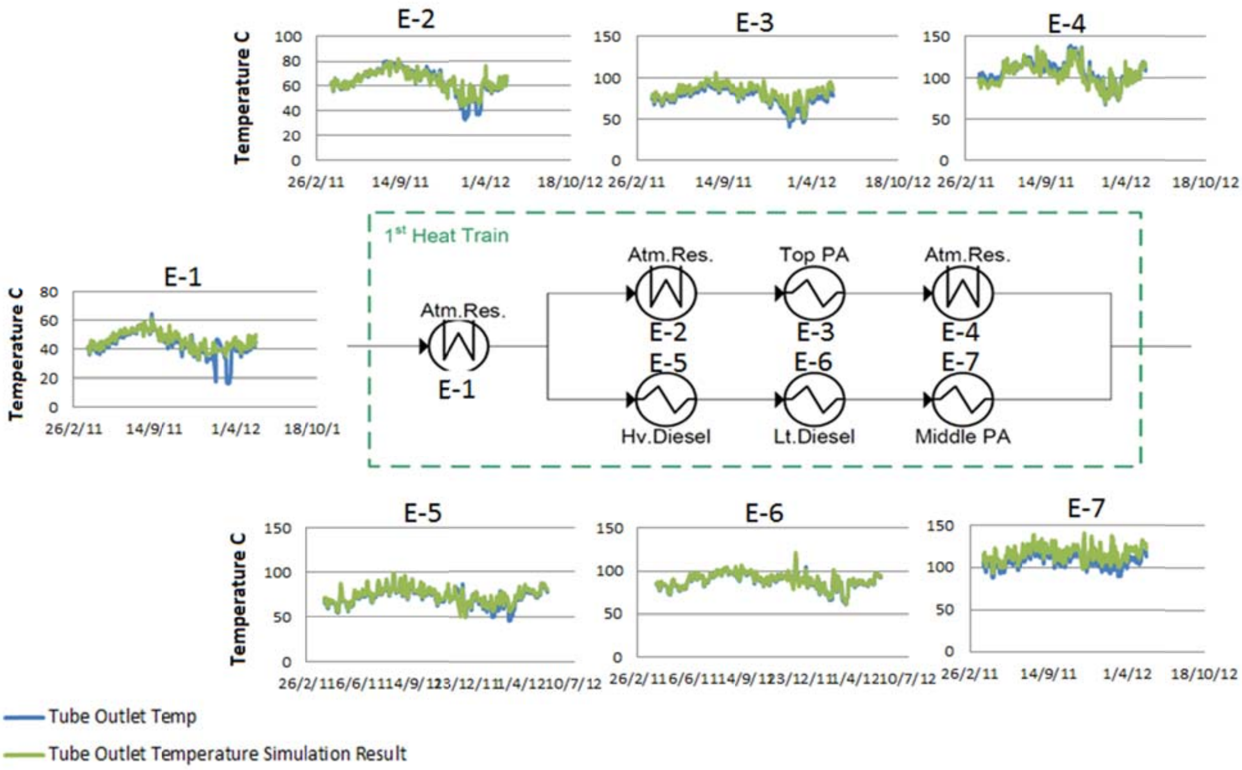

Figure 4: Operational and Simulated Tube Outlet Temperatures

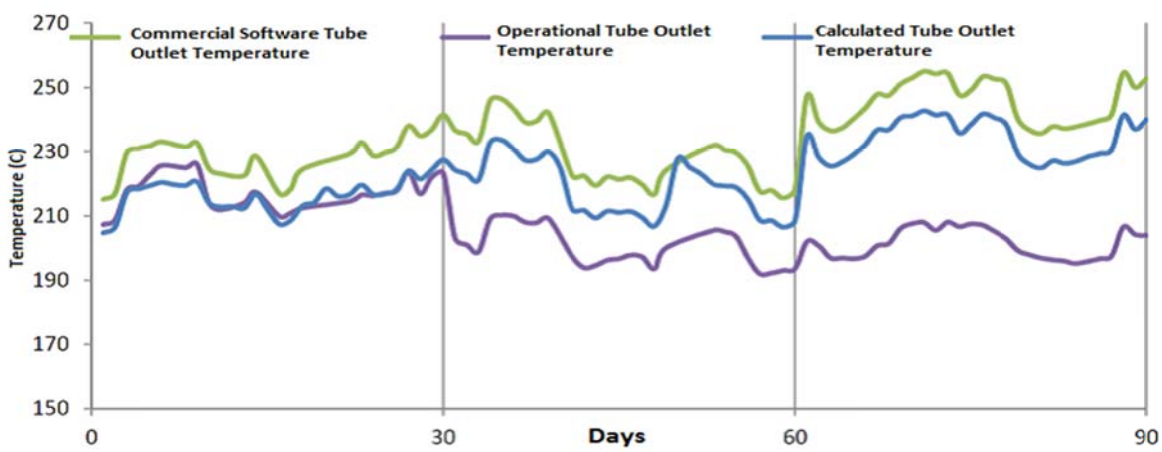

Figure 5: Comparison with commercial software (E12 exchanger)

CONCLUSION

The operational tube outlet temperatures of the clean heat exchangers were found to be consistent with the calculated outlet temperatures by using the software. Also, it is observed that the results of the software developed were closer to the operational data in comparison to the commercial software.

NOMENCLATURE

c_p: Specific heat capacity
HE : Heat exchangers
k: Thermal conductivity
LMTD: Log mean temperature difference
μ: viscosity
ρ: Density
R_f: Fouling resistance
$T_{av\text{-}t}$: Average temperature (tube side)
$T_{av\text{-}s}$: Average temperature (shell side)
$T_{t\text{-}in}$: Tube side inlet temperature
$T_{t\text{-}o}$: Tube side outlet temperature

$T_{s\text{-}in}$: Shell side inlet temperature
$T_{s\text{-}o}$: Shell side outlet temperature
U_c: Clean overall heat transfer coefficient
U_d: Dirty overall heat transfer coefficient

ΔT_1 : Hot end temperature difference
ΔT_2 : Cold end temperature difference

superscript
i: current iteration

REFERENCES

[1] Zubair S. M., Sheikh a. K., Younas M., Budair M.O., 2000, A risk based heat exchanger analysis subject to fouling, Part I: Performance evaluation , Energy 25, pp. 445–461.
[2] Bott T. R., Fouling of Heat Exchangers,1995 , Chapter 5,11, Elsevier.
[3]Orman S., Sahin G., Becer M., Ayhan U.B., Ozcelik Y., Balkan F., 2011, Fouling Monitoring in Diesel Unit Preheat Exchangers, Proceeding of International Conference on Heat Exchanger Fouling and Cleaning Conference Proceedings
[4] Aminian J., Shahhosseini S., Applied Thermal Engineering, Volume 28, Issue 7, pp: 668-674
[5] Polley, G. T., Wilson, D. I., Pugh, S. J., 2007, Extraction of crude oil fouling model parameters from plant exchanger monitoring, Heat Transfer Engineering, Vol. 28, pp. 185-192.
[6] Liporace, F. S., Oliveira S. G., 2007, Real time fouling diagnosis and heat exchanger performance, Heat Transfer Engineering, Vol. 28, pp. 193-201.
[7] The American Petroleum Institute, Epcon International, API Technical DataBook, 8th Edition, 2006