**Fouling Detection in Industrial Heat Exchanger**

**Using Neural Network Models**

Željka Ujević Andrijić1\*, Nenad Bolf1, Adriana Brzović1, Hrvoje Dorić1

*1 University of Zagreb, Faculty of Chemical Engineering and Technology, Zagreb, Croatia*

*\*Corresponding author: zujevic@fkit.hr*

**Highlights**

* There is a need for continuous detection of fouling formation on heat exchangers
* NN models are developed for predicting heat exchanger outlet temperatures.
* By applying models on-site more stable operation and significant savings are expected.

**1. Introduction**

Companies are more than ever aware of the potential that lies in machine learning for improving predictive maintenance in order to increase process efficiency and address concrete process issues.

One of the major problems in operation of a refinery plant is the heat exchanger fouling build-up, so there is a need for continuous detection of fouling formation on heat exchangers in order to optimize servicing within preventive maintenance programme.

Traditional diagnostics of the fouling formation methods have a number of limitations, with some requiring stationarity of the process. In more than a few instances fundamental models are difficult to develop. On the other hand data-driven models can be developed using identification methods.

In our research an online monitoring system is developed for a shell and tube heat exchanger at hydrocracking plant. Neural network models are developed using inferential variables (temperature and flow rates of hot and cold stream) for predicting heat exchanger outlet temperatures. The deviation between predicted and actual values indicates performance degradation due to fouling. The developed models are designed to establish an on-line monitoring system for maintaining operating efficiency of refinery plants.

**2. Methods**

The first step was choosing the data representative for the overall dynamical process and selecting data from the period when fouling does not yet appear (right after cleaning). The model inputs for predicting outlet temperatures of hot and cold streams are: the inlet cold stream temperature (*T*C,i), the inlet hot stream temperature (*T*H,i), the hydrogen mass flow rate ($\dot{m}$). The neural networks models were developed using R software. Data preprocessing included detection and removing outliers. Heat transfer coefficient for clean and dirty heat exchanger is calculated using (1) and (2):

$U\_{fouling}=\frac{\dot{m} \* c\_{p} \* \left(T\_{H, i}-T\_{H, o}\right)}{A \* F \* \frac{\left(T\_{H, i}-T\_{C, o}\right) - \left(T\_{H, o}-T\_{C, i}\right)}{ln\left(\left(T\_{H, i}-T\_{C, o}\right) / \left(T\_{H, o}-T\_{C, i}\right)\right)}}$ (1)

$U\_{clean}=\frac{\dot{m }\* c\_{p} \* \left(T\_{H, i}-T\_{H, o, model}\right)}{A \* F \* \frac{\left(T\_{H, i}-T\_{C, o, model}\right) - \left(T\_{H, o, model}-T\_{C,i}\right)}{ln\left(\left(T\_{H, i}-T\_{C, o, model}\right) / \left(T\_{H, o, model}-T\_{C, i}\right)\right)}}$ (2)

*U*fouling is calculated based on the measured outlet temperatures, while *U*clean is calculated based on the predicted outlet temperatures. The heat exchanger performance is then assessed by comparing results of clean and fouled systems. Any trend observed at the model residual indicates that the performance is decreased due to fouling. The fouling factor is calculated according to the (3).

 (3)

**3. Results and discussion**

Good matching between actual outlet temperature and the model prediction right after the cleaning is observed. Over the longer period the deviation constantly increases as a result of emergence fouling. From Fig.1 it can be seen that initially, the fouling factor fluctuates close to zero indicating no fouling is occurring. After a while the fouling factor begins to rise indicating deposition. Calculated value of fouling factor is similar to the design fouling value of this heat exchanger.



Fig. 1. Fouling factor

**4. Conclusions**

The performance criteria of developed models together with residual monitoring indicate that the neural networks effectively detect fouling formation. By applying developed models on-site more stable plant operation and significant savings could be expected.

**References**

1. C. Ahilan, J. Edwin Raja Dhas, K. Somasundaram and N. Sivakumaran, "Performance assessment of heat exchanger using intelligent decision making tools", Applied Soft Computing, vol. 26, pp. 474-482, 2015.
2. S. Lalot and H. Pálsson, "Detection of fouling in a cross-flow heat exchanger using a neural network based technique", International Journal of Thermal Sciences, vol. 49, no. 4, pp. 675-679, 2010.
3. M. Navvab Kashani, J. Aminian, S. Shahhosseini and M. Farrokhi, "Dynamic crude oil fouling prediction in industrial preheaters using optimized ANN based moving window technique", Chemical Engineering Research and Design, vol. 90, no. 7, pp. 938-949, 2012.