The 12th EUROPEAN CONGRESS OF CHEMICAL ENGINEERING

ECCE 12 ECAB 5

Florence 15–19 September 2019

FKITMCMXIX

LAM LABORATORY FOR AUTOMATION & MEASUREMENTS

Fouling Detection in Industrial Heat Exchanger Using Neural Network Models

Željka Ujević Andrijić*, Nenad Bolf, Adriana Brzović, Hrvoje Dorić

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

** Corresponding author: zujevic@fkit.hr*

Introduction

One of the major problems in operation of a refinery plant is the heat exchanger *fouling* build-up. Therefore, there is a need for continuous detection of fouling formation on heat exchangers in order to schedule *preventive maintenance*.

Traditional diagnostics of the fouling formation have a number of limitations. On the other hand data-driven models can be developed using identification methods based on existing DCS data.

An *online* monitoring system is developed for a shell and tube heat exchanger. Heat exchanger outlet temperatures are predicted using neural network models from inferential input variables. The heat exchanger performance is assessed by comparing results of heat transfer coefficient of clean (based on the model prediction outlet temperatures) and fouled (based on the measured outlet temperatures) systems. The deviation between predicted and actual values indicates *performance degradation* due to fouling.

Observed process and the methods

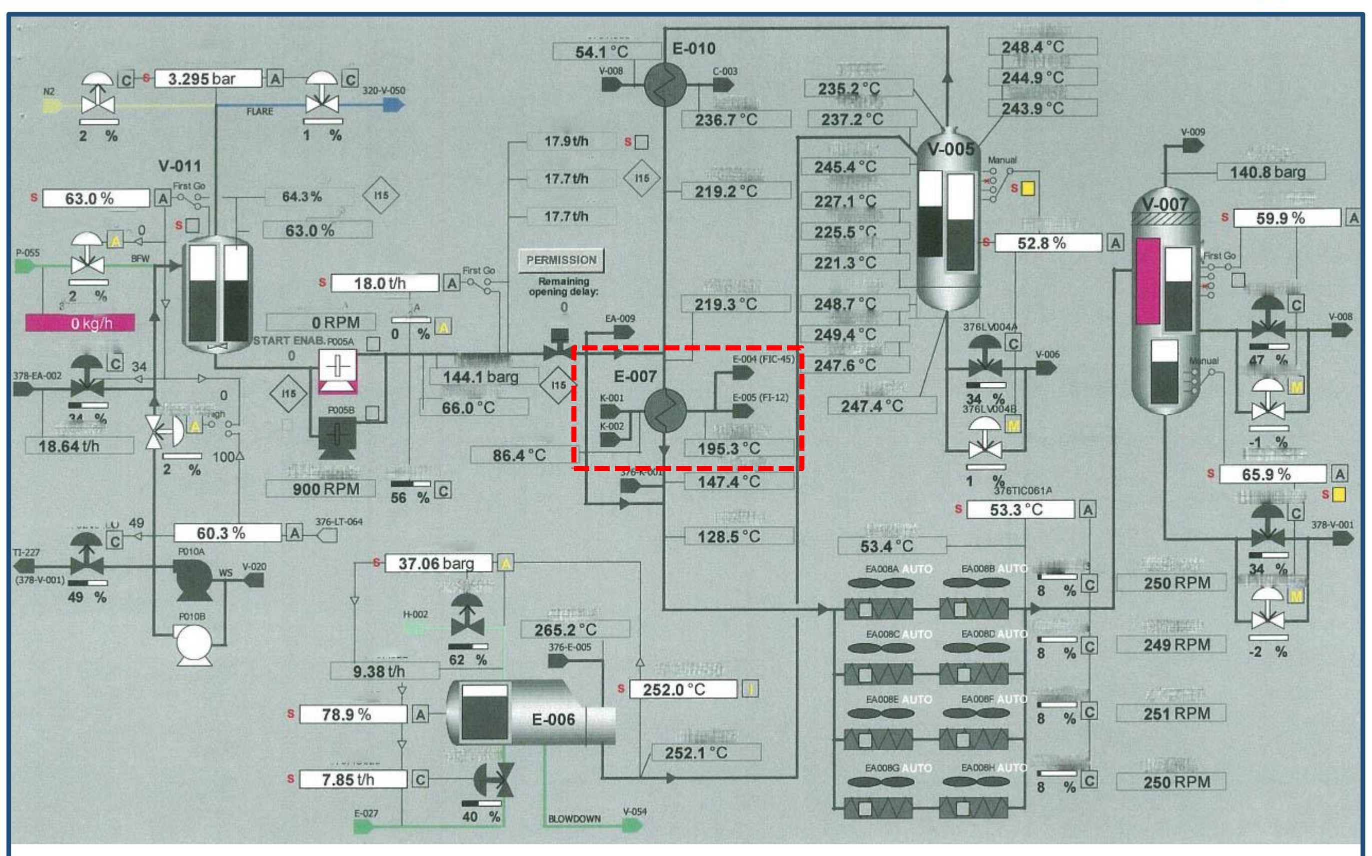

Figure 1. *Hydrocracker unit with E-007 heat exchanger*

Reduced heat transfer efficiency due to ammonium bisulphide salt precipitation in the heat exchanger tubes.

Heat transfer coefficient based on measured data

$$U_{fouling} = \frac{\dot{m} * c_p * (T_{H,i} - T_{H,o})}{A * F * \dfrac{(T_{H,i} - T_{C,o}) - (T_{H,o} - T_{C,i})}{\ln\left((T_{H,i} - T_{C,o}) / (T_{H,o} - T_{C,i})\right)}}$$

Heat transfer coefficient based on predicted data

$$U_{clean} = \frac{\dot{m} * c_p * (T_{H,i} - T_{H,o,model})}{A * F * \dfrac{(T_{H,i} - T_{C,o,model}) - (T_{H,o,model} - T_{C,i})}{\ln\left((T_{H,i} - T_{C,o,model}) / (T_{H,o,model} - T_{C,i})\right)}}$$

Fouling factor (R_f):

$$R_f = \frac{1}{U_{fouling}} - \frac{1}{U_{clean}}$$

Table 1. *Neural network model*

Input variables		Output variables	
$T_{H,i}$	Inlet hot stream temperature	$T_{H,o}$	Outlet hot stream temperature
$T_{C,i}$	Inlet cold stream temperature	$T_{C,o}$	Outlet cold stream temperature
$\dot{m}$	Hydrogen mass flow rate		

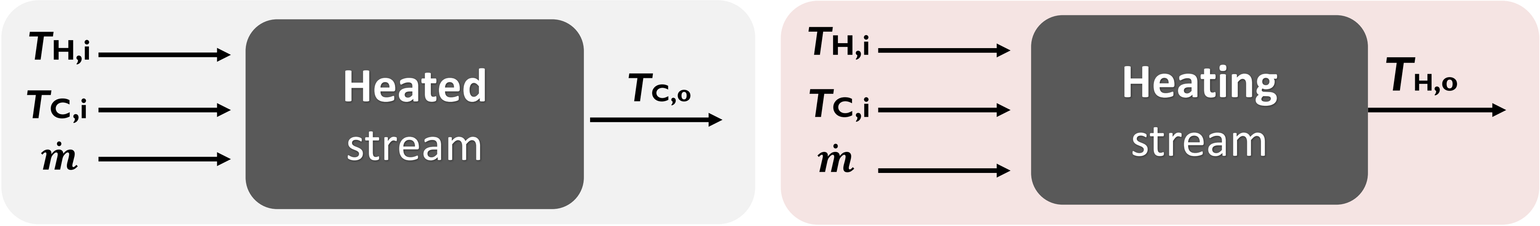

Figure 2. *The models for predicting the outlet temperatures*

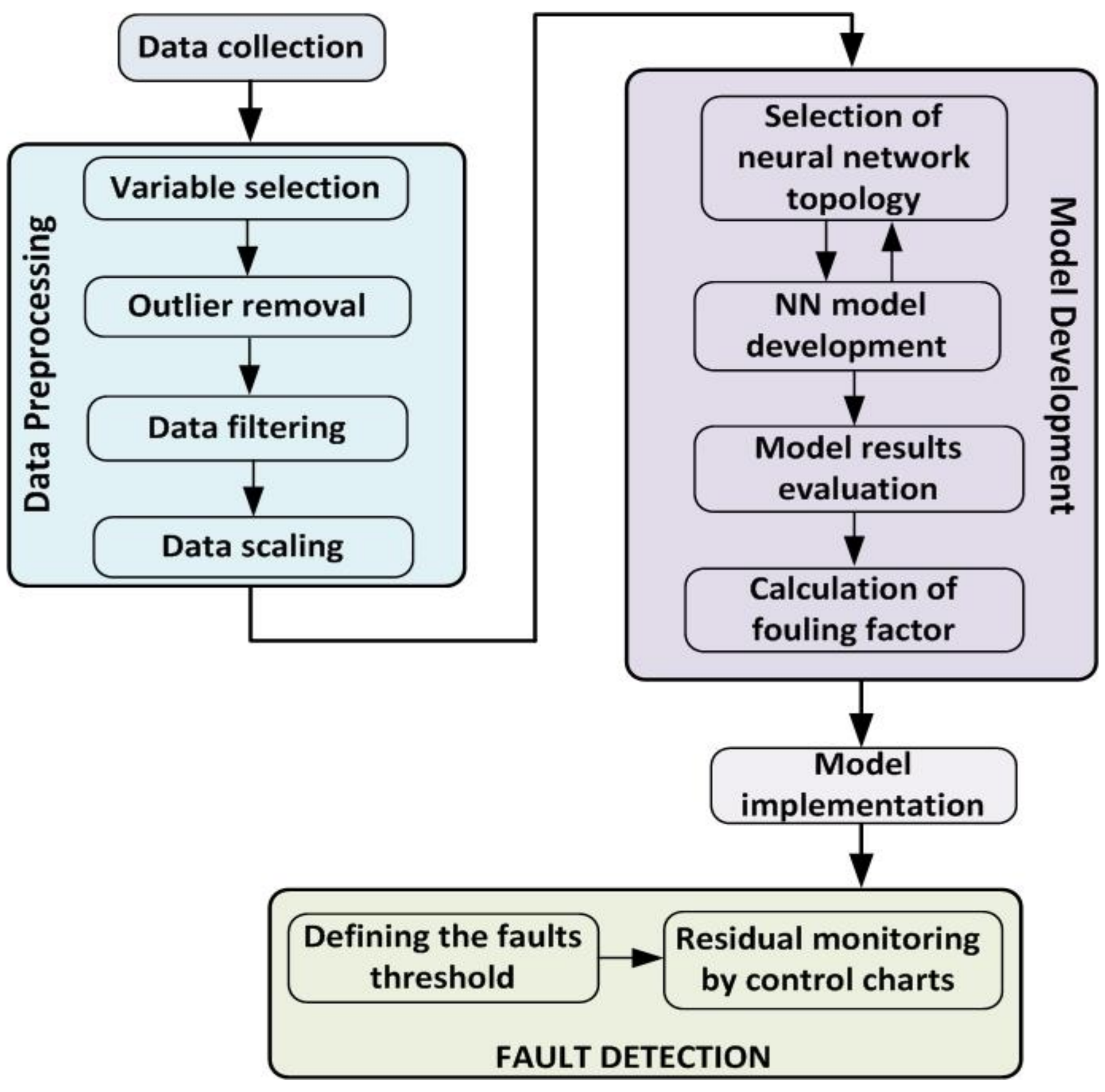

Figure 3. *Online monitoring system development procedure*

The neural networks models for predicting outlet temperatures were developed in R software.

Results

Table 2, *The perormance of developed neural network*

Neural network structure	Training R	Test R	Validation R	Training MSE	Test MSE	Validation MSE	Algorithm	Hidden act.	Output act.
4-5-1	0,972	0,973	0,973	0,008	0,009	0,008	BFGS 200	Tanh	identitiy

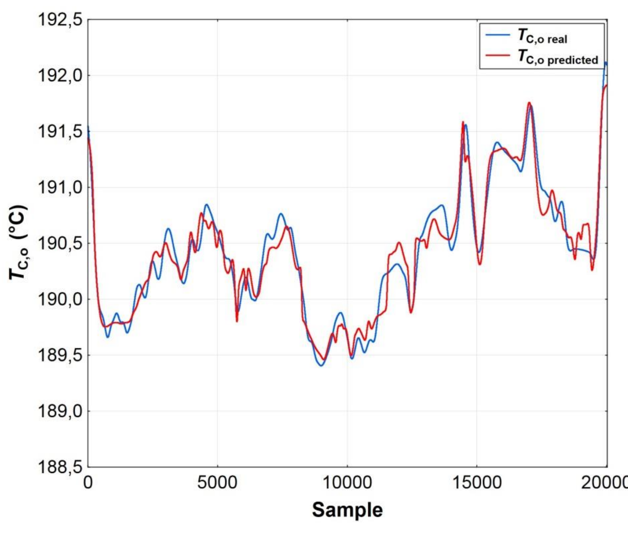

Figure 4, *Comparison of actual and predicted $T_{C,o}$, on the validation dataset*

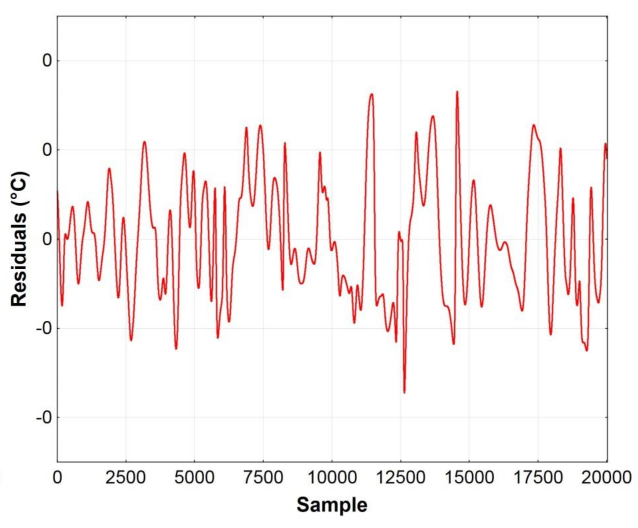

Figure 5, *Residuals $T_{C,o}$, estimation on the validation dataset*

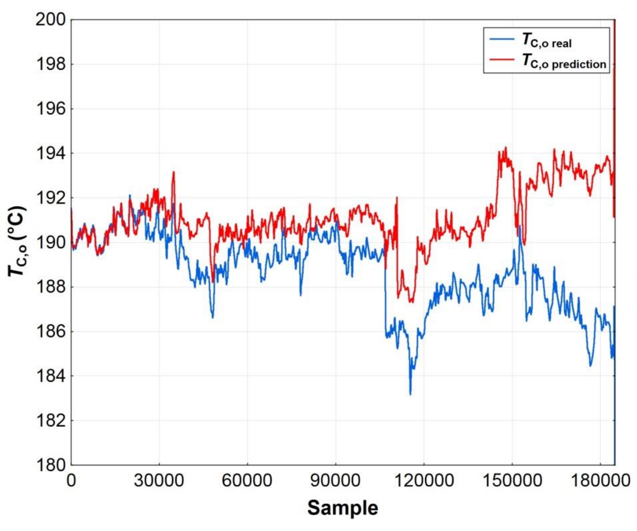

Figure 6, *Comparison of actual and predicted $T_{C,o}$, period after the heat exchanger cleaning*

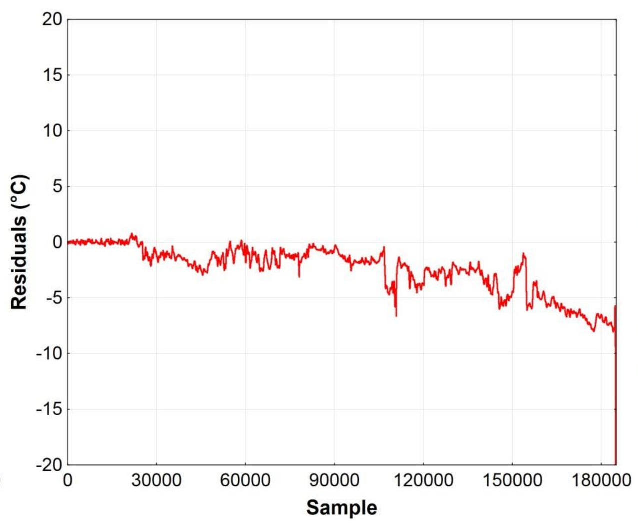

Figure 7, *Residuals $T_{C,o}$, period after the first heat exchanger cleaning*

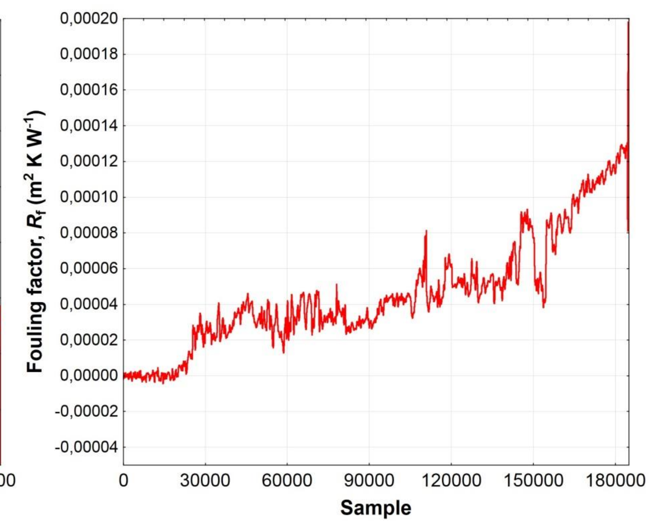

Figure 8, *Fouling factor*

Conclusion

The performance criteria of developed models together with residual monitoring indicate that the neural networks effectively detect fouling formation.

By applying developed models *onsite* more stable plant operation and significant savings could be achieved.

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.

[4] Ž. Ujević Andrijić, N. Bolf, „Using the PI System in Chemical Engineering Education and Research", OSISOFT PI World EMEA 2018 - Barcelona