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# Determination of the Influence of Fouling on Heat Exchangers using Control Parameters

Shabna Shihab[1], A. Nasar[2]
[1]Student, Department of Electrical & Electronics Engineering, TKM College of Engineering, Kollam, India
[2]Professor, Department of Electrical & Electronics Engineering, TKM College of Engineering, Kollam, India

***Abstract*: It belongs to industrial practice that the operation of heat exchanger may be affected by fouling. In order to determine this a mathematical model was proposed. Heat exchanger is modeled using lumped-parameter approach. The model was implemented in Simulink and compares with different years of operation. For different periods of exchanger operation tuning parameters were used. The values of tuning parameters changed under changing thermal resistance of fouling.**

***Keywords*: Shell and tube heat exchanger, PID Controller, Cell based model.**

## 1. Introduction

Heat exchanger fouling is defined as the accumulation and deposit of unwanted substances that form on the external and internal surfaces of a variety of processing equipment called heat exchangers. Fouling layer imposes an additional resistance to heat transfer and the narrowing of the flow area. Consequences of fouling includes burning extra fuel and reducing exchanger efficiency and other problems and other problems. Innovations and research related to fouling has gained achievements in the field of industrial area. In this paper determination fouling influence is identified. For this, cell based modeling of heat exchanger is used. Shell and tube type heat exchanger is used. It is one of the most common type of heat exchanger is used in oil refineries and petro-chemical and large chemical processes and is suited for higher pressure applications. The performance of heat exchanger depends on so many factors. Some of them may occur due to fouling. To make any exact prediction about the performance of heat exchanger under a set of fouling conditions is always a tough job. However, by using effective controllers the influence of fouling can be obtained. The present paper is also an attempt of analyzing the influence of fouling using controllers. For the analysis of this shell and tube heat exchanger is used. For the efficient use of heat exchangers under changing conditions it requires proper models. For this purpose, mathematical equations are used. With the help of Laplace transform transfer function is created using cell division method. In this each cell is divided into four input signals and generates two output signal. The model of a heat exchanger eight combinations of ratios is formed. The block diagram is chosen on the basis of basic parameters like thermal conductivity, viscosity, specific heat capacity, density.

## 2. Shell and tube heat exchanger

It provides a large heat transfer area. The tubes are placed in bundle and the ends of tubes are mounted in tubes sheets. The tube bundle is enclosed in a cylindrical shell, through which the second fluid flows. Most shell and tube exchangers used in practice are of welded construction. It is used to heat or cool process fluids, either through a single-phase heat exchangers or a two-phase heat exchanger. In single-phase, the tube side and shell side fluids remains in the same phase. These heat exchangers are used when other heat exchangers do not provide sufficient area for heat transfer. It is more economical and requires less materials for construction.

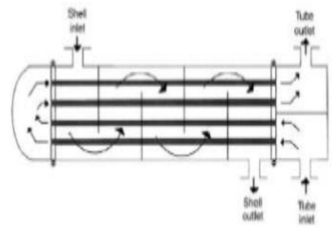

Fig. 1. Shell and tube heat exchanger

Large amounts of thermal energy are transferred between fluids for heating or cooling in industries. Heat exchangers are frequently operating under varying conditions. Their appropriate use in flexible heat exchanger networks as well as maintenance related calculations require adequate dynamic models. These models are used for estimating their behavior. One of the model are often used to represent heat exchangers are cell based model.

### A. PID controller

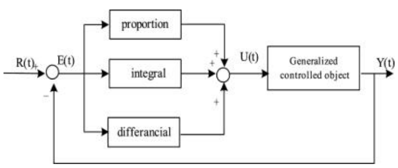

Fig. 2. Diagram of PID Controller

PID stands for proportional integral derivative. Controllers

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are designed to eliminate the need for continues operator attenuation

*B. PID tuning*

PID control is based on feedback. The output of the device or process is measured and compared with the set point. If a difference is detected a correction is calculated and applied. PID stands for proportional integral derivative. There are three approaches are used to determine, the optimal combination of these settings manual tuning, tuning heuristics, and an automated methods. Here we use auto tune method

## 3. Cell based model

Heat exchangers are changing according to different changing conditions. For example, conditions resulting from fouling build up time. Different types of modeling are used for heat exchanger dynamics. The changing nature of operating conditions are generally modeled in the concepts of flexibility, controllability, reliability. The appropriate use of heat exchangers under varying conditions require adequate dynamic models. Cell models can result a large number of equations but equations are simple. It offers modeling flexibility to accommodate any type of surface heat exchanger with any flow arrangement.

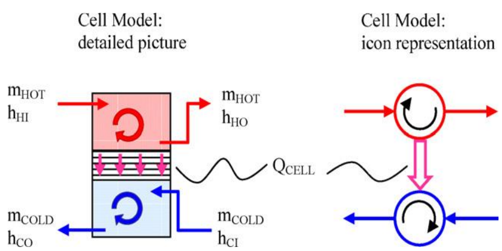


Fig. 3. Representation of a cell

## 4. Heat exchanger cell

A Simple heat exchanger cell is defined as two perfectly tanks exchanging heat only with each other through a dividing wall. The following modeling assumptions are employed to drive the dynamic cell model.

1. Temperature constant because of the cell feature.
2. Fluid densities are constant.
3. The tanks are completely full with the corresponding fluids.
4. The wall resistance to the heat transfer is neglected.

With regards to the system techniques, any quantity material or energy entering the system is considered to positive, also any quantity leaving the system is negative. The equations used for cell representation are derived from the energy-balance equation. Energy accumulation in the control volume is equal to the energy amount in the inflowing fluid minus energy amount in the outflowing fluid, minus heat amount transferred out the control volume. The energy balance of the entire cell is represented by three ordinary differential equations that describes the energy balances of the tube side fluid, tube walls and shell side fluid.

$$\rho_t \cdot c_{pt} \cdot V_t \cdot \frac{dT_{to}}{dt} = M_t \cdot c_{pt} \cdot T_{ti} - M_t \cdot c_{pt} \cdot T_{to} + n_b \cdot \pi \cdot D_1 \cdot l \cdot h_{ft} \cdot (T_{tw} - T_{to}) \quad (1)$$

$$\rho_w \cdot c_{pw} \cdot V_w \cdot \frac{dT_w}{dt} = -n_b \cdot \pi \cdot D_1 \cdot l \cdot h_{zt} \cdot (T_{tw} - T_{to}) + n_b \cdot \pi \cdot D_2 \cdot l \cdot h_{fs} \cdot (T_{so} - T_{sw}) \quad (2)$$

.

$$\rho_s . c_{ps} . V_s . \frac{dT_{so}}{dt} = M_s . c_{ps} . T_{si} - M_S . c_{ps} . T_{si} - M_s . c_{ps} . T_{so} - n_b . \pi . D_2 . l . h_{fs} . (T_{So} - T_{sw}) \quad (3)$$

For these equations the constants used are

$$a_1 = \frac{1}{\rho_t . V_t} \quad (4)$$

$$a_2 = \frac{n_b . \pi . D_1 . l . h_{ft}}{\rho_t . c_{pt} . V_t} \quad (5)$$

$$a_3 = \frac{n_b . \pi . D_1 . l . h_{ft}}{\rho_w . c_{pw} . V_w .} \quad (6)$$

$$a_4 = \frac{n_b . \pi . D_2 . l . h_{fs}}{\rho_w . c_{pw} . V_W} \quad (7)$$

$$a_5 = \frac{1}{\rho_s . V_s} \quad (8)$$

$$a_6 = \frac{n_b . \pi . D_2 . l . h_{fs}}{. \rho_s . c_{ps} . V_s} \quad (9)$$

In this section, the heat exchanger system are mathematically modeled using available data. The experimental process data are summarized below.

## 5. Cell model of a heat exchange

The described heat exchanger cell model can be used by system and control engineers to constant dynamic models of complete heat exchangers. By solving the mathematical model transfer function is used. Operator transmittance G(s) is a widely used tool for describing a dynamic system. Prior to this model, a block diagram of the heat exchanger should be developed to visualize the interdependence of between exchanger cells. The developed block diagram can be implemented and converted into a simulation tool using simulation software in MATLAB environment. In the present work, for each cell the data base includes parameters like fluid temperatures, mass, flows, heat transfer coefficients, thermo physical parameters.

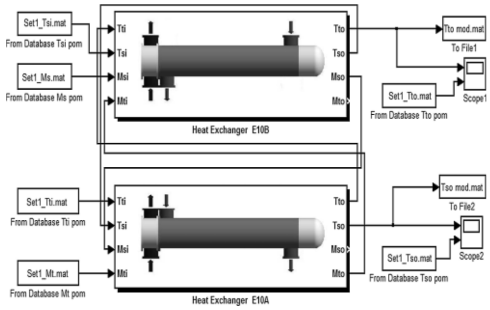

Fig. 4. Model of heat exchanger

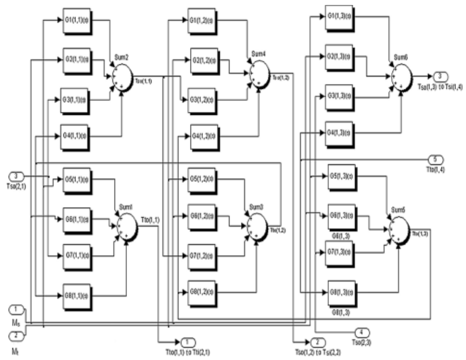
Fig. 5. Cell model of heat exchanger

## 6. Fouling impact of heat exchanger without controllers

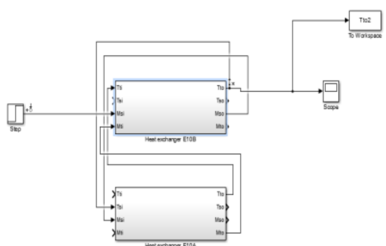
Fig. 6. Impact of fouling on heat exchanger

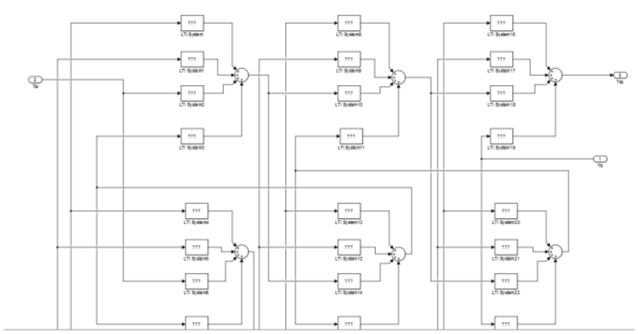
Fig. 7. Cell model

### A. Closed loop analysis

It represents the results of Simulink modelling of a heat exchanger Unit including feedback PID controller. For each of the selected operation periods, the values of the tuning parameters of PID controller were determined using auto tuning method. The obtained results indicate that to compensate to fouling build up on the heat transfer surfaces. Periodic corrections of the tuning of PID controllers are required.

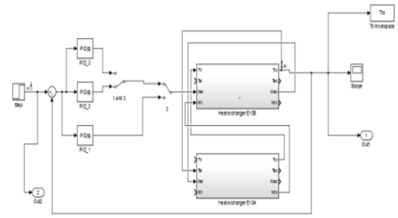
Fig. 8. Fouling detection using PID controllers

### B. Result after one year of operation

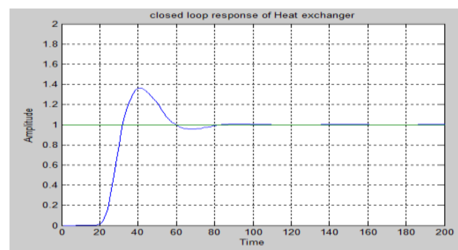

Fig. 9. Result after one year

### C. Result after two year of operation

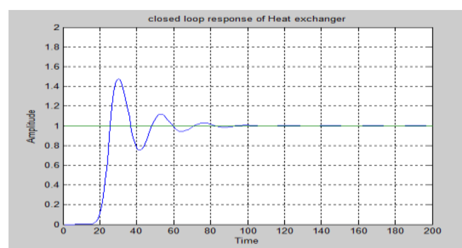

Fig. 10. Detection of fouling after two year

### D. Result after three year of operation

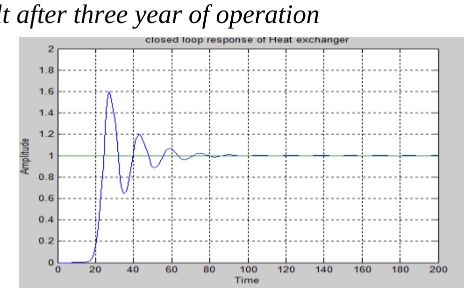

Fig. 11. Fouling detection after three year

Table 1
Tuning parameters of PID, Values of PID

| Controllers | First year | Second year | Third year |
|---|---|---|---|
| Kp | 34.90 | 23.03 | 12.68 |
| Ki | 1.80 | 1.594 | 0.96 |
| Kd | 0.25 | 36.59 | 15.73 |

## 7. Conclusion

From the earlier studies found that the influence of fouling on heat transfer in heat exchangers are identified. But the studies are not completed. In the present paper, control-theory based approach was used for the faster identification of fouling. The method allows step by step simulation on the effect of fouling on heat exchangers. This method can be applied in industries.

## References

[1] M. Markowski, K. Urbaniec, Optimal cleaning schedule for heat exchangers in a heat exchanger network, Appl. Therm. Eng. 25 (7) (2005) 1019-1032.

[2] L. Wang, B. Sundén, Detailed simulation of heat exchanger networks for flexibility consideration, Appl. Therm. Eng. 21 (12) (2001) 1175–1184.

[3] C.O.R. Negrao, P.C. Tonin, M. Madi, Supervision of the thermal performance of heat exchanger trains, Appl. Therm. Eng. 27 (2) (2007) 347–357.

[4] J. Aminian, S. Shahhosseini, Evaluation of ANN modeling for prediction of crude oil fouling behavior, Appl. Therm. Eng. 28 (7) (2008) 668–674.

[5] F.S. Liporace, S.G.D. Oliveira, Real time fouling diagnosis and heat exchanger performance, Heat Transf. Eng. 28 (3) (2007) 193–201.

[6] J. Nesta, C.A. Bennett, Fouling mitigation by design, in: Proc ECI Conf Heat Exch. Fouling Clean. – Chall. Oppor., Kloster Irsee, Germany, 2005, pp. 342–347. June5–10, RP2, no. 49.

[7] M.A.S.S. Ravagnani, J.A. Caballero, Optimal heat exchanger network synthesis with the detailed heat transfer equipment design, Comput. Chem. Eng. 31 (11), (2007), 1432–1448.

[8] S. Macchietto, G.F. Hewitt, F. Coletti, B.D. Crittenden, D.R. Dugwell, A. Galindo,G. Jackson, R. Kandiyoti, S.G. Kazarian, P.F. Luckham, O.K. Matar, M. Millan-Agorio, E.A. Müller, W. Paterson, S.J. Pugh, S.M. Richardson, D.I. Wilson, Fouling in crude oil preheat trains: a systematic solution to an old problem, Heat Transf. Eng. 32 (3–4), (2011), 197–215.

[9] H. Müller-Steinhagen, M.R. Malayeri, A.P. Watkinson, Heat exchanger fouling: mitigation and cleaning strategies, Heat Transf. Eng. 32, (3–4).