Journal of Engineering and Technology (JET) Vol. 7, No. 1 & 2 August 2012

SIMULATION STUDIES OF HEAT EXCHANGERS IN UNTL KADUNA

GARBA, I. and YAHAYA, D.B.

Department of Mechanical Engineering, Faculty of Engineering, Bayero University, Kano, E-Mail: isagar2051@yahoo.com

ABSTRACT

Process simulation is a critical step in the identification of areas of energy inefficiencies in industrial facilities. The result of simulation if properly carried out should aid in identifying points of intolerable energy losses in the system. This paper investigated the heat losses through computer simulations. Strategic plans for energy systems efficiency improvement were presented and opportunities for energy savings were also identified. The exact value of heat losses for the heat exchanger is 2720000Kj/h. The adiabatic and polytropic efficiencies of the heat exchanger were found to be 0.86% and 0.79%. A computer software package in Hysys version 3.1 was used for the simulation. From the simulation carried out, it was discovered that the simulation model developed satisfied all the conditions of the empirical model.

Significance of the Paper: Results from computer simulation are very helpful for system design, since they allow one to learn about the complex interaction of a large number of variables in a short time whereas physical experiments are time consuming and costly. It also helps in predicting the performance of the system under similar operating conditions.

Keywords: Simulation, Polytropic efficiency, Hysys, Thermal expansion, Energy system

1.0 INTRODUCTION

Heat exchanger is a device used to transfer heat between fluids that are at different temperatures and separated by a solid wall. Common uses for heat exchangers are found in waste removal, air-conditioning, power production and chemical processing. The simple heat exchanger model may be used to simulate heat exchange between two process streams, heat exchange between a process stream and a utility stream, or to heat or cool a single process stream. The simple model does not rigorously rate the exchanger, i.e., pressure drops, shell and tube side heat transfer coefficients, fouling factors are not calculated (Shanon, 2005). The designer of heat-transfer equipment can do much to minimize maintenance costs and production losses by anticipating the problems associated with the cleaning, leakage, startup and shutdown. Heat - transfer equipment provides the economic and process viability for many plant operations. The basis for successful application of such equipment depends on the designer (Adkws 2003). Sometimes a small leakage from the tube side to the shell side, or vice versa, can cause a large production loss or maintenance expense. Leaks may develop at the tube - to - tube sheet joints of fixed - tube sheet exchangers because of differential thermal expansion between the tubes and the shell causes overstressing of the roiled joints (Bowman E.H. 2006).

2.0 MATERIALS AND METHODS

Heat exchangers are used to transfer heat between two process streams, or between a process stream and a utility stream such as air or steam. For all three heat exchanger models, the following basic design equation holds:

$$\delta_q = U_0 \Delta T \delta_A --- (1)$$

Where: $\delta_q =$ Heat transferred in elemental length of exchanger, dz; $U_0 =$ Overall heat transfer coefficient; $\Delta T =$ Overall bulk temperature difference between the two streams;

$\delta_A =$ Element of surface area in exchanger length dz.

Once an appropriate mean heat-transfer coefficient and temperature difference is defined, the equation may be re-written for the entire exchanger as follows:

$$Q = U_{0m} A_0 \Delta T_m = H_{out} - H_e - - - (2)$$

Where: Q = Total exchanger heat duty; U_{0m} = Overall mean heat-transfer coefficient; A_0 = Total exchanger area; ΔT_m = Mean temperature difference.

Table 1: Input Parameters of Heat Exchanger

S/N	Input Parameters	Values
1	Tube inlet Temperature (°C)	121
2	Tube inlet Pressure (kPa)	6996
3	Tube outlet Temperature (°C)	195
4	Tube outlet Pressure (kPa)	6996
5	Shell inlet Temperature (°C)	125
6	Shell inlet Pressure (kPa)	997.6
7	Shell outlet Temperature (°C)	150
8	Shell outlet Pressure (kPa)	997.6
9	Tube Mass Flow (kg/hr)	45.36
10	Shell Mass Flow (kg/hr)	49.00

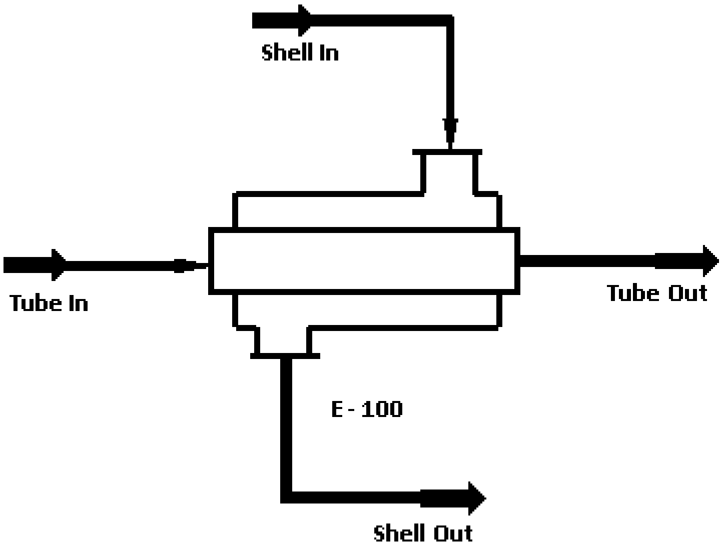

Figure 1: Shell and Tube Heat Exchanger

3.0 RESULTS AND DISCUSSION

3.1 Simulation results

Table 2: Properties of heat exchangers

Parameter	Overall		Aqueous Phase	
	Tube in		Tube out	
Vapour/phase fraction	0.0000	1.0000	0.0000	1.0000
Temperature: (°C)	121.1	121.1	90.56	90.56
Pressure: (kPa)	6996	6996	6996	6996
Molar flow (kgmol/h)	2.518	2.518	2.518	2.518
Mass flow (kg/h)	45.36	45.36	45.36	45.36
Std. ideal liq. Vol. flow (m^3/h)	4.545e-002	4.545e-002	4.545e-002	4.545e-002
Molar enthalpy (kJ/kgmol)	-2.776e+005	-2.776e+005	-2.799e+005	-2.799e+005
Mass enthalpy (kJ/kg)	-1.541e+004	-1.541e+004	-1.54e+004	-1.54e+004
Molar entropy (kJ/kgmol-°C)	75.78	75.78	69.81	69.8
Mass entropy (kJ/kg-°C)	4.206	4.206	3.875	3.875
Heat flow (kJ/h)	-6.990e+005	-6.990e+005	-7.047e+005	-7.047e+005
Molar density (kgmol/m^3)	51.80	51.80	53.21	53.21
Mass density (kg/m^3)	933.2	933.2	958.6	958.6
Std. ideal liq. Mass density (kg/m^3)	998.0	998.0	998.0	998.0
Liq. Mass density @std. cond (kg/m^3)	1015	1015	1015	1015
Molar heat capacity (kJ/kgmol-°C)	74.78	74.78	73.39	73.39
Mass heat capacity (kJ/kg-°C)	4.151	4.151	4.074	4.074
Thermal conductivity (W/m-k)	0.6868	0.6868	0.6762	0.6762
Viscosity (cSt)	0.2277	0.2277	0.3093	0.3093
Surface tension (dyne/cm)	54.53	54.53	60.38	60.53
Molecular weight	18.02	18.02	18.02	18.02
Z factor	4.120e-002	4.120e-002	4.348e-002	4.348e-002

Table 3: Heat Exchanger Shell in Properties

Parameter	Overall	
Vapour/Phase Fraction	0.0000	1.0000
Temperature (°C)	51.67	51.67
Pressure (kPa)	997.6	997.6
Molar Flow (kgmol/h)	2.720	2.720
Mass Flow (kg/h)	49.00	49.00
Std. ldeal Liq. Vol. Flow (m^3/h)	4.910e-002	4.910e-002
Molar Enthalpy (kJ/kgmol)	-2.828e+005	-2.828e+005
Mass Enthalpy (kJ/kg)	-1.570e+004	-1.570e+004
Molar Entropy (kJ/kgmol-°C)	61.66	61.66
Mass Entropy (kJ/kg °C)	3.422	3.422
Heat Flow (kJ/h)	-7.693e+005	-7.693e+005
Molar Density (kgmol/rrr^3)	54.80	54.80
Mass Density (kg/m^3)	987.3	987.3
Std. Ideal Liq. Mass Density (kg/m^3)	998.0	998.0
Liq. Mass Density @Std. Cond. (kg/m^3)	1015	1015
Molar Heat Capacity (kJ/kgmol-°C)	72.79	72.79
Mass Heat Capacity (kJ/kg-°C)	4.040	4.040
Thermal Conductivity (W/m-K)	0.6450	0.6450
Viscosity (cSt)	0.5291	0.5291

Surface Tension (dyne/cm)	67.44	67.44
Molecular Weight	18.02	18.02
Z Factor	6.741 e-003	6.741 e-003

Table 5: Stream Properties

Parameter	Tube in	Tube out	Shell in	Shell out
Vapour Fraction	0.0000	0.0000	0.0000	0.0000
Temperature (°C)	121.1	90.56	51.67	65.56
Pressure (kPa)	6996	6996	997.6	997.6
Enthalpy (kJ/kg-°C)	2.776e+005	2.799e+005	2.828e+005	2.818e+005
Molar Flow (kgmol/h)	2.518	2.518	2.720	2.720
Mass Flow (kg/h)	45.36	45.36	49.00	49.00
Std. Ideal Liq Vol. Flow (m^3/h)	4.545e-002	4.545e-002	4.910e-002	4.910e-002
Heat Flow (kJ/h)	6.990e+005	7.047e+005	7.693e+005	7.665e+005

Table 6: Summary of results

Parameter	Value
Shell HT coeff. (kJ/h-m^2-°C)	Empty
Tube HT coeff. (kJ/h- m^2-°C)	Empty
Overall U (kJ/h- m^2-°C)	3.879
Overall UA (kJ/°C-h)	324.0
Shell DP (kPa)	0.0000
Tube DP (kPa)	0.0000
Heat Trans. Area per shell (m^2)	60.32
Tube Volume per Shell (m^3)	0.1930
Shell volume per shell (m^3)	2.272
Total transfer rate, (W) $Q = M_h C_{ph} (T_{h,out} - T_{h,in})$	14.38×10^6

3.2 Discussion of results

The heat loss was found to be 4.873e + 03 J/h. The logarithmic mean temperature difference Limited was 45.16°C.The uncorrected logarithmic mean temperature limited was found to be 46.73°C and the heat leak was estimated to be -7.816e + 03 kJ/h. The heat flow at shell side was 2752.48 kJ/h at a temperature of 65.56°C, whereas the heat flow at the tube side was found to be 5694.92 kJ/h at a temperature of 121.11°C. The heat transfer area per shell for the heat exchanger was found to be 60.32 m^2 while the shell volume per shell was 2.272 m^3. The overall U was found to be 3.879 kJ/hm^2 °C and the overall UA was estimated to be 234.0 kJ/°Ch. The enthalpy increases with an increase in temperature for both the tube and shell side of the heat exchanger. The pressure is constant when the enthalpy increases and also the pressure remain constant when the heat flow increases for both the tube and shell side of the exchanger. The temperature increases when the heat flow increases.

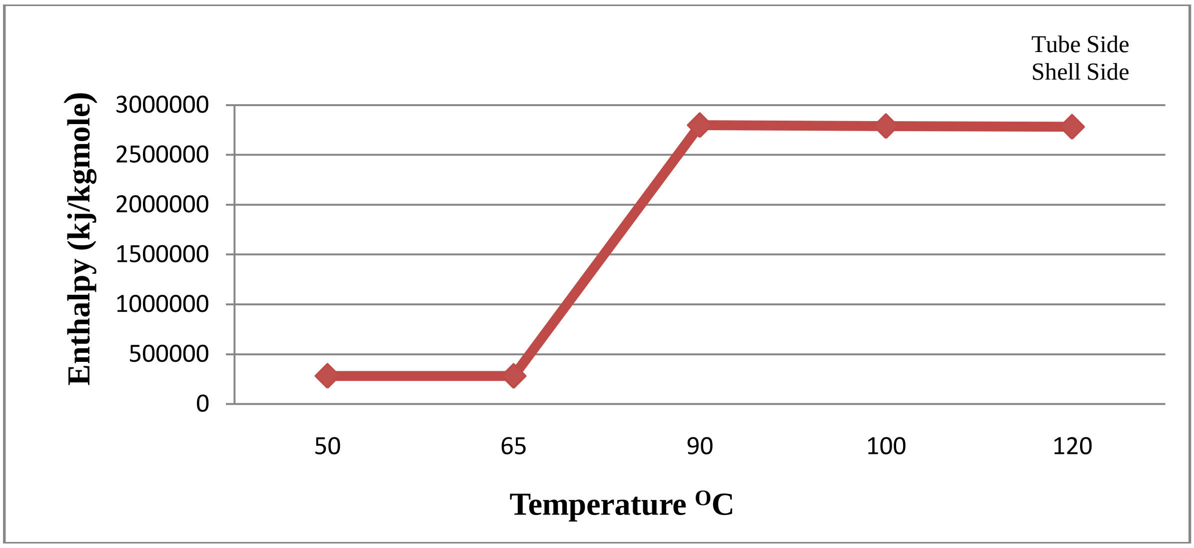

Figure 2: Graph of Enthalpy versus Temperature for heat exchanger I

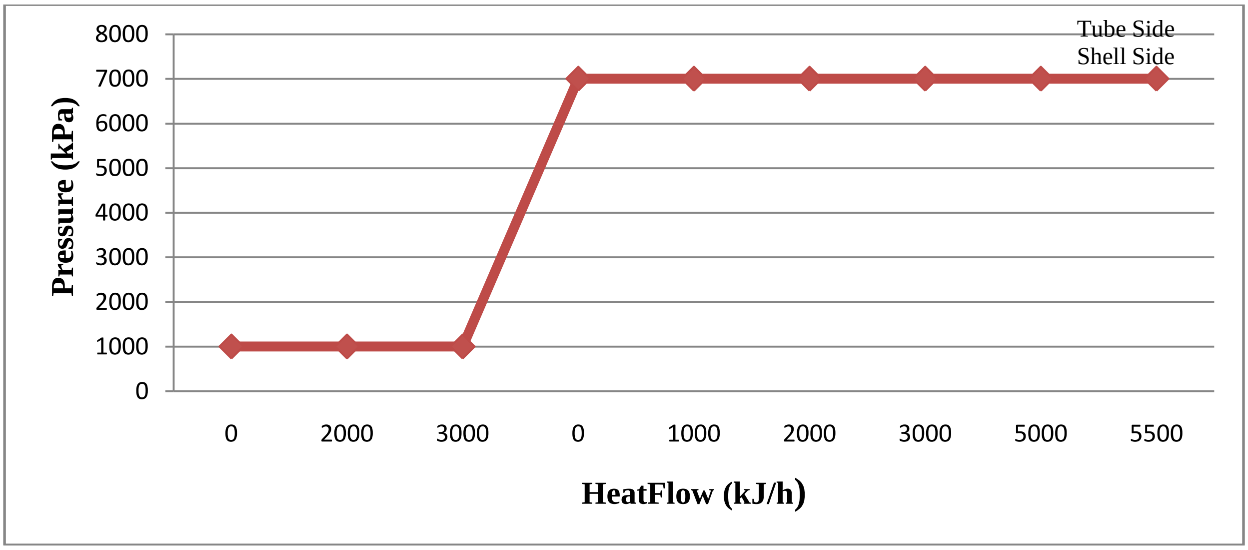

Figure 3: Graph of Pressure versus Heat Flow for heat exchanger I

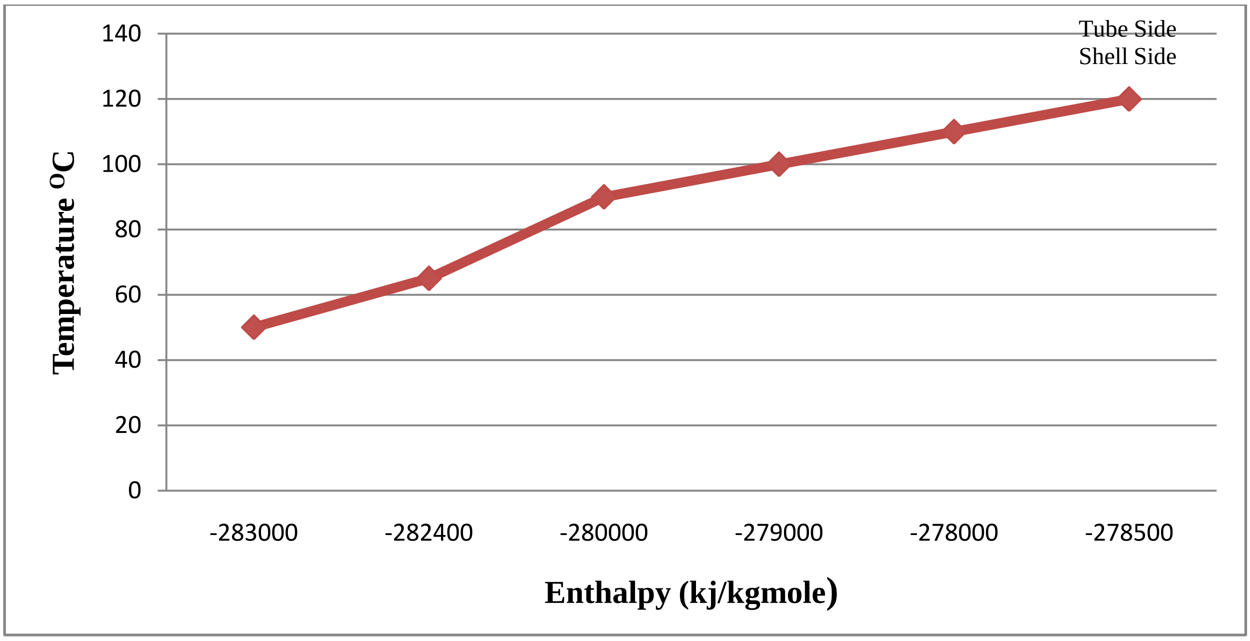

Figure 4: Graph of Temperature versus Enthalpy for heat exchanger II

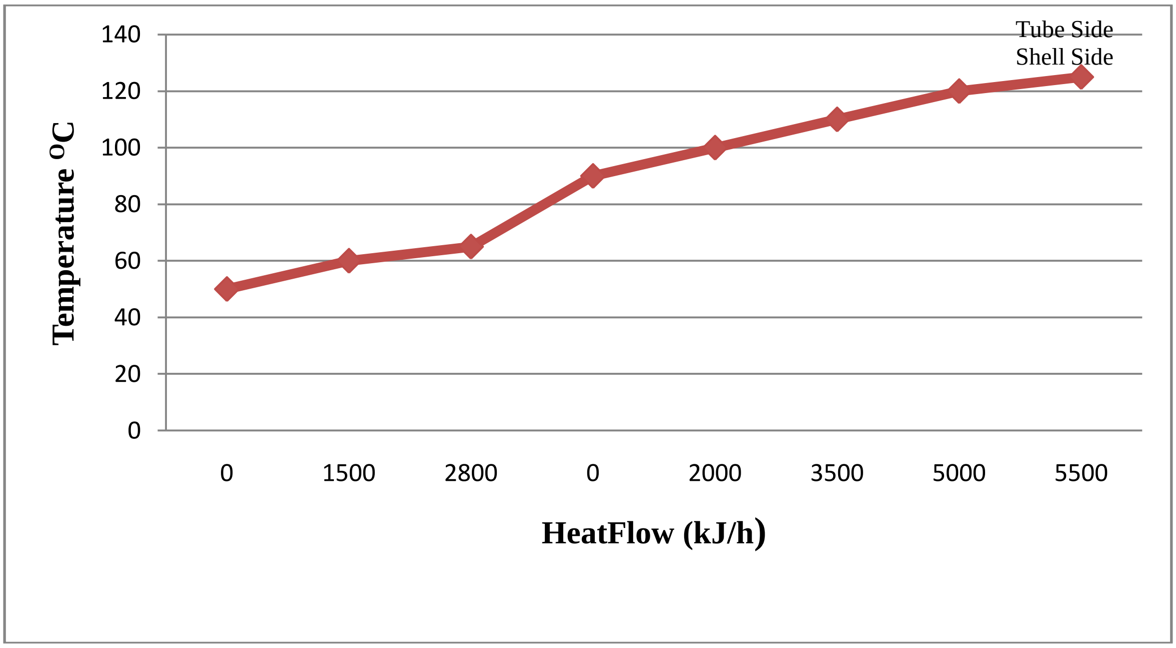

Figure 5: Graph of Temperature versus Heat Flow for heat exchanger II

4.0 CONCLUSION

Simulation of energy systems aims primarily at reduction of expenses on energy through prevention of unnecessary losses. This paper pointed out that an effective energy saving which is expected to reduced energy cost, higher profit and increased capacity utilization was achieved. A computer simulation model of a system should be validated. A validation consists of comparing the models performance with the performance of the actual system being simulated. Both input and output variables of the simulation model should reasonably replicate the actual system. The empirical process heat loss, actual values heat loss and simulation heat loss were found to be 3720000 kJ/h, 3960000 kJ/h and 3873000 kJ/h respectively.

REFERENCES

(1) Shanon. R.E. (September, 2005): "Simulation: A survey with research suggestions". AIIE Transactions 7, No. 3, pp. 289 -301.

(2) Adkws, G. and Pooch, U.W. (April, 2003). "Computer Simulation": A Tutorial Computer 10, No. 4, pp12-17.

(3) Carr, C.R. and Howe, C.W. (2002). "Quantitative Decision Procedures in Management and Economics". New York, McGraw" Hill.

(4) Hickok, H.N. (1999). "How and Where to Save Electrical Energy". Part 1. Energy Management Handbook, pp. 226

(5) Hes, L. and Kranpa, P. (1998). "Energy Balance of the False Twist Texturing Process", Textile 34, p.414.

(6) Bowman, E.H. and Fetter R.B. (2006). "Analysis for Production and Operations Management". Third Edition, Homewood, Illinois: Richard D. Irwin, Inc.

(7) Cooper, S.G. (1999). "The Textile Industry Environment Control and Energy Conversation", Noyes Data Corporation.

(8) Dryden, G.C (2001). "The Efficient Use of Energy", Butterworth and Co. (Publishing) Ltd.

(9) Bonstead and Hancock, G.F. (1979). "Handbook of Industrial Energy Analysis , Ellis Harwood.

(11) Reistad, G.M and Gaggioli, R.A. (2000). "Available Energy Costing", Thermodynamics: Second Law Analysis, American Chemical Society, Washington. D. C., pp. 143.