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Experimental and CFD analysis of Shell and tube heat exchanger

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ABSTRACT

The shell and tube heat exchanger (STHE) has been designed to cool the water from 60°C to 51°C. The experimental work is fabricated with the components of the exact dimensions as derived from the designing using CATIA and ANSYS. Tests are conducted on heat exchanger under the direction of flow, insulations under the atmosphere conditions. The observations and the result are discussed in the paper.

KEY WORDS: Shell and tube heat exchanger, ANSYS16.1, Insulations and Effectiveness.

1. INTRODUCTION

The STHE is a vital component in heat exchanger. The model is designed according to Indian Standard IS: 4503 – 1967 (Indian Standard, 1967). Yang (2015) analysed numerically the temperature field, pressure field, and path lines of a novel SHTE. Yonghua (2015) modified the shell side convection heat transfer coefficient of heat exchanger varies between 51115.5 & 14051.4 W/m^{2}K using baffles. Tianyi (2015) validated the heat exchanger configurations, including counter flow and cross flow heat exchangers with experimental works. Oguz (2014) analyzed the design variables including baffle spacing, shell diameter, tube outer diameter and number of tube passes are used to minimize total cost. Sandeep (2012) determined the tube pitch ratio, tube length, tube layout are important like baffle spacing ratio. Yusuf amd Ozbilen (2004) analyzed the shell diameter; baffle spacing, number of tube-side pass to identify configurations that satisfy the specified heat transfer and pressure drops. Abdur and Saad concluded that STHE with 20° baffle inclination angle results in better performance compared to 10° and 0° inclination angles (2012). Shahrul and Mahbubul (2016), showed 50% improvement in heat transfer coefficient and around 51% enhancement in actual heat transfer has been found for the nanofluids. Saeed and Robert (2016), found that higher ratios of L/d and smaller values of R/r_o increase the total number of pipes, which is not desirable in terms of the total cost of the LHTES unit. Based on the literature, a parallel flow STHE is analyzed by simulation and experimental method is presented here.

2. EXPERIMENTAL WORK

A copper tube of inner diameter (d_i) =10 mm and outer diameter (d_o) =12 mm of length (l) = 500 mm were used in which the hot water is flowed. The outer tube of Iron material whose inner diameter (D_i) =159 mm and Outer diameter (D_o) =149 mm were used in which the cold water is flowed.4 thermocouples were fixed each on either side of inlet and outet valves on the inner pipe as well as the outer pipe to measure the temperature difference of hot and cold water. 2 ball valves were fixed on the connecting pipewhich connects the cold water from the storage tank to the outer pipe.

Figture.1. Experimental setup of STHE

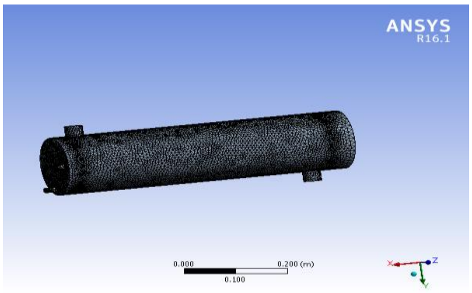

Figure.2. Mesh of STHE.

The thermal performance of a heat exchanger depends upon several factors like thermal conductivities and convection involved fluids and materials, fluid flow velocity, turbulence, quality and quantity of the insulation provided, ambient conditions flow conditions etc.

$$\text{Continuity: } \frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

$$\text{X-Momentum } \frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial z} = -\frac{\partial p}{\partial x} + \frac{1}{Rer}\left(\frac{\partial \tau xx}{\partial x} + \frac{\partial \tau xy}{\partial y} + \frac{\partial \tau xz}{\partial z}\right)$$

$$\text{Y-Momentum } \frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho uv)}{\partial x} + \frac{\partial(\rho v^2)}{\partial y} + \frac{\partial(\rho vw)}{\partial z} = -\frac{\partial p}{\partial y} + \frac{1}{Rer}\left(\frac{\partial \tau xy}{\partial x} + \frac{\partial \tau yy}{\partial y} + \frac{\partial \tau yz}{\partial z}\right)$$

$$\text{Z-Momentum } \frac{\partial(\rho w)}{\partial t} + \frac{\partial(\rho uw)}{\partial x} + \frac{\partial(\rho vw)}{\partial y} + \frac{\partial(\rho w^2)}{\partial z} = -\frac{\partial p}{\partial z} + \frac{1}{Rer}\left(\frac{\partial \tau xz}{\partial x} + \frac{\partial \tau yz}{\partial y} + \frac{\partial \tau zz}{\partial z}\right)$$

$$Energy: \frac{\partial(E)}{\partial t}+\frac{\partial(uE)}{\partial x}+\frac{\partial v(E)}{\partial y}+\frac{\partial(wE)}{\partial z} = -\frac{\partial(up)}{\partial x}-\frac{\partial(vp)}{\partial y}-\frac{\partial(wp)}{\partial z}-\frac{1}{Re_r Pr_r}\left(\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}+\frac{\partial q_z}{\partial z}\right) + \frac{1}{Re_r}\left(\frac{\partial}{\partial x}[u\tau_{xx}+v\tau_{xy}+w\tau_{xz}]+\frac{\partial}{\partial y}[u\tau_{xy}+v\tau_{yy}+w\tau_{yz}]+\frac{\partial}{\partial y}[u\tau_{xz}+v\tau_{yz}+w\tau_{zz}]\right)$$

Volumetric flow rate of hot water, $Q_h = \frac{1}{\rho \, X \, t_h}$

Mass flow rate $(m_h) = Q_h . \rho_h$

Logarithmic mean temperature difference, LMTD = $\frac{dT_i - dT_o}{\ln(\frac{dT_i}{dT_o})}$

Area of Heat Exchanger $A_i = \pi d_i L$

Nusselt Number (Nu) $Nu = 0.023\,(Re)^{0.8}(Pr)^{0.3}$

Actual Overall Heat Transfer Co-efficient $U = \frac{q}{A_i \, X \, LMTD}$

Theoretical over all heat transfer co-efficient $\frac{1}{U} = \frac{1}{h_i} + \frac{r_i}{k_c}\ln\frac{r_o}{r_i} + \frac{r_i}{r_o}\frac{1}{h_o}$

Effectiveness, $\mathcal{E} = \frac{q}{C_{min}\,(T_{hi} - T_{ci})}$

3. RESULTS AND DISCUSSION

Table.1. Geometric dimensions of shell and coil tube heat exchanger

Heat exchanger length, *L*	500 mm
Shell inner diameter, *Di*	149 mm
Tube inner diameter, di	10 mm
Tube outer diameter, do	12 mm
Tube bundle geometry and pitch Square	15 mm
Number of tubes, *Nt*	52
Tie – rod diameter	10 mm
Tube sheet thickness	12 mm

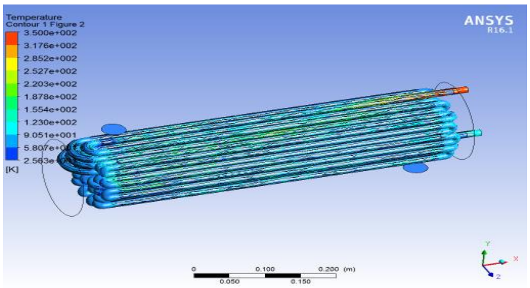

Figure.3. Temperature Distribution tube side.

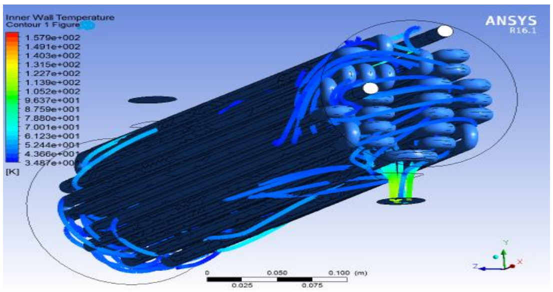

Figure.4. Fluid Flow Shell side.

The nodes and elements considered for shell and tube are 151301, 723109 and 111641, 437624 respectively. Thermocouples are placed in position at hot water inlet and outlet and cold water inlet and outlet. The flow on hot water side through the annular space is adjusted with a valve. Maintaining the flow rate constant, record the inlet and outlet temperature of hot & cold water at equal intervals of time till the steady state temperature is obtained. Measure the flow rate of hot and cold water by recording the time taken for collecting 1 litre of water. The effectiveness of STHE as computed from the ANSYS 16.1. The effectiveness value of software and experimental method are 0.332 and 0.34 respectively. With use of insulation materials the effectiveness was improved 4 % when the hot water flows in shell and cold water flowing in tubes. When the hot Water flowing in tube and cold water flowing in shell effectiveness was improved 5.9 % with use of insulation.

3. CONCLUSION

The effectiveness values computed from the software ANSYS 6.1 model and experiment are almost same. A high degree of cooling when the hot water flows in the tubes as compared to the condition in which it has flown through the shell. Also the effectiveness of the heat exchanger is better when the hot fluid flows into the tubes. It means that flowing cold water through the shell side may be beneficial, however sure comments cannot be made over this universally as it is a very special case of equal heat capacity rates of both the fluids. After using the insulation in parallel flow the heat transfer rate increases because the thickness of insulation is well below the critical thickness of insulation. With use of insulation materials the effectiveness was improved 4 % when the hot water flows in shell and cold water flowing in tubes. When the hot Water flowing in tube and cold water flowing in shell effectiveness was improved 5.9 % with use of insulation.

REFERENCES

Abdur Rahim S.M, Saad Jameel, Shell side CFD analysis of a small shell-and-tube heat exchanger considering the effects of baffle inclination on fluid flow, YMCA University of Science & Technology, Faridabad, Haryana, 2012, 167-173

Indian Standard, Specification for shell and tube heat exchangers, IS, 8, 1967, 4503.

Jie Yang, Numerical investigation on a novel shell-and-tube heat exchanger with plate baffles and experimental validation, Energy Conversion and Management, 101, 2015, 689–696.

Oguz Emrah Turgut, Design and economic investigation of shell and tube heat exchangers using Improved Intelligent Tuned Harmony Search algorithm, Ain Shams Engineering Journal, 5 (4), 2014, 1215–1231

Saeed Mostafavi Tehrani S, Robert A, Taylor Design and feasibility of high temperature shell and tube latent heat thermal energy storage system for solar thermal power plants, Renewable Energy, 96, 2016, 120–136.

Sandeep K, Patel, Shell & tube heat exchanger thermal design with optimization of mass flow rate and baffle spacing, IJAERS, 2 (1), 2012, 130-135

Shahrul I.M, Mahbubul I.M, Experimental investigation on Al_2O_3–W, SiO_2–W and ZnO-W Nano fluids and their application in a shell and tube heat exchanger, International Journal of Heat and Mass Transfer, 97, 2016, 547–558.

Tianyi Gao, James Geer, Development and verification of compact transient heat exchanger models using transient effectiveness methodologies, International Journal of Heat and Mass Transfer, 87, 2015, 265–278.

Yonghua Youa, Yuqi Chen, Numerical simulation and performance improvement for a small size shell-and-tube heat exchanger with trefoil-hole baffles, Applied Thermal Engineering, 89, 2015, 220–228.

Yusuf Ali Kara, Ozbilen Guraras, A computer program for designing of shell-and-tube heat exchangers, Applied Thermal Engineering, 2, 2004, 1797–1805.