International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-04, Issue-04, July 2018

Performance Study of Spiral Plate Heat Exchanger

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Abstract - Heat conservation is gaining much more prominence over the past few years due to the continuous increase in artificial luxuries of mankind. Heat exchanger is one of the best devices designed to use heat effectively. Out of the different available heat exchangers, spiral plate heat exchangers are known as excellent heat exchange devices because of compact structure and high heat transfer efficiency. The flow of the two fluids in this type of heat exchanger is counter flow, which makes it possible to have a close temperature approach between the two medias being treated in the heat exchanger. A large variety of fluids can be suitable for a spiral plate heat exchanger. This paper is studied to analyze the performance of a spiral plate heat exchanger. In this current research work, different mass flow rates are used for hot fluids (100 LPH, 200 LPH 300 LPH) and for each mass flow rate of hot fluid, flow rate of cold fluid is varied from 100LPH to 300LPH for the investigation of thermal performance of spiral plate heat exchanger. The results obtained shown considerable improvement in heat transfer rate i.e., 5.006 kW for the flow rate of 300 LPH for both hot and cold fluids.

Keywords: Spiral plate heat exchanger, Mass flow rate, Performance and Heat transfer rate.

Nomenclature

T_{hi} - Temperature of hot water inlet (^{0}C), T_{ho} - Temperature of hot water outlet (^{0}C), T_{ci} - temperature of cold water inlet (^{0}C), T_{co} - temperature of cold water outlet (^{0}C), m- Mass flow rate [Kg /Sec]

I. INTRODUCTION

A heat exchanger is the means to transfer the heat between flowing fluids.We useit to transfer heat between a solid object and a fluid or between two or more fluids. These fluids are separated by a solid wall to prevent mixing if not they would be in direct contact. The usage of heat exchangers can be seen in many day to day processes power production, transportation, air conditioning, refrigeration, Cryogenic, heat recovery, automobile radiators, condensers, evaporators, and oil coolers and in many other industries.

Some types of heat exchangers familiar to us in day-to-day use are
1. Shell and tube heat exchanger
2. Plate heat exchanger
3. Helical heat exchanger
4. Spiral plate heat exchanger etc.

Among many of the available heat exchangers one of the most intricate and upcoming in its efficiency and usages is the SPIRAL PLATE HEAT EXCHANGER.

Spiral plate heat exchanger is deemed an excellent heat exchanger because of its compact structure and high heat transfer efficiency.Spiral plate heat exchangers have evinced significant interest owing to their compact size, large heat transfer surface area per unit volume, high heat transfer rates, lower fouling, operational flexibility and ease of maintenance. Several papers are studied Kondhalkar and Kapatkat [1] they carried out research on the performance analysis of spiral tube heat exchanger over the shell and tube type heat exchanger for sugandh mantri oil emulsion and found the relation between mass flow rate and effectiveness which says for the same mass flow rate effectiveness increases for the spiral tube heat exchanger. Bhavsar et al. [2] they suitably designed and fabricated the spiral tube heat exchanger to measure the experimental tests. They have designed methodology for spiral tube heat exchanger and performed experiments on it to analyze pressure drop and temperature change in hot and cold fluid on shell side and tube side at transfer coefficient increased with increase in Reynolds number. M. S. Tandale and S. M.Joshi [3] they designed a spiral heat exchanger to recover the waste heat from producer gas. They realized that several forces (viscous, buoyancy, and centrifugal)

 DOI : 10.18231/2454-9150.2018.0476

influenced the flow in spiral tubes. P. Naphon [4] in their experiments thermal performance and pressure drop of the helical-coil heat exchangers were considered. This work showed that mass flow rate of both the hot and cold fluids flows had considerable effects on the heat exchanger performance. Baghel and Upadhyaya [5] They study was on effect of coil diameter on pressure drop in Archimedean spiral coils. They developed a relation between the pressure drop and the feed flow rate for the steady state Newtonian fluid into the Archimedean spiral tubes. Kalb and Seader [6] have performed numerical studies for uniform wall heat flux with peripherally uniform wall temperature for Dean numbers in the range of 1-1200, Prandtl numbers of 0.005-1600, and curvature ratios of 10 to 100 for fully developed velocity and temperature fields. Yan et al. [7] have inspected design and economic analysis of three compact heat exchangers like plate-fin, plate and spiral plate heat exchangers. They studied that optimization is minimum pressure drop for a given capacity. Adamski [8] Developed correlations to guess heat transfer coefficients and the Fanning friction factor for air flowing through a longitudinal flow spiral recuperator, and also investigated the thermal efficiency of the heat exchanger. Wang et al.[9] associated the improvement to particle motion and surface action and electro-kinetic effects. The hydrodynamic force in the form of micro-convention can also be a cause of the enhancement, and he also depicted that Brownian motion is not a significant contributor to the heat transfer improvement. Meibo Xing et al [10] Investigated the thermal conductivities of three types of carbon nanotubes (CNT)- nanofluids with volume concentration from 0.05 to 0.48 vol% at the temperatures of 10 0 c to 60 0 c. T he results show that predictive values with those models underestimate or overestimate the thermal conductivity in terms of the experimental results. A novel thermal conductivity predictive model is proposed with experimental data. In the proposed model, the straightness ratio of the CNT's is modified by considering two factors of the concentration and length of CNTs, and temperature effect is also introduced. The predictive results indicate that the proposed model agrees with all the experimental data points within a ±5% error band. Laura Fedeleet. al. [11] Has studied experimentally on stability, dynamic viscosity and thermal conductivity of water-based nanofluids containing TiO2 nanoparticles. Four different nanoparticle concentrations are studied (1 wt%, 10 wt%, 20 wt% and 35 wt%) and the considered experimental temperature ranges are between 283 K and 343 K and between 293 K and 353 K for viscosity and conductivity measurements, respectively, with steps of 10 K. They found that measured thermal conductivity of TiO2-water nanofluids increases with mass concentration and with temperature. The effect of increasing conductivity is more evident at higher temperatures. Lemenand and Peerhossaini[12] have investigated the correlation among Nusselt number, Reynolds number and Prandtl number and the number of bends in the pipe. They proposed the Nusselt number slightly drops off with increasing number of bends. Keblinski et al. [13] He presented that liquid layering around the particle could give a path for rapid conduction. The mechanism of ballistic heat transport gains significance because the phonon mean free path is of the order of nano-particle dimensions. Liquid layering theory was shown to be promising, but it uses an adjustable parameter of the thickness of the liquid layer. He also showed that even though the Brownian motion appears to be a probable mechanism, results of a time scale study led to its rejection. Zhao, C. Y., and Lu, T. J., [14] The emergence of nanofluids along with modern materials technology provided the opportunity to produce nanometer-sized particles which are quite different from the parent material in mechanical, thermal, electrical, and optical properties.

II. EXPERIMENTAL SETUP

The construction of an experimental set-up is shown in fig 1. They consists of a spiral plate heatexchanger, resistance temperature detectors (RTD), rotameters, control valves and tanks.The heat exchanger was constructed using 316 stainless steel plates. Spiral plate heat exchangers consist of plates rolled together forming a spiral. The space between the plates is kept by welded studs to form the channels for the flow of the fluids. The dimensions of spiral plate heat exchanger as shown in table-1.

Spiral plate heat exchanger details	Value
Plate width, mm	320
Plate spacing, mm	25
Plate thickness, mm	0.9
Material of construction	SS316

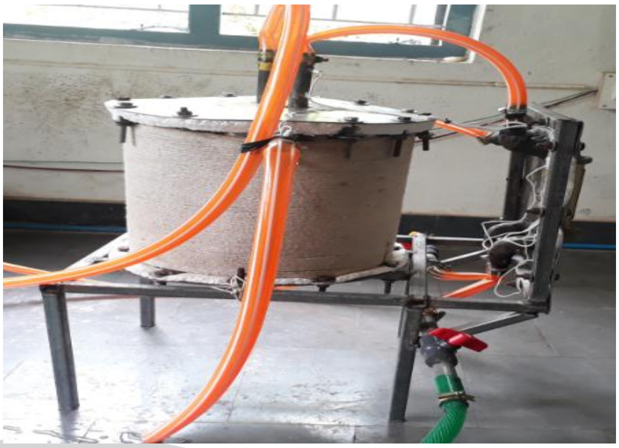
Table-1 Dimensions of the spiral plate heat exchanger

We had taken two fluid storage tanks. One tank will have hot fluid in it and another tank will have cold fluid in it. The heaters are placed in the tank for hot fluid. The rotameter which is used to measure the flowrate of fluid is placed between hot fluid storage tank and spiral plate heat exchanger. Similarly, another rotameter is placed between cold fluid tank and heat exchanger by using pipe connections. The valves are placed between fluid tanks and rotameters to control the flow of fluids.The hot fluid inlet pipe is connected at the center core of the spiral heat exchanger and the outlet pipe is taken from periphery of the heat exchanger.Thecold fluid inlet pipe is connected to the periphery of the exchanger and the outlet istaken from the centre of the heat exchanger. The cold fluid is supplied at room temperature from cold solution tank.The hot fluid is heated between 60 and 80 °C using heaters. The RTD (Resistance temperature detector)s are connected to the inlet and outlets of the heat exchanger. The resistance temperature detectors are used to measure the inlet and

 DOI : 10.18231/2454-9150.2018.0476

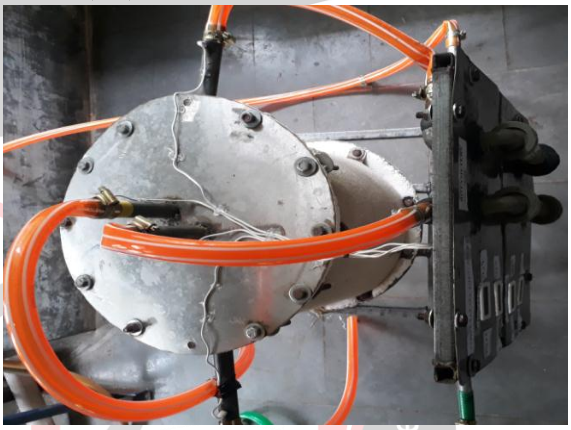
outlet temperatures of cold and hot fluids. The views of experimental setup as shown in the following figures (1.a), (1.b), (1.c), (1.d).

(1.a)Front view.



(1.b) Side view.

(1.c)Inner design.



(1.d) Top view.

Fig 1 Experimental setup of spiral plate heat exchanger.

III. Experimental Procedure

Firstly, the hot fluid is allowed to flow through operating valve from storage tank to rotameter. Simultaneously the cold fluid let to flow through operating valve from cold water tank to rotameter. The hot fluid is passed to hot fluid inlet of spiral plate heat exchanger from rotameter. Similarly the cold fluid also passed to cold fluid inlet. The heat interaction between two fluids, as the result of the cold fluid absorbs heat from hot fluid. The both hot and cold fluids are flowing opposite direction that is the type flow counter flow. Same procedure should be continued with measured by using digital thermo couples, and noted the inlet and outlet of hot and cold fluids. The rotameter readings also to be noted.

The following equations are used for the experimental analysis of spiral plate heat exchanger.

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Heat lost by the hot water (Q_h)

$Q_h = m_h c_p \Delta T_h$

$\Delta T_h = T_{hi} - T_{hO}$

Where,

m_h is mass flow rate of hot fluid (kg/sec)

C_p is the specific heat of the water J/(kgk)

ΔT_h is the mean temperature difference of hot fluid (^{0}C)

T_{hi} is the hot fluid inlet temperature (^{0}C)

T_{h0} is the hot fluid outlet temperature (^{0}C)

Heat lost by the cold water (Q_c)

$Q_c = m_c c_p \Delta T_c$

$\Delta T_c = T_{CO} - T_{Ci}$

Where,

m_c is mass flow rate of hot fluid (kg/sec)

C_p is the specific heat of the water J/(kgk)

ΔT_c is the mean temperature difference of cold fluid (^{0}C)

T_{Ci} is the hot fluid inlet temperature (^{0}C)

T_{C0} is the hot fluid outlet temperature (^{0}C)

Average heat transfer (Q)

$$Q = \frac{Qh + Qc}{2}$$

Where,

Q is the heat transfer rate W

IV. RESULTS AND DISCUSSION

4.1 Experimental study of heat transfer rate of a spiral plate heat exchanger

In this study, water is used for both hot and cold fluids. The effect of heat transfer rate on various mass flow rates is shown in figure 2. Firstly, the flow rate of hot water (100 LPH) is fixed and cold water flow rate is varied up to three levels such as 100LPH, 200LPH, 300LPH and heat transfer rate is measured. The heat transfer rate of 1.50 kW was noticed for 100 LPH of cold fluid, 2.11 kW for 200 LPH of cold fluid and 2.23 kW for 300 LPH of cold fluid. Improvement in heat transfer rate is observed with the increase in mass flow rate of cold fluid.

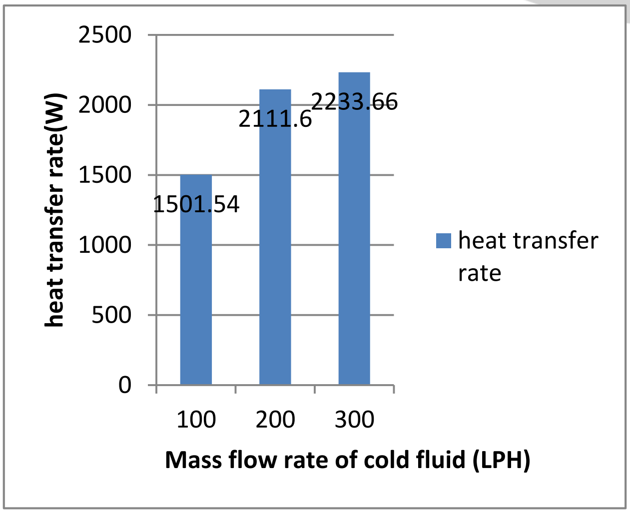

Fig 2-The flow of hot fluid is constant at 100 LPH (Liter Per Hour)

Secondly, the flow of hot fluid is fixed at 200 LPH and cold fluid varied up to three levels such as 100LPH, 200LPH, 300LPH.The graph plotted is shown in below figure 3. The heat transfer rate of 2.43 kW was observed for 100 LPH of cold fluid, 2.81 kW for 200 LPH of cold fluid and 3.12 kW for 300 LPH of cold fluid. Finally, improvement in heat transfer rate is observed with the increase in mass flow rate of cold fluid.

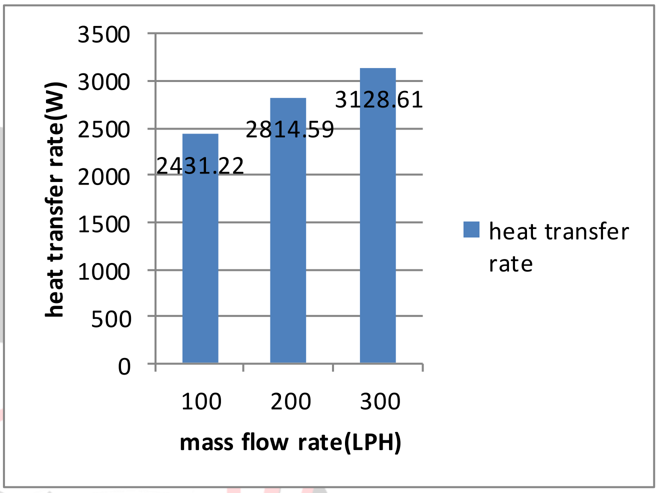

Fig 3 The flow of hot fluid is constant at 200 LPH (Liter Per Hour)

Finally, the flow of hot fluid is fixed at 300 LPH and cold fluid varied at 100LPH, 200LPH, 300LPH.The graph plotted is shown in below figure 4. Maximum heat transfer rate of 5.006 kW was observed for the maximum flow rate of cold fluid.

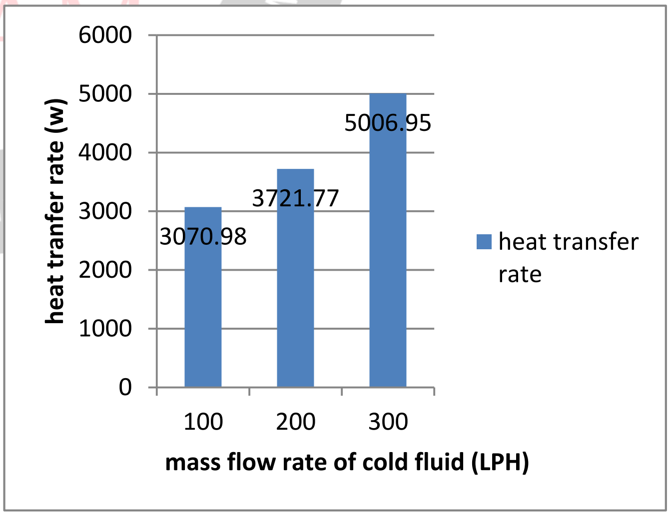

Fig 4. The flow of hot fluid is constant at 300 LPH (Liter Per Hour)

 DOI : 10.18231/2454-9150.2018.0476

V. CONCLUSIONS

In this study experiments are successfully performed on a spiral plate heat exchanger with hot and cold fluids. The conclusions drawn by varying mass flow rates of hot fluid and cold fluid are as follows.

- Out of the different mass flow rates maximum heat transfer of 5.006kW was observed for 300 LPH of both cold and hot fluids

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