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HEAT FLOW ANALYSIS OF CONCENTRIC TUBE PARALLEL FLOW HEAT EXCHANGER WITH HELICAL INTERRUPTER

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ABSTRACT

A heat exchanger is a device used to transfer heat between two or more fluids. In this work it has been mainly focused on enhancement of heat transfer rate in concentric tube parallel flow heat exchanger with helical interrupter. There are different techniques to enhance heat transfer rate such as active, passive or a combination of both. For increase in heat transfer and decrease the cost of equipment various shapes of interrupters can be used in the tubes. In this work helical interrupter has been used in tubes to study the flow analysis. By keeping constant flow in tube, heat transfer rate, LMTD, overall heat transfer coefficient and effectiveness of concentric tube heat exchanger without helical interrupter and with helical interrupter are calculated and compared.

Keywords: *Heat exchanger, concentric tube, Parallel flow, Wire coil helical Interrupter.*

I. INTRODUCTION

The heat exchangers have an important role in the energy storage and recovery. Due to the development of modern technology, the heat exchangers required in various industries for high heat-flux cooling to the level of megawatt per meter square. At this level, cooling with conventional fluids such as water and ethylene glycol and so forth, are challenging. Hence, it is necessary to increase the heat transfer performance of working fluids in the heat transfer devices. Heat transfer augmentation techniques (passive, active and compound) are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc. Prof.Rahul A. Lekurwale et al (2014) performed an assessment on heat exchanger tubes for improving the heat transfer rate in turbulent flows. They used different types of twisted tapes inserts i.e. clock wise, counter clock wise and serrated twisted tapes and with three twist angles, θ=30°, 60° and 90° in a tube. After experimentations they concluded that the heat transfer rate as per Nusselt number increases with increase in depth ratio and decreases with raising the width ratio. M.J.Patel (2014) made a review on the enhancement in heat exchanger using twisted tape insert and concluded that rate of heat transfer in tube can be increased by inserting a twisted tape made of metallic wiry sponge, as it has more contact area with fluid.Jagpreet Singh, et al [2014] conducted experimental study on convective heat transfer characteristics on heat exchanger using twisted tapes different cuts shapes i.e. square, circular and triangular respectively. They used different materials such as GI, Al and Cu inside the inner tube of single unit on heat transfer and friction factor for heating of water for Reynolds number range 500-3000. They concluded that with maximum inlet and outlet, minimum temperature difference is observed in the pipe with Cu insert. M. Mulla (2014) conducted the experimental study on heat transfer and friction factor characteristics flowing through laminar flow in tubes of shell and tube heat exchanger fitted with twisted tapes with baffles. He concluded that during the experimentations if heat exchangers operate under laminar flow condition at low flow rate, the twisted tapes with baffles are goes to increase the heat transfer coefficient and pressure drop. For the experimentation they placed twisted tapes inclination with baffles at 45^0 which is at normal axis of twisted tape. From the experimentation he showed that the Nusselt number is increased for same flow rate in tubes with twisted tape with baffle as compared to plain tubes as well as tubes with typical twisted tapes. He obtained highest heat transfer coefficient for tubes fitted with twisted tape with baffle compared to the plain tubes as well as tubes with typical twisted tapes for same Reynolds number and for same flow rate. Dr. Mallikarjun. C. et al (2016) came to conclusion after all theoretical and practical calculations and testing prototype for different flows copper naturally being good conductor of heat, it accelerates heat transfer rate immensely. They came to know that copper has high metallurgical qualities like rustproof, antifouling, corrosion free, cheap and easily available makes it very useful for heat exchanger. They twisted the inserts helically, such that water flowing through tubes moves in helically rotation and inserts push them towards the wall of copper tubes which helps in heat transfer. They found 20.15% increase in heat transfer theoretically.

II. METHODOLOGY

The hot fluid namely hot water is obtained from the geyser (heater capacity 3 kW) and it flows through inner tube. The helical interrupter inserted in concentric tube is shown in Fig. 1. The cold fluid i.e. cold water can be admitted at any one of the ends enabling the heat exchanger to run as a parallel flow exchanger. Measuring jar used for measure flow rate of cold water and hot water. These can be adjusted by operating the different walls values provided. Temperature of the fluid can be measured using thermo-couples with digital display indicator. The outer tube is provided with insulation to minimize the heat loss to the atmosphere. The methodology of parallel flow heat exchanger with helical interrupter is shown in Fig. 2. The helical interrupter is made from stainless steel rod on which a copper wire is wounded around on it. Stainless steel rods are made from alloyed steel with 12% chromium. This interrupter spiraled with copper wiring creates turbulence for normal flow of water inside the concentric tube of heat exchanger. The technical specifications of helical interrupter are shown in Table 1.

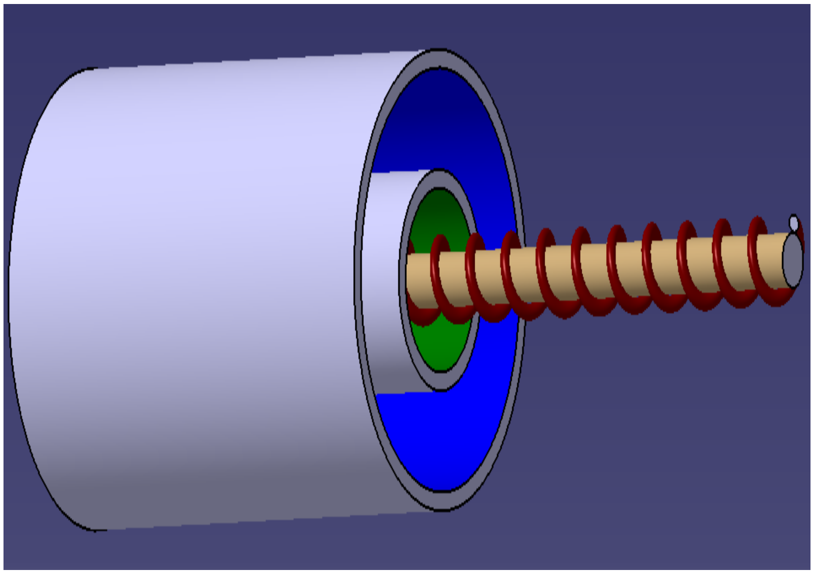

Fig.1: Insertion of Helical Interrupter in the Concentric Tube

Table 1: Specification of the set up

Sl. No	Name of the Specification	Value
1	Material	Copper tube
2	Size	ϕ12.5mm x 1500mm long
3	Outer shell material	G.I2
4	Size of the outer shell	ϕ40mm
5	Geyser Capacity	1 litre, 3 kW

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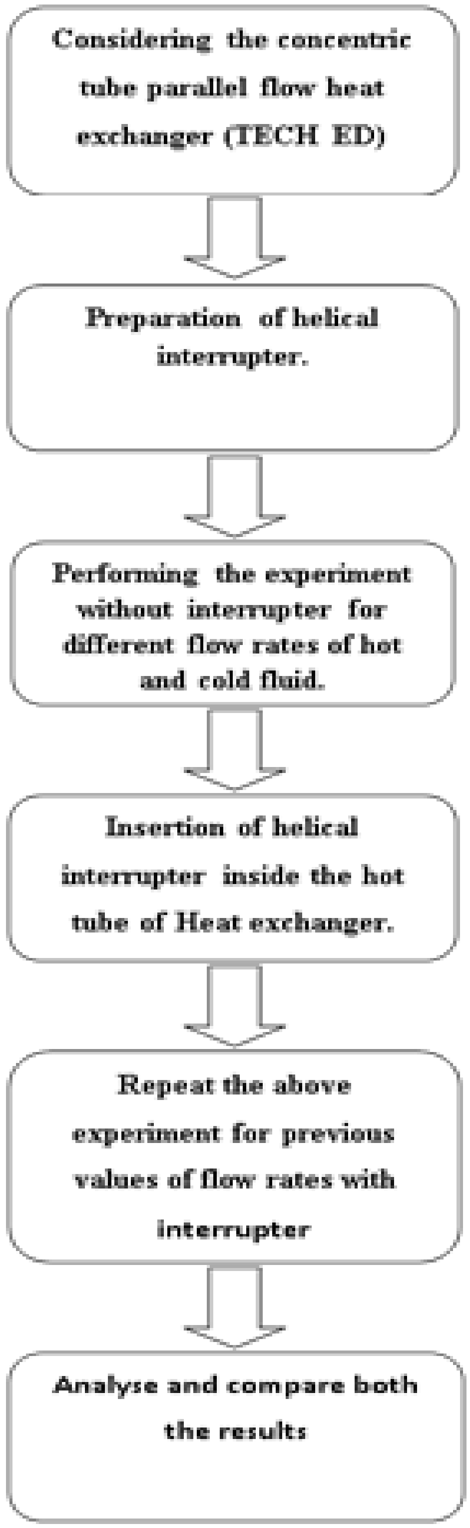

Fig. 2: Methodology of the Parallel Flow Concentric Tube Heat Exchanger

III. RESULTS AND DISCUSSIONS

Heat transfer, also referred to simply as heat, is the movement of thermal energy from one thing to another thing of different temperature. The heat transfer is calculated using the following formulae:

$$Q = m_h cp\ (T_{hi} - T_{ho})\ \ W \qquad \ldots (1)$$

The logarithmic mean temperature difference (also known as log mean temperature difference or simply by its initialism LMTD) is used to determine the temperature driving force for heat transfer in flow systems, most notably in heat exchangers. The LMTD is a logarithmic average of the temperature difference between the hot and cold feeds at each end of the double pipe exchanger. The larger the LMTD, the more heat is transferred. The LMTD can be calculated using the following formulae:

$$LMTD = \Delta T_m = (T_i - T_o) \qquad \ldots (2)$$

Where, $T_i = T_{hi} - T_{ci}$, $T_o = T_{ho} - T_{co}$

The overall heat transfer coefficient, in thermodynamics and in mechanics is the proportionality constant between the heat flux and the thermodynamic driving force for the flow of heat and can be calculated using the following formulae:

$$U = Q/(\Delta Tm.Ai)(w/m^2\ {}^\circ c) \qquad \ldots (3)$$

Where, $A = \pi DiL$

Effectiveness is defined as the ratio of the actual heat transfer rate to the maximum possible heat transfer rate for the given flow and temperature conditions. The effectiveness can be calculated using the following formulae:

$$E = m_h.cp(T_{hi} - T_{ho})/(mcp)min\ .\ (T_{hi} - T_{ci}) \qquad \ldots (4)$$

Table 2 and Table 3 show the experimental values of hot and cold water inlet and outlets through heat exchanger for without and with helical interrupter at various flow rates. Fig. 3 shows the rate of heat transfer is higher in case of heat exchanger with interrupter compared to heat exchanger without interrupter for all the flow rates. The highest increment is found for the flow rate 0.01 (cc/sec) which is 68.62%.Fig. 4 showsthe rate of LMTD is higher in case of heat exchanger with interrupter compared to heat exchanger without interrupter for all the flow rates. The highest increment is found for the flow rate 0.01 (cc/sec) which is 33.82%.Fig. 5 shows the rate of overall heat transfer coefficient is higher in case of heat exchanger with interrupter compared to heat exchanger without interrupter for all the flow rates. The highest increment is found for the flow rate 0.01 (cc/sec) which is 26%.Fig. 6 showsthe rate of effectiveness is higher in case of heat exchanger with interrupter compared to heat exchanger without interrupter for all the flow rates. The highest increment is found for the flow rate 0.01 (cc/sec) which is 30%. The main reason behind the increment in values of heat transfer rate, LMTD, overall heat transfer coefficient, effectiveness respectively is due to the turbulence created by the helical interrupter near the inner surface of the tube wall. The helical shape of the interrupter disturbs the flow.

Table2: Experimental results for the heat exchanger without helical interrupter

Sl. No.	**Flow Rate (cc/sec)**		**Temperatures (°C)**			
	Hot Water (mh)	Cold Water (mc)	Cold Water Inlet (T_{ci})	Cold Water Outlet (T_{co})	Hot Water Inlet (T_{hi})	Hot Water Outlet (T_{ho})
1	0.01	0.025	20	21.02	34.1	29
2	0.015	0.030	20	22.10	34.2	29.3

3	0.02	0.035	20	21.91	34.8	30.3
4	0.025	0.040	20	22.04	35.6	31.5

Table 3: Experimental results for the heat exchanger with helical interrupter

Sl. No.	**Flow Rate(cc/sec)**		**Temperatures (°C)**			
	Hot Water (mh)	Cold Water (mc)	Cold Water Inlet (T_{ci})	Cold Water Outlet (T_{co})	Hot Water Inlet (T_{hi})	Hot Water Outlet (T_{ho})
1	0.010	0.025	20	22.4	38.1	29.5
2	0.015	0.030	20	22.93	38.2	31.4
3	0.020	0.035	20	22.4	38.3	32.6
4	0.025	0.040	20	22.23	38.3	33.8

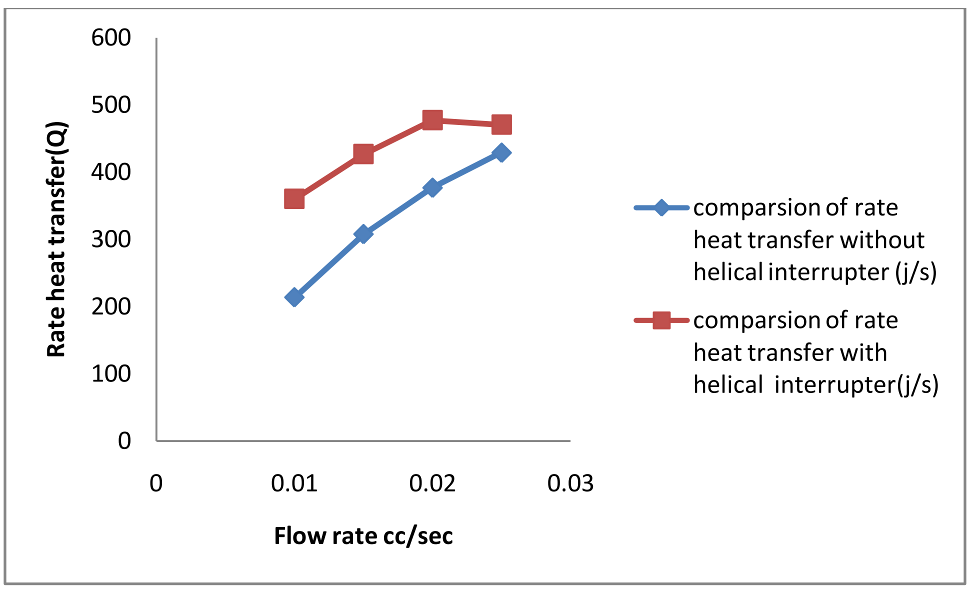

Fig. 3: Comparison of rate of heat transfer rate between with and without interrupter

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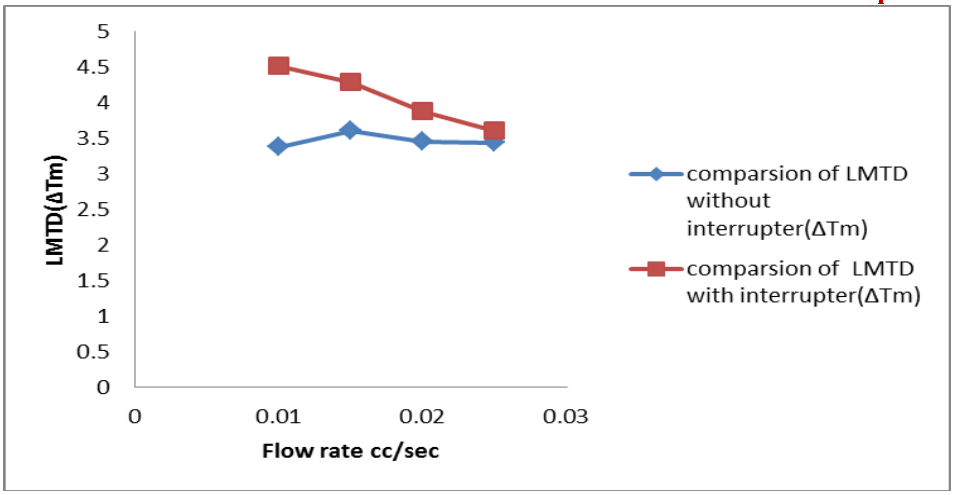

Fig. 4: Comparison of Rate of LMTD between With and Without Interrupter

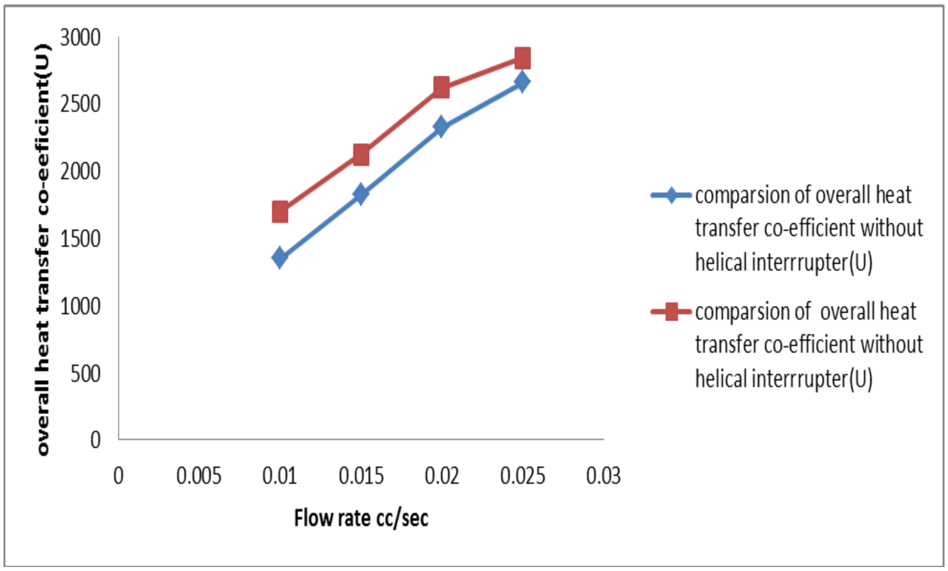

Fig. 5: Comparison of Overall Heat Transfer Coefficient between With and Without Interrupter

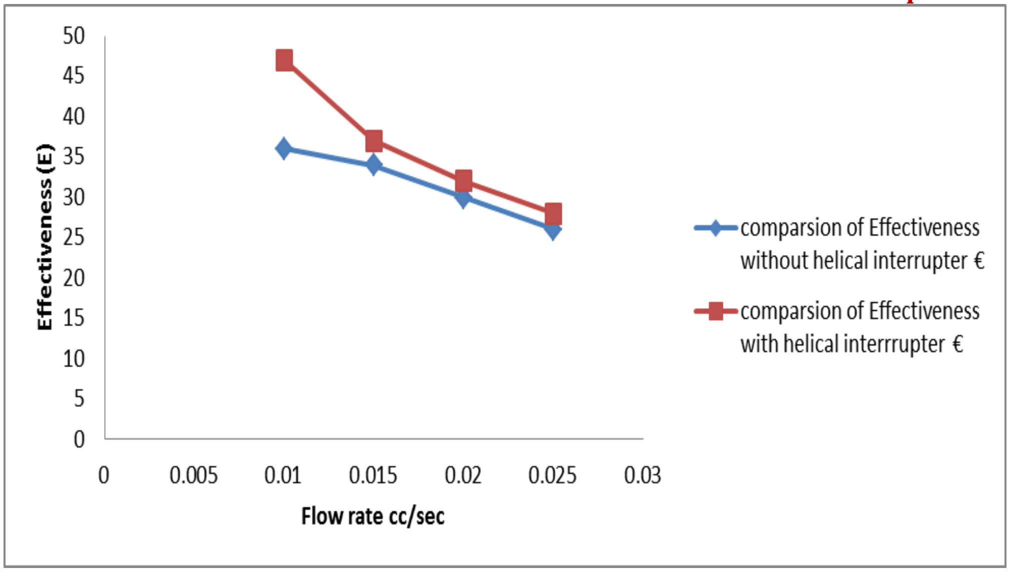

Fig. 6: Comparison of Effectiveness between With and Without Interrupter

IV. CONCLUSIONS

The following conclusions are drawn from the present work are:

- The heat transfer rate, LMTD, overall heat transfer coefficient and effectiveness are calculated for both with and without helical interrupter.
- By observing graphs, the heat transfer rate, LMTD, overall heat transfer coefficient and effectiveness of concentric tube parallel flow heat exchanger with helical interrupter are high when compared to heat exchanger without interrupter.

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