EXPERIMENTAL EVALUATION OF PERFORMANCE INTENSIFICATION OF DOUBLE TUBE HEAT EXCHANGER WITH FINS

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ABSTRACT: A device called a heat exchanger is used to transfer heat from one fluid to another. There are several ways, both direct and indirect contact, in order to exchange heat in fluids. The thermal conductivity and heat transfer capacity of the working fluid have a significant impact on a heat exchanger transfers heat. The performance of heat exchangers in industrial processes is frequently improved by the application of heat transfer enhancement. It is completed by utilizing fins or inserts with different forms to increase. The surface area of the heat exchange surface. Along with being widely used in applications involving the sensible heating or cooling of process fluids and their simple design, maintenance, and cleaning, over time, double pipe heat exchangers have become more significant. Basically, the rate of heat transmission increases as surface area increases, but small to medium-sized enterprises cannot expand surface area. Double concentric pipe is utilized to enhance the rate of heat transmit quickly in order to address these problems. This study, reports on the experimental evaluation of the performance intensification of a double tube heat exchanger with fins. Rectangular fins are connected to inner pipe to improve heat transmission, performance, and surface area. The experimental analysis will show that using RIE (Rotated Inclined Elliptic) turbulators in place of Non-Rotated Inclined Elliptic (NRIE) turbulators enhance heat transfer.

KEYWORDS: Heat Exchanger, Pipe, Fins and Double –pipe Heat exchanger, Rotated Inclined Elliptic Turbulators.

I. INTRODUCTION

Whenever a solid surface and a fluid, a solid particle and a fluid, or two or more fluids in thermal contact with each other and are at various temperatures, thermal energy (enthalpy) is transferred between them using a heat exchanger. Between a process stream and a utility stream (such as cold water, pressurized steam, etc.), a power source and a process stream (such as electricity), or all of the process streams between two process throughout, which reduces the need for external heat sources and promotes energy integration [5]. Two process streams are typically used with a heat exchanger.

The process industry uses a number of heat exchanger types. The following are examples of these types: condensers and Air coolers, fired heaters, direct contacting (quenching towers), heat exchangers can be shell and tube exchangers, plate and frame exchangers, spiral heat exchangers, or plate-fin exchangers. Numerous variables determine the choice of a heat exchanger, comprising operating and capital costs, temperature ranges, fouling, pressure drop, corrosion tendencies, and safety issues (leakage tolerance) [4].

Engineering, industrial, and technical devices including air-cooled aircraft engines, air conditioners, computers, automobile radiators, CPUs, gas turbines, and refrigerators will all profit from improving heat transfer from heated surfaces. Increasing the fluid around the heated surface's heat exchange, an optimized extended surface or fin is used. The fin's duty is to disperse heat to the surrounding air by convection and radiation after transferring heat from the base to its surface by conduction. The transport of heat has been examined by taken into consideration convection and radiation with varying geometries and nonlinearity and various attempts have been made to analyze a range of parameters for fins [3].

To improve heat transmission and decrease unnecessary heat loss, a heat exchanger's thermal resistance can be reduced. Utilizing porous media with various arrangements, materials, and geometric structures the flow channel to increase heat transfer in heat exchangers. Smaller, more cost-effective heat transmission systems are produced through a porous media. Porous medium issues are consequently crucial to the planning and estimate of heat exchangers. To reduce fluid pressure loss and pumping power, porous media's design parameters must be optimized [1].

Fins improve the heat exchanger tubing's effective surface area. Whenever the coefficients of heat transfer are high, finned tubes are utilized on both the inner and outer sides of the tubes differ noticeably from one another. To maximize the efficiency of heat transmission, a wide range of fin designs can be utilized, including simple fins, slit fins, spiral fins, and fins with delta wing vortex generators. The goal is to identify the optimal fin for a certain application. Multiple researchers have examined numerous possibilities under varied working conditions and have produced remarkable work in the field.

Numerous research have looked at the impact of fin geometry on throughout the years, turbulent heat transfer has occurred in numerous types of heat exchangers. It has been demonstrated that the operating circumstances and the improvement of heat transport is impacted by fin geometry. Researchers have increased the thermal efficiency of heat exchangers and solar heaters using a number of other components, such as twisted tapes, V-shaped winglet inserts, surface disc turbulators with helical, V-cut twisted tapes, nanofluids, baffled tapes, conical rings, grooved surfaces, twisted tap and a dimpled tube, transversely twisted-turbulators, and combinations of these methods. In order to improve its effectiveness in a wide range of applications, Double-Pipe Heat EXchangers (DPHEX) received the focus of various research [6].

To enhanced heat exchangers thermohydraulic performance, the purpose of the heat exchanger industry has to reduce pumping power and increase thermal contact (improved heat transfer coefficient) [2]. Due to the fact that it enables to reduce the amount of heat transfer surface area required for specific applications, on the industrial level. Improving heat transmission in heat exchangers is becoming more and more significant. In their heat exchangers, the automotive and refrigeration sectors frequently utilize improved surfaces. Furthermore, the process sector is actively developing improved heat transfer surfaces for their heat exchangers. Heat exchangers ability to transmit heat using a number of analytical and experimental research techniques. These methods can be separated into "active" and "passive" categories.

The heat transfer medium's (fluid's) thermal conductivity has a considerable effect on the efficiency of the heat exchanger. However, when using a transfer medium with high thermal conductivity, the efficiency of the heat exchanger may be considerably increased, when using a restricted medium with low thermal conductivity. A double pipe heat exchanger has one pipe placed concentrically included inside of a larger diameter pipe and from one segment to the next, the flow is directed by the fittings. In order to fulfil pressure drop and mean temperature difference requirements, the twin pipe heat exchanger may be configured in a number of series and parallel patterns. Double pipe heat exchangers are typically employed when modest heat transfer zones (up to $50m^2$) are required for the sensible heating and cooling of process fluid. This arrangement is also effective when one or both of the fluids are high pressure. The majority of fin type heat exchangers have complex internal structures implementing them unsuitable for exhaust gas recovery systems. The main drawback is soot deposit inside the heat exchanger's inner part, which lowers the exchanger's efficiency. In contrast to a smooth tube with a same Reynolds number, internal fins will result in huge pressure reductions in the tube. If the fin design is complicated, the efficiency of the internal fins tube side pump will increase.

However, considering few tests are conducted in this area, and neither the advantages of perforated turbulators nor the rotational effects were taken into consider in previous numerical or experimental studies. In this study, the experimental assessment of performance intensification of a double tube heat exchanger with fins is reported to cover the lack in the research that currently exists on rotating inserts. The following is the structure of the remaining work: The literature survey is included in part II. In Section III discusses the experimental evaluation of the performance intensification of a double tube heat exchanger with fins. Section IV contains an examination of the results. The process is consequently completed in Section V.

II. LITERATURE SURVEY

K.Balashowry, K.Sri Hari Charan Reddy, T.Saikrishna, Mandhula Kalyan et. al., [9] uses computational fluid dynamics to explain the effect of heat transfer through arbitrary shaped fins. Heat transfer analysis is done in the current study using fins of any shape with the same surface area. Utilizing the Fluent software from ANSYS (Analysis System).The study is completed. This study's primary goal is to use fins of arbitrary shapes to accelerate heat transmission. The outcomes are contrasted with solid fins that have a standard shape. According to the results, the arbitrary-shaped fins significantly increase heat transmission,. Compared to other models of fins utilized in the investigation, the fin with the elliptical hole had a higher rate of heat transmission.

Valeria Palomba, Andrea Frazzica et. al., [10] an experimental study's objective includes a fin-and-tube heat exchanger that works as an evaporator at subatmospheric conditions. A fin-and-tube heat exchanger that functions as an evaporator between 1 and 7 kPa of pressure is a topic of this paper's research. The experimental investigation examines the impact of the key operational parameters (heat transfer fluid temperature, superheat, and heat exchanger tilt) and looks for correlations that are appropriate for the engineering design of the evaporator under the examined circumstances. Differences in logarithmic mean temperatures were the primary variables impacting heat transfer, secondarily, the fluid's temperature and expressions connecting the evaporation power heat transfer coefficients to operating conditions were derived from the results.

Kotian Shreyas, Methekar Nachiket, Nishant Jain and Pritish Naik et. al., [11] Part I: Experimental Investigation, Heat Transfer and Fluid Flow in a Double Pipe Heat Exchanger. Heat transmission and fluid flow were tested experimentally in a double-pipe heat exchanger using both theoretical and practical data. In experiments for 60 Re 240, the cold fluid's inlet temperature was set at 31°C while the hot fluid's input temperature ranged from 50 to 70 degrees Celsius. The graphs, along with other measures of performance, the efficiency, NTU (Number of Transfer Units) and Plots of fluid mass flow rates outlet temperatures of the hot and cold streams have been generated.

C Kannan, P Sathyabalan, S Ramanathan et. al., [14] provides a mathematical examination of heat transmission in rectangular fins with varied perforations. In terms of density, velocity, and temperature, this study evaluates three different perforation geometries parallel square, inclined square, and circular improve heat transfer. Several perforated fins were examined for density change, velocity, and temperature decreases using CFD (Computational Fluid Dynamics). The heat transmission rate of this particular sort of perforated fin is higher than that of a solid fin with a similar dimensionality. This result showed that the parallel square design provides a higher rate of heat transmission than other types.

S. Ramu, Tariku Achamyeleh, R. Srinivasan and Krishna Kumar K et. al., [15] in double pipe heat exchanger, the rate of heat transfer at the surface contact of an elliptical fin: An experimental evaluation and comparison's description. In this paper, the heat production in an elliptic fin heat exchanger was presented. The experiment was successfully conducted, compared to the current approach, the comparison to the four other methods (Tube-Tube, Rectangular inline inserted fins, Annular, and Spiral rod), a double pipe heat exchanger with an elliptic fin was demonstrated have a higher heat transfer rating. This analysis recommended analyzing elliptical fin heat exchangers and then examining the increased heat transfer rate of the elliptic fin. These techniques are used to evaluate the efficiency of a double pipe heat exchanger over a range of flow rates and the maximum amount of heat transfer, also to compute the heat loss from the surface and associated fluid temperature transformations. In contrast to the thermodynamic analysis of heat transfer in experiment and simulation, the increased surface is primarily used to speed up the heat transmission.

Ishwar J.Dhangar, Dr. Manojkumar Chopra et. al., [16] Utilising experimental research and CFD analysis, discussion over the effectiveness of a fin and tube heat exchanger with various fin types. Five alternative fin-and-tube heat exchanger designs with 12 tube rows and an 18 mm tube diameter each had their air-side heat transfer and friction properties tested experimentally. Five different fin designs were used to create the test samples: plain, slit, spiralled, crimped, fin with rear 6-row slit fins and front 6-row vortex-generators combined into a delta-wing longitudinal Vortex Generator (VG) fin. Three different sets of criteria were used to assess the performance of the heat exchangers with five fins. When Reynolds numbers were high, the mixed-fin heat exchanger performed better than the heat exchanger with fins that included delta-wing vortex generators was identified. The optimized vortex-generator fins' performance and slit fins to transfer heat has been examined using a computational technique.

Mayank Jain, Kanhaiya Patidar, Mahendra Sankhala, lokesh Aurangabadkar et. al.,[17] offers Heat Transfer Analysis and Fin Optimization Through Geometric Variation. The analysis primary goal is to examine fins thermal heat dissipation changes in their shape. The transient thermal behavior of fins has been predicted using parametric models. After that, by modifying the geometry that includes rectangular, circular, triangular, and extended fins models will be developed. Modeling is done with Creo Parametric 2.0. With ANSYS 14.5, the analysis is performed. Presently, the most common material used aluminium alloy 204, this ranges from 110 to 150 W/m-0 C in terms of thermal conductivity, is used to create fin bodies.

Jatinder, Gautam Kocher et. al., [18] a double pipe heat exchanger's flow dynamics and heat transmission are analysed. The thermohydraulic performance of the heat exchanger is enhanced by the use of a two pipe heat exchanger with corrugated pipes. In order to finish the investigation of the pressure drop and heat transfer of the Double pipe heat exchanger (DPHE), Computational fluid dynamics (CFD) is being utilized. The analysis's mass flow rates are based on the real-world scenarios used in industrial refrigeration systems. In addition, the corrugations in the pipes are projected to lead to a greater loss of pressure. This pressure reduction in the DPHE would have an impact on the refrigeration system's compressor's functionality, which would lower the system's Coefficient of Performance (COP). Corrugated Double Pipe Heat Exchangers (DPHE) specific friction factors and Nusselt Numbers are examined.

Hac Mehmet S, Es,ref Baysal, ahin, Necmettin S, Ali Rıza Dal, ahin et. al., [19] describes investigating the enhancement of heat transfer implementing solar parabolic trough systems in a new form of heat exchanger. In order to investigate the requirements of heat transmission and friction in a concentric tube heat exchanger with various coiled wire turbulator pitches, experimental and computational research was conducted. To gather experimental data, a system was set up for experimentation. A three-dimensional CFD computer programme was used to carry out the numerical simulations. Comparisons between the experimental and numerical results were done for a Reynolds number range of 3000 to 17000, and empirical correlation data. Nusselt number was used to relate the results in relation to the Prandtl number and Reynolds number. At pitch distances of p=15, 30, and 45 mm, turbulators increased heat transfer by 2.07, 2.28, and 1.95 times in comparison to a smooth tube.

Kannan M., Ramu S., Santhanakrishnan S., and G.Arunkumar et. al., [20] explains Heat Transfer in a Double Pipe Heat Exchanger by contrasting experimentation and analysis. The purpose of these studies is to support typical heat transfer procedures as well as the tools and procedures that may be applied to accelerate heat transmission. The apparatus and experimental set-up required to carry out the experiment using the twin pipe heat exchanger. The device includes tube-within-tube heat exchangers with threaded thermometers on either end, measuring flasks, water pumps, electric geysers, and other components. One of the above methods for improving heat transmission has been adjusted in three of the four heat exchangers. These techniques for measuring heat loss from surfaces and the temperature changes associated with fluid movements are also used to determine efficacy, in order to assess efficiency, find the flow rate that will enable the most heat transfer in a double pipe heat exchanger., it is necessary to compare the various flow rates.

III. EXPERIMENTAL EVALUATION OF PERFORMANCE INTENSIFICATION OF DOUBLE TUBE HEAT EXCHANGER

This Section discusses the experimental evaluation of the performance intensification of a double tube heat exchanger with fins. The Fig. 1 shows the workflow diagram of presented approach. The thermal energy of two fluids with varying temperatures can be exchanged between them using devices called double-tube heat exchangers. Sometimes only a few heat transfer areas are necessary, for fluid heating or cooling, these heat exchangers are often utilised. The concentric, or one tube inside another, Double-Pipe Heat Exchanger (DPHEx) is the most basic HEx used in industrial applications for low heat load. The inner tube might be simple or finned. Although the other fluid enters the annulus gap between the two pipes, the first fluid passes through the inner pipe. Parallel or concurrent flow is utilised for instances in which a stable wall temperature is required, whereas counter-flow arrangement helps in achieving the optimum thermal performance. Simpleness, compactness, ease of manufacture, ease of maintenance, etc. are benefits of the DPHEx. Compared to heat exchangers without a fin, rectangular and curved fin heat exchangers are 81% and 85% more efficient. Therefore, this analysis makes use of rectangular fins.

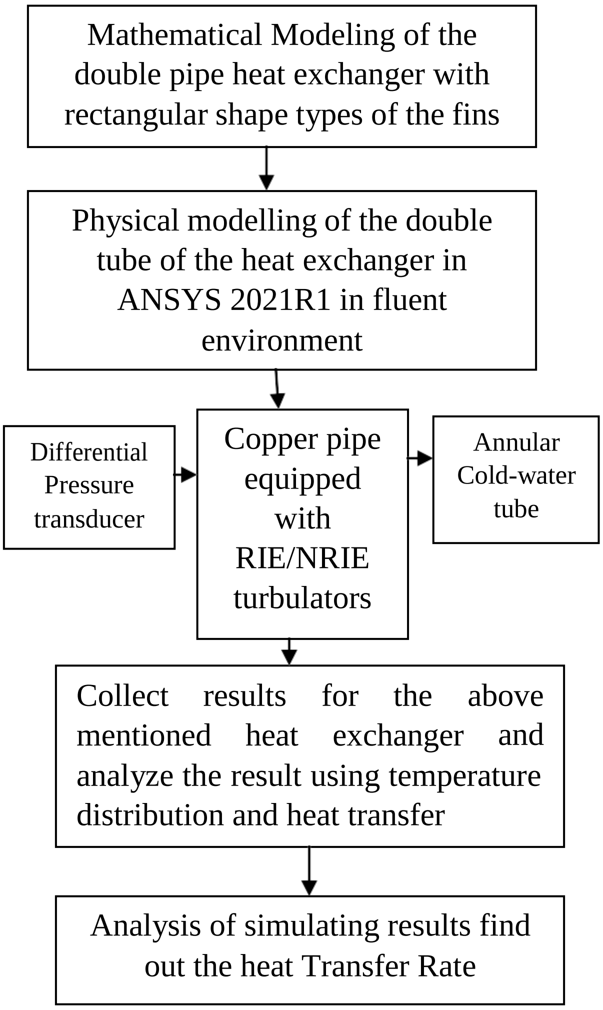

Fig. 1: Workflow of Presented Approach

A generate of heat exchanger known as a double pipe heat exchanger functions by distributing its work across two pipes. Heat and air are typically transported with this device. A heat exchanger's objective is to enable the interaction of two different flows at a conductive barrier, which can result in the transfer of thermal energy.

The essential heat exchanger equation is as follows:

$$Q = UA\Delta T \quad (1)$$

The total heat transfer coefficient of the heat exchanger is represented by U. The total area for heat transmission is A. The fluid entering and exciting is at a different temperature, which is indicated by the symbol ΔT. A, ΔT, U, or any combination of the three can be increased to enhance a heat exchanger's performance. The following are some various ways to improve heat transmission in a heat exchanger.

i) Operating pressure: The ideal gas law (PV=nRT) is well known. P=ρrT may be used to rewrite this expression, where stands for fluid density. One might determine from this relationship that operational pressure and density are closely connected. A fluid's pressure also falls when it passes through a heat exchanger. Inversely proportional to density and directly related to velocity. As a result, working at greater pressures permits faster velocity, greater Reynolds numbers for a given pressure drop lead to improved heat transfer coefficients.

ii) Operating temperature: Viscosity, thermal conductivity, and heat capacity may all be increased by raising the operating temperature. If U and A are fixed, increasing the temperature differential between the cold fluid and preventing fluid from entering the heat exchanger may improve efficiency.

iii) Enhanced surface:

Fins should be used for increased surface area. The main function of fins, which are expanded surfaces is to increase the space accessible for the body to transmit heat.

Due to the interruption of the flow and temperature boundary layers caused by the staggered surfaces along the specified flow orientation, rectangular fins exhibit the maximum heat transfer capabilities. The choice of fin material is also very important. In the Fluent module of ANSYS, the heat transport analysis is performed. The actual representation of any system in mathematics is known as mathematical modelling. Simple approximations and for this, idealisations are used. Different laws are used, including physical laws and laws of conservation of mass, momentum, and energy.

In order to simulate fluid flow, heat and mass transfer, chemical reactions, other processes are Ansys Fluent is a general-purpose Computational fluid dynamics (CFD) application. With a single window workflow, Fluent offers a modern the CFD process is made simpler from pre- to post-processing by the user-friendly interface. With the newly released Ansys 2021 R1, engineers can drive new levels of product innovation by utilising advancements in simulation technology and ever-increasing computing power. Ansys 2021 R1 equips the engineers to create the next generation of products that are safe, dependable, and deliver breakthrough performance.

The test portion is a component of the double-pipe heat exchanger, measurement devices, and two cycles of 0.5 in. 151 W of a Wilo Star-RS 25/1-8 circulation pump that circulates hot and cold water, 8 Lit/min capacity crystal-conical rotameter and 0.1 Lit/min reading accuracy is used in conjunction with all of these components. Hot water tank complete the hot-flow cycle. The brass Y-sifter valve has 3.8 m of connecting pipes and a working stream quality of 6 bar at 110 ^{o}C.

The difference in pressure between two points, commonly referred to as P1 and P2 or high side and low side, measured by differential pressure transducers. This kind of sensor may be used to check the cleanliness of a filter and the level in a sealed tank. RIE/NRIE turbulators are connected in copper pipes using this differential phase transducer. There will be a high and low pressure when a restrictive element is used on one of the sides. As the flow rises, more pressure drop is produced. As particles pass through openings and filters, differential pressure is utilised to evaluate whether a pipeline has any obstructions or contamination. The differential pressure will rise or fall if a section of the pipe gets obstructed since it will modify the pressure. Typically, a typical diaphragm-type differential pressure transducer is used, while silicon-based microsensors are being utilised more frequently. The recorded differential pressure is related to the liquid level.

$$h = \frac{\delta P}{\rho g} \quad (2)$$

where „g" is the gravitational acceleration and „ρ" is the density of the liquid. The RIE inserts are spaced apart (P) at a 40 mm distance. N, the chosen range for the number of holes, ranged from 0 to 5. The holes ranged in diameter from 0mm to 1.5mm. The connecting rod's and the RIE vortex generators' slant angle () is set between 15o to 25o. Additionally uncertain were the remaining geometrical parameters, which were the inner and outer diameters of the elliptical strips (b=6 mm and c=10 mm), as well as the thickness of the RIE enhancers (t=1 mm). The difference in elliptic turbulators having a rotation angle of β=90◦ degrees between their non-rotated and rotated geometries.

One of the various approaches to enhance "Q" (heat transfer) an exchanger's surface area has to be increased as its major design. ANSYS 2021R1 fluent environment is used to increase the surface area, this consider the impact of the fins in a heat exchanger for various mass flow rates.

The following formula is used to calculate the heat transfer parameters, such as the heat transfer rate and Reynolds number Re:

The heat transfer rate is calculated as follows:

$$Q = c_p m(T_{in} - T_{out})(3)$$

Where „m" is the fluid's mass flow rate and „Q" is its rate of heat transfer. The Reynolds number Re is as follows:

$$Re = \frac{\rho n D i v i}{\mu n}$$

Where: Vi is the fluid's velocity within the tube (in m/s), kn is its dynamic viscosity (in kg/m/s), and n is its thermal conductivity (in W/m. C). These heat transfer characteristics are investigated and their result analysis is discussed in next section.

IV. RESULT ANALYSIS

In this section, experimental evaluation of performance intensification of double tube heat exchanger is implemented. A double pipe heat exchanger of the coil pipe type with separate circuits for hot and cold fluids serves as the experimental setup in this research to carry out the experimental investigation. The ANSYS 2021R1 fluent environment is utilized to investigate the performance of presented approach.

The table 1 shows the heat transfer rate of hot fluid (a) with and (b) without rectangular fins.

Table 1: Heat transfer rate of hot fluid (a) with and (b) without rectangular fins

Mass -flow Rate	Hot fluid (inlet temperature)	Hot fluid (outlet temperature)	Q (heat transfer rate)
0.028	330	320.823	0.27734
0.056	330	322.386	0.4232
0.072	330	323. 017	0.50652
0.089	330	323.453	0.5850
0.15	330	323.382	0.7982

With out fins:

Mass -flow Rate	Hot fluid (inlet temperature)	Hot fluid (outlet temperature)	Q (heat transfer rate)
0.028	330	320.051	0.2562
0.056	330	323.342	0.2813
0.072	330	324. 26	0.33645
0.089	330	324.423	0.38924
0.15	330	325.356	0.5558

The table 2 shows the Heat transfer rate of clod fluid (a) with and (b) without rectangular fins.

Table 2: Heat transfer rate of clod fluid (a) with and (b) without rectangular fins

Mass Flow rate	Cold fluid (inlet temperature)	Cold fluid (outlet temperature)	Q (heat transfer rate)
0.028	306.6	314.1165	0.2999
0.056	306.6	313.2344	0.4823
0.072	306.6	312.71891	0.623
0.089	306.6	312.321	0.6992
0.15	306.6	311.523	0.999

Mass Flow rate	Cold fluid (inlet temperature	Cold fluid (outlet temperature	Q (heat transfe

	)	)	r rate)
0.028	306.6	310.1123	0.1354
0.056	306.6	310.823	0.2389
0.072	306.6	310.843	0.2435
0.089	306.6	310.783	0.3203
0.15	306.6	310.654	0.5843

It is noticeable from the results of the analysis, given approach with fins, and approach without fins that it is always advantageous to utilize heat exchangers with fins. Figure 3 demonstrates the changes in mass flow rate to heat transfer rate in clod fluid.

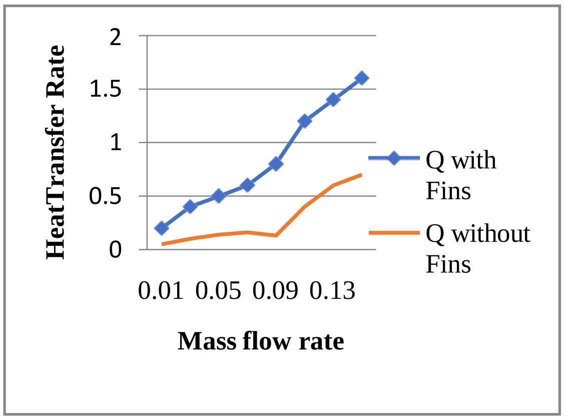

Fig. 2: The variations of mass flow rate verses heat transfer rate in clod fluid

In comparison to double heat exchangers without fins, the former have a better heat transfer rate. The relationship between the mass flow rate and the rate of heat transfer in a hot fluid is seen in Fig. 3.

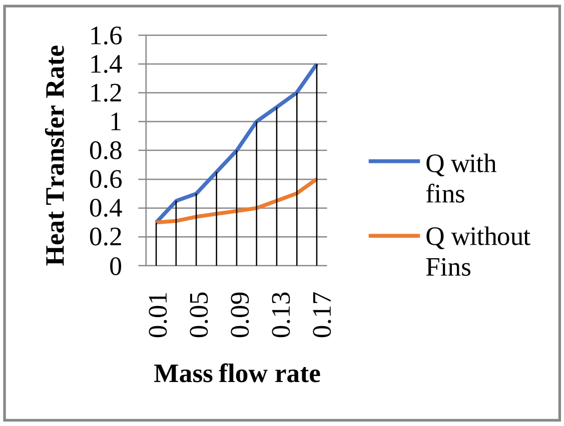

Fig. 3: Variation of the mass flow rate verses heat transfer rate in hot fluid

In comparison to double heat exchangers without fins, the one with fins has a higher heat transfer rate. The Fig. 4 shows the variations of friction verses Reynolds number.

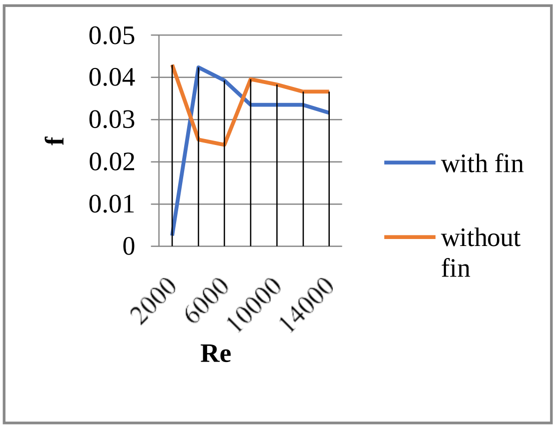

Fig. 4: Variation of friction verses Reynolds number

The double heat exchanger with fins has better friction Reynolds number results. Because steel is a strong product, the concentric double tube heat exchanger consisted and inexpensive. It is also shown that the fins 'Q' rises with higher 'm' when heat exchangers with and without fins are compared for similar 'm'. similar to the lack of fins. The analysis is further run on a range of "m" values to determine the impact of the distribution of temperatures on the concentric double tube heat exchangers. The friction factor should be kept to a minimum while the 'm' increases. Concentric double tube heat exchanger fin number should be optimized.

V. CONCLUSION

The Experimental evaluation of the performance intensification of a double tube heat exchanger is performed in this analysis. Concentric-tube heat exchanger with copper-coiled RIE/NIRE turbulators uses the Fluent code to study heat transfer and pressure loss. The results of the numerical, experimental, and empirical correlations are all very comparable. Readings of various mass flow rates are kept on record. The loss and gain of heat caused by hot and cold fluid was noticed. Different pressure drop values and increases in heat transmission were seen in the examined fin designs in the present study. When weighed against the increase in heat transmission, the pressure drop values may be negligible. In comparison to earlier research in this sector, the RIE/NIRTE turbulators can significantly enhance the heat exchanger's thermal performance without raising production costs. They might also be simply inserted within the heat exchanger's pipes. The results show that heat exchanger sizes may be reduced while heat transfer performances are effectively improved. The result analysis makes it easily apparent that using a heat exchanger with fins, is always advantageous, whether it contains two concentric tubes or not.

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