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EXPERIMENTAL INVESTIGATION OF HEAT EXCHANGERS USING SERPENTINE TUBES

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Abstract: With a wide range of applications in the chemical and food industries, nuclear reactors, refrigeration and air conditioning systems, waste heat recovery systems, and many other power factors, heat exchangers are an essential component of engineering systems. Natural convection is a method of heat transfer in which the flow of fluid is brought about by variations in fluid density brought on by varying temperature conditions. The effectiveness of fluid heat transfer rate in a heat exchanger with serpentine tubes with an oval shape and constant pitch in longitudinal flow is experimentally assessed in the current study. The experimental results show that fluid flowing through serpentine tubes consistently outperforms fluid flowing through straight tubes for a given Reynolds number (Re), Nusselt number, heat transfer coefficient, and performance of Heat Exchanger systems. Additionally, experimental results show that fluid flowing through serpentine oval-shaped tubes has a somewhat higher friction factor (f) and, thus, a smaller pressure drop than fluid flowing through regular straight tubes.

***Index Terms* – Heat Exchangers, Reynold Number, Shell & Tube, Nusselt Number.**

INTRODUCTION

The area of thermodynamics known as heat transfer is responsible for researching the production, transformation, exchange, and utilisation of energy in the form of heat (thermal energy) between various systems. There are numerous ways to transfer heat, including conduction, convection, and radiation. The quantity of heat that is transmitted through a material per unit of time is known as the rate of heat flow and is often expressed in watts (joules per second). Understanding the idea of heat is crucial in many engineering domains. Heat transfer is very important to civil, mechanical, and chemical engineers since it has a significant impact on material choice, machinery effectiveness, and reaction kinetics, respectively. The heat exchanger happens by three principles • Conduction • Convection • Radiation Conduction heat transfer is the transfer of heat through matter (i.e., solids, liquids, or gases) without bulk motion of the matter. In another ward, conduction is the transfer of energy from the more energetic to less energetic particles of a substance due to interaction between the particles. The molecules collide and diffuse as they move randomly, which causes conduction heat transmission in gases and liquids. It is important to relate the heat transfer to mechanical, thermal, or geometrical aspects in order to study conduction heat transfer. Consider steady-state heat transmission through an aorta wall with thickness x, where the interior wall (Th) is warmer than the exterior wall (Tc). Heat transfer Q (W) is perpendicular to the plane of temperature difference and in the direction of heat flow.

Serpentine Tube:

Fins, connection pipes, and a single microchannel tube bent into a serpentine shape make up a serpentine heat exchanger in most cases. In a controlled atmosphere brazing (CAB) furnace, every component is integrally brazed together. a serpentine bend was made in a microchannel tube. stripey fins. Adapters for outlets and inlets. An original equipment manufacturer (OEM) can transfer heat from one environment to another by bending a tube into the shape of a serpentine.

Numerous studies have already been conducted to examine the flow properties and heat transmission in helical heat exchangers. Centrifugal forces cause the heat transfer in helically coiled tubes to be enhanced. The fluid particles travel towards the tube's core region due to a secondary flow field that is created by the tube's curvature and circulatory motion. By lowering the temperature gradient across the tube's cross-section, the secondary flow accelerates the rate of heat transfer. Consequently, a further convective heat transfer mechanism that is perpendicular to the main flow and absent from straight tube heat exchangers arises. K.S. Bharuka, D.Y. Kasture When the inner Dean number of a twin pipe helical heat exchanger was increased, it was discovered, the overall heat transfer coefficients increased. But this growth depends on the proportion of the mass flow rates. In an experiment on a tube-in-tube heat exchanger, Vimal Kumar, Burhanuddin Faizee, Monisha Mridha, and K.D.P. Nigam found that as operating pressure in the inner tube increases, so does the overall heat transfer coefficient, and the friction factor value in the inner-coiled tube agrees with data from the literature. Study tubes with shorter corrugation periods are often more effective, according to Kristina Navickaite, Andrea Mocerino, Luca Cattani, Fabio Bozzoli, Christian Bahl, and Klaus Liltrop. . The corrugation period has a greater effect on the thermal and overall performance of the tested tubes than the aspect ratio. While slightly less efficient than spirally corrugated tubes with twisted tape inserts, the double corrugated tubes' innovative design shows higher thermal performance in contrast to AEA tubes. Although data for double corrugated tubes is lacking, the majority of experimental results on the performance of improved surfaces were acquired in higher Re flow regimes. A more thorough experimental examination is needed in order to compare the performance of double corrugated tubes and other improved surfaces in detail. Anand Kumar Singh and Dr. Manish Gangil The results demonstrate that there are several types of serpentine tube heat exchangers, depending on their pitch length, and also help to find the quantity of heat transfer either in the flow of parallel or counter. Different pitch lengths that the fluid running through the tube must pass through will increase the fluid flow timing inside the shell, increasing the rate of heat transfer. As a result, heat transfer efficiency is improved. The structure and working of serpentine tube heat exchangers as shown in Figure 1 & 2.

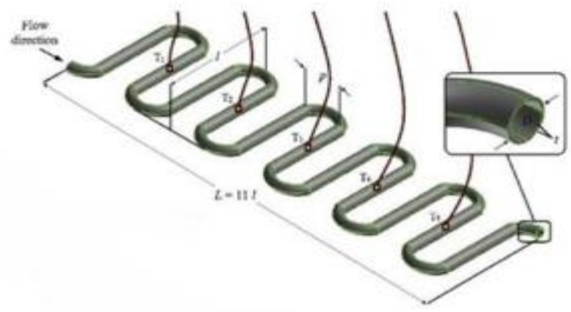


Fig 1 Structure of serpentine tube.

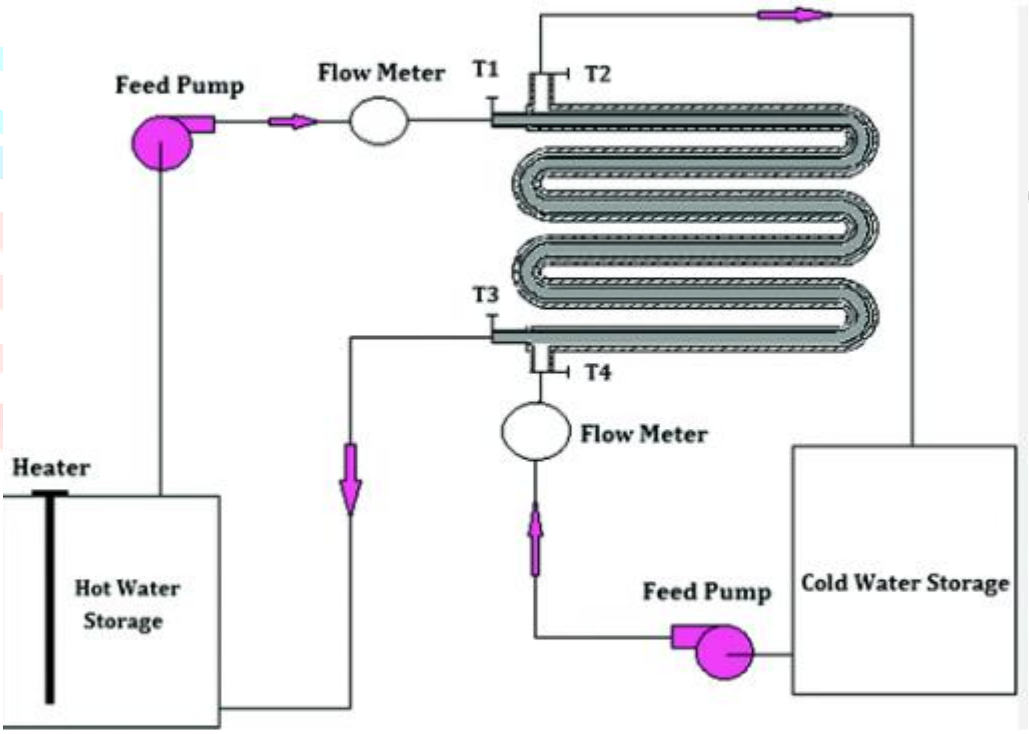
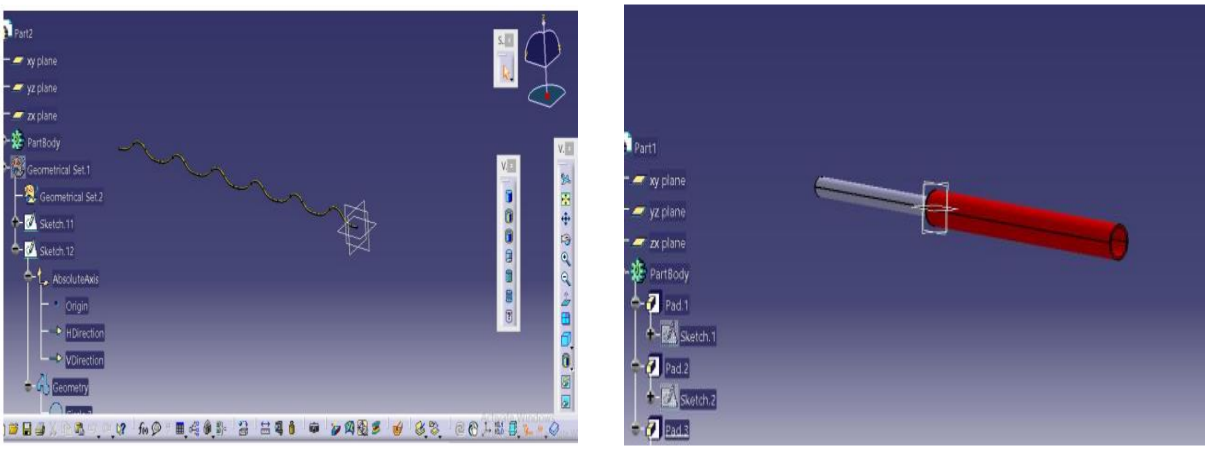


Fig 2 Heat transfer process in Heat Exchangers

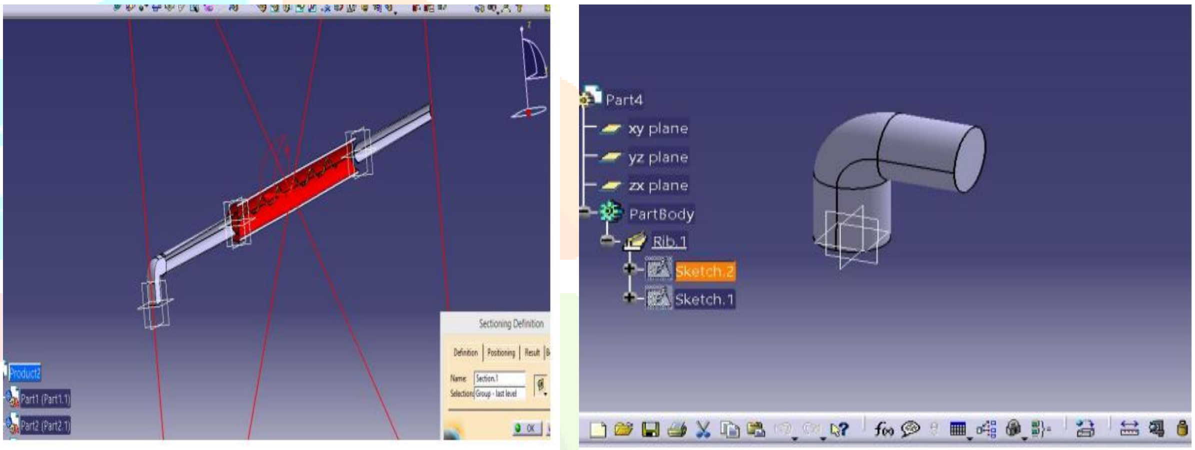
Modelling of Serpentine Tube:

Working Principles of heat exchanger Heat exchangers work because heat naturally flows from higher temperature to lower temperatures. Therefore, if a hot fluid and a cold fluid are separated by a heat conducting surface heat can be transferred from the hot fluid to the cold fluid. The modelling of heat exchangers was performed using Catia software and as shown figure 3 to Figure 5.



(a) (b)

Fig. 3 Tubes details (a) Serpentine tube longitudinal view (b) Pipe and outer casing



(a) (b)

Fig. 4 Tubes details (a) Test Section (b) Elbow Section

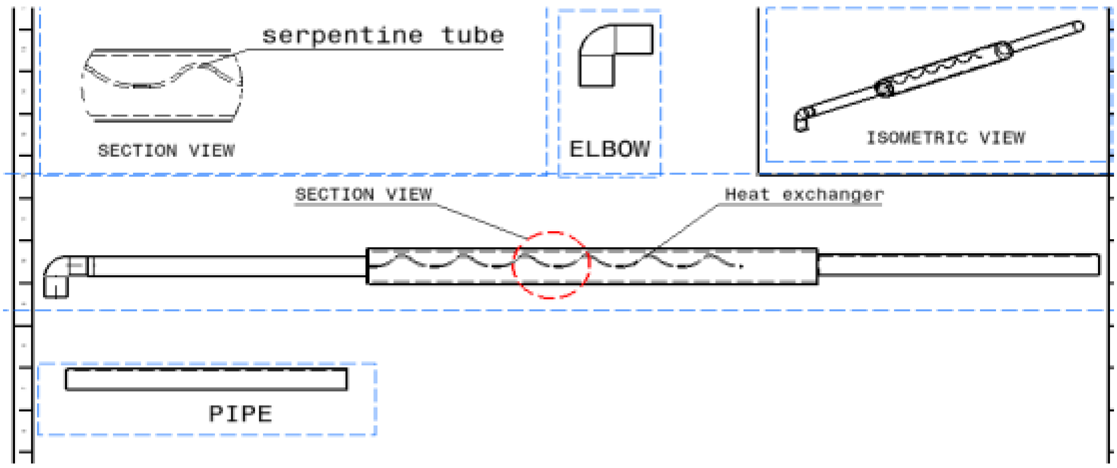


Fig. 5 Drafting of Experimental Model

Design Methodology

To examine the performances of thermos-hydraulic characteristics of modified and conventional heat exchanger, the following equations must be solved.

The performances of HE from hot air to the cold water flowing through tube bundle is evaluated as

$$\dot{Q} = \dot{m} \times C_{P,w} \times (T_{w,o} - T_{w,i}) \quad (1)$$

Where,
m is the rate at which mass of water flowing through test section, , Cp,w is the heat capacity of water, and Tw,i represents inlet water temperature and Tw,o indicates outlet water temperature.

$$\dot{Q} = \dot{m} \times C_{P,a} \times (T_{a,o} - T_{a,i}) \quad (2)$$

where,
m is the flow rate of air, Cp,a is the heat capacity of air, Ta,i and Ta,o are inlet and outlet air temperature, respectively.

$$\frac{h \times D_h}{k} = 0.023\, Re^{0.8} \times Pr^{0.4} \quad (3)$$

The Nusselt Number is calculated by using following equation.

$$Nu = \frac{h \times D_h}{k} \quad (4)$$

Dittus-Boelter correlation used to evaluate Nusselt number variation with Reynolds number

$$\text{Nu}\, D_h = 0.023\, Re^{0.8} \times Pr^{0.4} \quad (5)$$

Petukhov correlation used to evaluate Nusselt number variation with Reynolds number

$$\text{f} = (1.82 \log Re - 1.64)^{-2} \quad (6)$$

where, f = friction factor

Data Reduction

The aim of the experiment is to investigate the Nusselt number in square, house shaped and boot shaped ribbed channels. The independent parameters are Reynolds number and ribs pitch ratios. Reynolds number based on the channel hydraulic diameter is given by

$$Re = \frac{\rho V D}{\mu_{air}} \quad (7)$$

The local heat transfer coefficients are evaluated from the measured temperatures and heat inputs. With heat added uniformly to fluid (Qair) and the temperature difference of wall and fluid (Tw−Tb), average heat transfer coefficient will be

Due to the fluid's bulk being violently moved, mixing one component of the fluid with another is necessary for the convectional method of heat transmission. Although fluid displacement is still used to move fluid from one point in space to another, heat energy is still transferred from one fluid particle or molecule to another by conduction. The process of heat transfer of fluid particles may be either laminar or turbulent when the motion of the fluid is caused by the imposition of external forces in the form of pressure differences. This is dependent upon the relative magnitude of inertia and viscous forces, determined by the dimensionless parameter Reynolds number. In free convection, the velocity of fluid particle is very small in comparison with the velocity of fluid particles in forced convection, whether laminar or turbulent.

(a) Cupper Serpentine Tubes (b) Actual model

Fig. 5 Experimental Set up

Results and Discussion

Prior to conducting research on a heat exchanger with an oval-shaped serpentine tube bundle, the validity and reliability of the experimental setup were tested by conducting experiments on a heat exchanger with a straight tube bundle. The results for friction factor and NU were compared with two correlations that were provided to assess the relationship between each variable and the Reynolds number. The experimental results appeared to differ by 9% from the correlation values, which shows the validity and dependability of the current experimental setup. Experimental research into the longitudinal flow behaviour and heat transfer properties of fluids in shell and tube heat exchangers used serpentine oval-shaped tubes in comparison to straight oval-shaped tubes. The following graphs are displayed to compare the performance of standard and modified heat exchangers using data from calculations and experimentation.

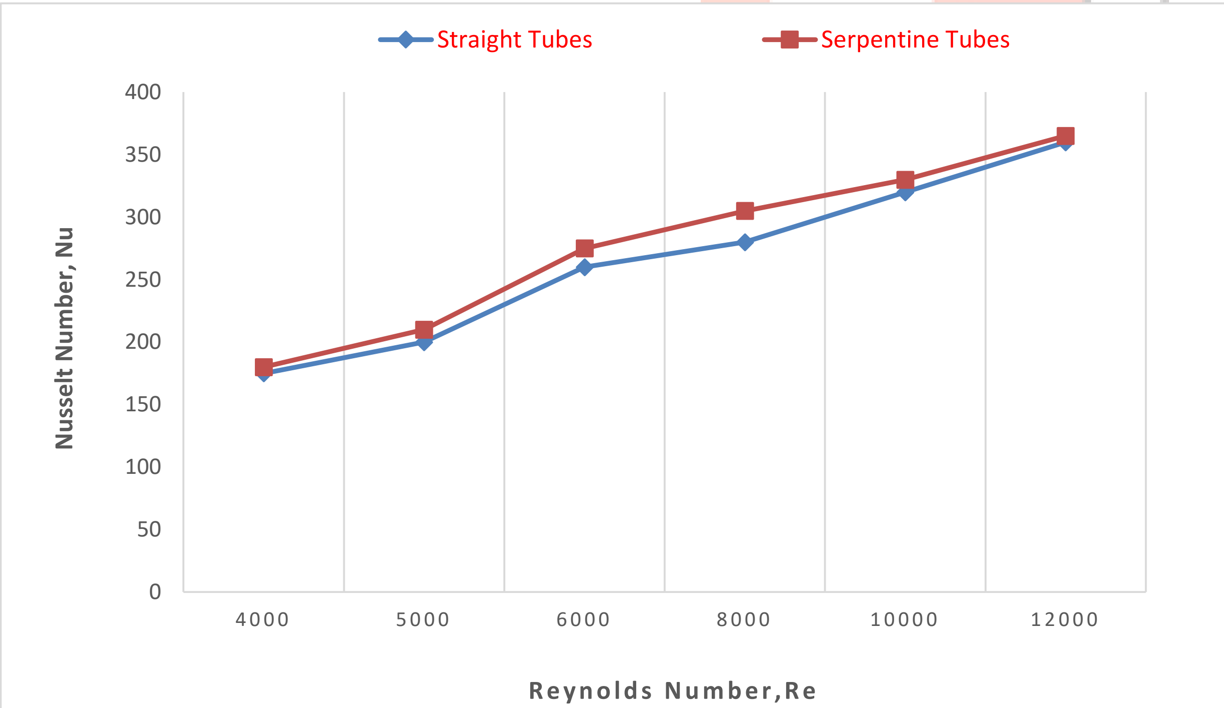


Fig. 6. Variation of Reynolds Number Versus Nusselt Number

Figure 6 illustrates how the Nusselt number increases as the Reynolds number increases for serpentine and straight tube bundles. The heat transfer coefficient and the rate of heat transfer between the fluids both climb as the Nusselt number does. Additionally, it was discovered that for all Reynolds values, the Nusselt number for a serpentine tube bundle is greater than that for a straight tube bundle. This is because the fluids running through both the shell and the tubes experience increased turbulence due to the serpentine tube bundle.

Figures 7(a) and 7(b) demonstrate that when Re increases, pressure decreases. For all Reynolds values, the pressure drop for a fluid flowing through a serpentine tube bundle is a little higher than it is for a straight tube bundle. This is because, in comparison to straight tubes, the design of serpentine tubes causes increased friction for the fluids passing through the shell and tubes. This raises the pressure drop in serpentine tubes by increasing the friction factor. The graph above illustrates how the overall heat transfer coefficient rises with increasing Reynolds number for heat exchangers with both serpentine and straight tubes. The use of serpentine tubes has been found to have a higher overall heat transfer coefficient than the use of straight tubes for all RE because the geometry of serpentine tubes produces more turbulence in the fluids flowing through the shell and tubes, which is responsible for flushing the fouling particles over the tubes and lowering the fouling resistance. Figure 8 shows that compared to straight tubes, serpentine tubes offer a greater temperature difference for a given flow rate. For serpentine tubes with increase in flow rate, turbulence of fluid also increases on both shell and tube side of heat exchanger which in turn vary the temperature difference between the fluids flowing through the heat exchanger.

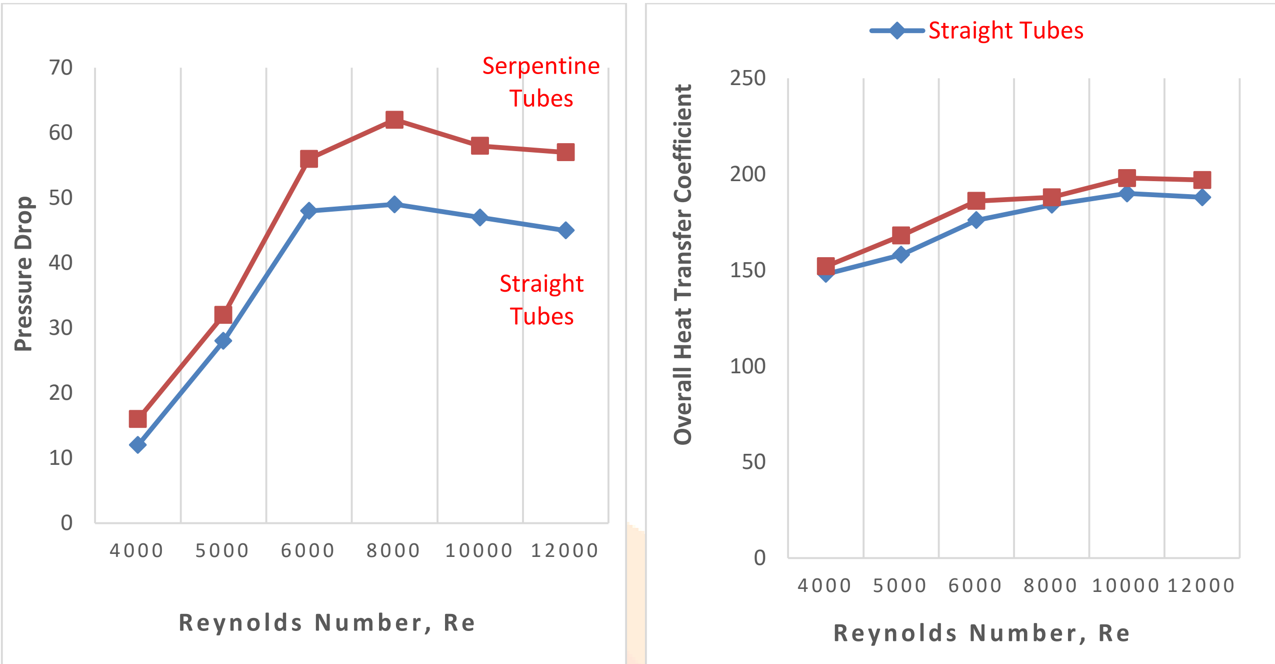


Fig. 7. Variation of (a) Pressure drop (*ΔP*) Versus Re. (b) Representation of Overall Heat Transfer Coefficient versus Re.

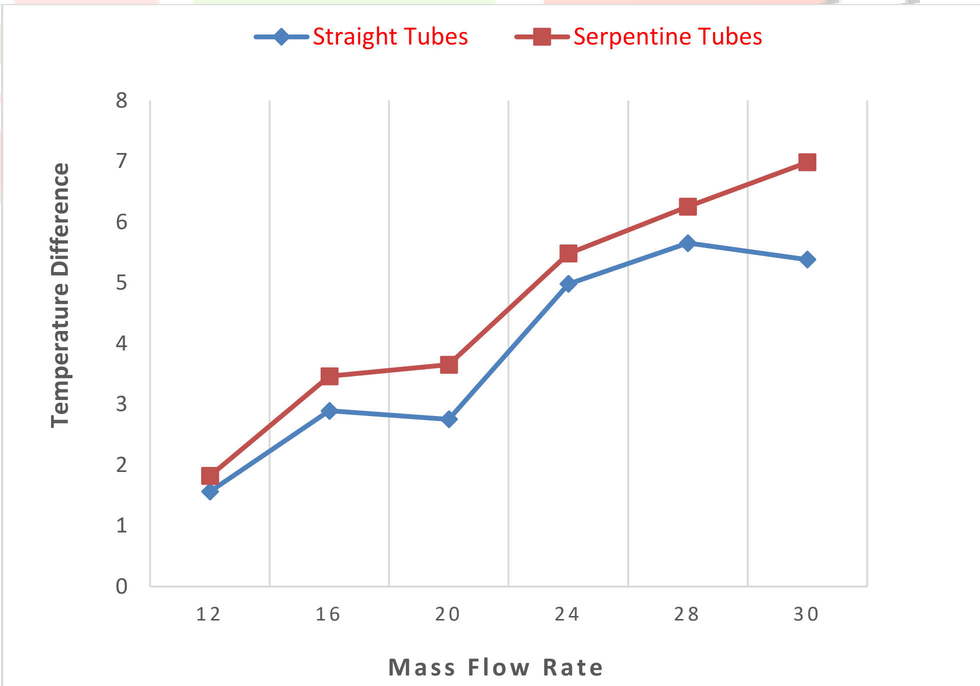


Fig. 8. Variation of Mass flow rate Vs Temperature difference (ΔT)

Conclusion:

The objectives in this study is to determine the heat transmission rate through serpentine, and to that end, has been completed work on Catia modelling and drafting. However, we are continuing working on the process and conducting additional research to reach our goals. The current study shows that heat exchangers with serpentine tubes perform better overall in terms of thermal and hydraulic performance than exchangers with straight tubes at high Reynolds numbers.

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