

Improved Shell and Tube Heat Exchanger (STHX) Customized using a variety of Baffle Arrangements

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Abstract— Thermal performance and pressure drop are important aspects to consider when evaluating a shell and tube heat exchanger. Thermal performance and pressure drop are both affected by the direction of fluid flow and the types of baffles used in different orientations. Increasing the intricacy of baffles improves heat transfer while simultaneously increasing pressure loss, which necessitates more pumping power. This affects the efficiency of the system. The numerical simulations on diverse baffles, such as single segmental, double segmental, and helical baffles, are presented in this thesis. The effect of baffles on pressure drop in a shell and tube heat exchanger is seen here. Single segmental baffles demonstrate the establishment of dead zones when heat transport is impeded. When compared to single segmental baffles, double segmental baffles reduce vibrational damage. Because dead zones are eliminated when helical baffles are used, pressure drop is reduced. Heat transfer is improved when there are fewer dead zones. Smaller pumping power is required as a result of the lower pressure drop, which improves overall system efficiency. The results reveal that helical baffles are superior to the other two types of baffles.

Keywords— Shell and tube heat exchanger, baffle, segmental baffle, double segmental baffle, helical baffle, Overall performance etc.

I. INTRODUCTION

Thermal energy is transferred between two or more fluids, or between solid particles and a fluid, that are at different temperatures and in thermal contact through the use of heat exchangers. The most important principle of a heat exchanger is that it transmits heat without exchanging the fluid that transports the heat in the process of transfer. Thermal energy and work exchanges with the surrounding environment are not present in heat exchangers. Conduction and convection are the primary mechanisms through which heat is transferred. According to the transfer processes, number of fluids, and degree of surface compactness, as well as construction features, flow configurations, and heat transfer mechanisms [1], heat exchangers are classed. In various engineering applications, such as chemical engineering processes, electricity generation, petroleum refining, refrigeration and air-conditioning, the food sector and others, heat exchangers are widely utilised. Out of all of the numerous types of heat exchangers, shell and tube heat exchangers have the advantage of being reasonably simple to produce and having a wide range of application options for gaseous as well as liquid media over a wide temperature and pressure range [2].

It is necessary to circulate two fluids with differing temperatures through a heat exchanger in order for it to function properly. Each has its own flow path, with one flowing directly through tubes and one flowing outside the tubes but still contained within the shell (the shell side). Heat is transferred from one fluid to another through the tube walls, either from one fluid to another on the tube side or from one fluid to another on the shell side. Fluids can be either liquids or gases on either the shell or the tube side, depending on the application. The utilisation of a broad heat transfer surface, as well as the usage of several tubes, is required in order to transmit heat efficiently. Using energy efficiently and avoiding waste of thermal energy is a good approach to save money. In the field of heat transfer, a heat exchanger is a piece of equipment that is used to transmit thermal energy (enthalpy) between at least two fluids, between a solid surface and a fluid, or between solid particles and a fluid at varying temperatures. In heat exchangers, there is typically no outside heat and no co-operation among the workers. Fluid stream heating and cooling, as well as the disappearance and re-formation of single and multi-part fluid streams, are all common uses for this technology. Different applications aim to recover or dismiss heat, sterilise, pasteurise, fractionate or distil a working fluid, concentrate a working fluid, crystallise a working fluid, or control the course of action in a working fluid. In a couple of heat exchangers, the fluids that are transferring heat are in direct touch with one another. Typically, in heat exchangers, heat transfer between fluids occurs through an isolating wall or into and out of a wall in a temporary way, rather than continuously. In many heat exchangers, the fluids are separated by a heat transfer surface, and they are not allowed to mix unless absolutely

necessary. Direct transfer forms of exchangers, also known as recuperators, are used for this purpose. The term "indirect transfer type" refers to exchangers in which there is discontinuous heat exchange between hot and cold fluids through the use of thermal energy storage and discharge through the exchanger surface or matrix. In general, such exchangers have leakage of fluid from one fluid stream to another, which is caused by differences in pressure and matrix rotation, as well as the exchanging of valves in the exchanger. It is referred to as a sensible heat exchanger if no phase change happens in any of the fluids that pass through it throughout the heating or cooling process. In exchangers, such as electric heaters and atomic fuel components, there could be inward thermal energy sources, which could be used to generate heat [3,4].

Boilers, fired heaters, and fluidized-bed exchangers, for example, are examples of exchangers where combustion and synthetic response can take place inside the exchanger. Mechanical forms of equipment can be found in a few exchangers, such as scratched surface exchangers and stirred tank reactors, and they can be used to transfer heat. Most of the time, heat transmission in the isolating mass of a recuperator occurs as a result of conduction. As it may be, in a heat pipe thermal exchanger, the heat pipe serves as an isolating wall while also promoting heat exchange by accumulating, dissipating, and conducting the working liquid within the heat pipe during operation. All things considered, if the liquids are immiscible, the isolating wall may be eliminated, and the interface between the liquids may serve in place of a heat exchanger surface, as in a direct contact thermal exchanger [5-8].

UTILIZATION OF HEAT EXCHANGERS

The use of heat exchangers is a significant issue that would necessitate a thorough investigation to cover all of the angles. Process industry, mechanical equipment industry, and home machines, vehicle, space heating, power production, and chemical processing are some of the typical applications for these materials. Heat exchangers can be used for heating region systems, which is something that is increasingly common these days. Heat exchangers are also used in air conditioners and freezers to help condense or evaporate the liquid on the inside. Additionally, these are utilised as a part of milk preparation machines for the purpose of filtration and sanitation. When it comes to different venture types, the use of heat exchangers can be discovered in Table 1.

Table 1: Utilization of heat exchangers in various industries

S.No	Industries Name	Applications
1	Food and Beverages	Ovens, cookers, Food handling and pre-heating, Milk sanitization, beer cooling and purification, juices and syrup purification, chilling or cooling the product with desired temperatures.
2	Hydrocarbon handling	Preheating of methanol, fluid hydrocarbon cooling, sustain pre-heaters, Recovery or expulsion of carbon dioxide, production of ammonia.
3	Pharmaceutical	Cleansing of water and steam, for purpose of utilization cooling on water for injection ring.
4	Marine	Marine cooling systems, Fresh water distiller, Diesel fuel pre-heating, Central cooling, Cooling of grease oil.
5	Car	Pickling, Rinsing, Priming and Painting
6	Polymer	Generation of polypropylene, Reactor jacket cooling for creation of polyvinyl chloride
7	Power	Cooling circuit, Radiators, Oil coolers, Air conditioners and Heaters, Energy recuperation

CLASSIFICATION OF HEAT EXCHANGER

The heat exchangers can be characterized by exchange forms, number of liquids, and heat exchange components and so on. Common types are shell and tube heat exchangers, printed circuit heat exchangers and plate and plate fin heat exchangers. The shell and tube heat exchanger configuration are ordinarily in light of connections; e.g., the Kern technique and Bell Delaware method are the most regularly utilized relationships

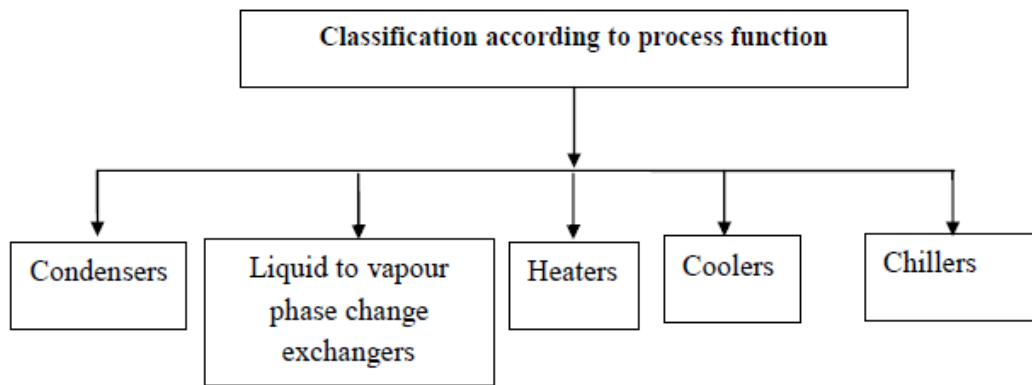


Figure 1: Classification according to process function

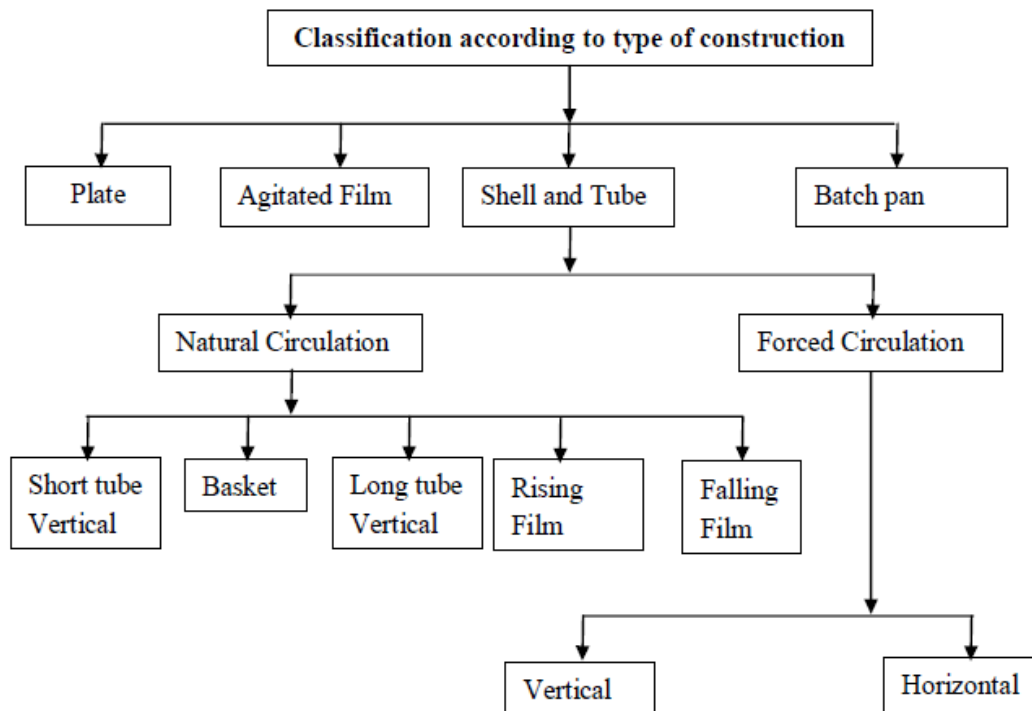


Figure 2: Classification according to type of construction

SHELL AND TUBE HEAT EXCHANGER

With a particular objective to minimize the aggregate cost related resources that go into conveying this heat energy, it has ended up being fundamental to set up heat exchanger equipment that is more powerful in execution and in declining or extra energy, cost and material. In such way, heat transfer transforms into a basic method.

The basic guideline of operation is to a greater degree clear as streams of two liquids with different temperatures are brought into close contact, however, they are still kept from mixing by a physical limit. By then, the temperature between two liquids tends to adjust by exchange of heat through the tube wall. Either liquids or gases in either the shell or the tube side can act as a fluid. The true objective is to exchange thermal energy successfully and an extensive heat exchange area should be used by provoking the usage of many tubes. Hence, waste heat can be put to use. This is an effective method to save energy [9-12].

Shell and Tube Heat Exchangers (STHEs) are thermal energy exchange contraptions that are used as a piece of sustenance handling industry, power plants, oil refining, marine applications, and in transmission cooler. For example, in power plants, they are normally used as condensers or boilers where the steam delivered is used to run a turbine and make power. Their blueprint fluctuates from other heat exchangers since they are made out of an outside shell with baffles and an inward tube bundle that is housed inside the STHE headers. The external

cylindrical shaped shell design works as a pressure vessel and empowers this kind of heat exchanger to withstand tremendous pressures.

One liquid is constrained all through the outer shell by the baffles, which are controlled walls that are a bit of the tube bundle, while another liquid transfer it through inside the tube bundle. These two liquids exchange heat through conductive tube bundle walls and, as both liquids move along the heat exchanger, one gets cooler while the other one gets hotter or the other way around. The headers could be affixed or welded to the outside shell and serve to pass on the fluid that streams inside the tube bundle. The alteration of STHE has encountered a nonappearance of research to think the interconnection between turbulent fluid stream structures and heat exchange coming to fruition as a result of effects on the baffles due to higher cost of the complex trial set up and complex showing geometries. The most typically used STHE is the segmental baffle shell and tube heat exchanger. This kind of heat exchanger similarly has outside shell and inner tubes, in any case, it merges transitional walls known as baffles that assist in fortifying the tube bundle and furthermore compel the outer shell stream to experience a more drawn out path as appeared in Figure 2.

These baffles could be of advantageous stature and their total length is portrayed by a parameter known as percent baffle cut. The percent baffle cut articulates to a rate of outer shell diameter. For instance, a half baffle cut infers that the baffles would have a total stature of half of the separation crosswise over of the shell that houses the tube bundle. In a similar manner, the detachment between each baffle is measured by a parameter known as baffle pitch and this parameter can change all through the heat exchangers [13].

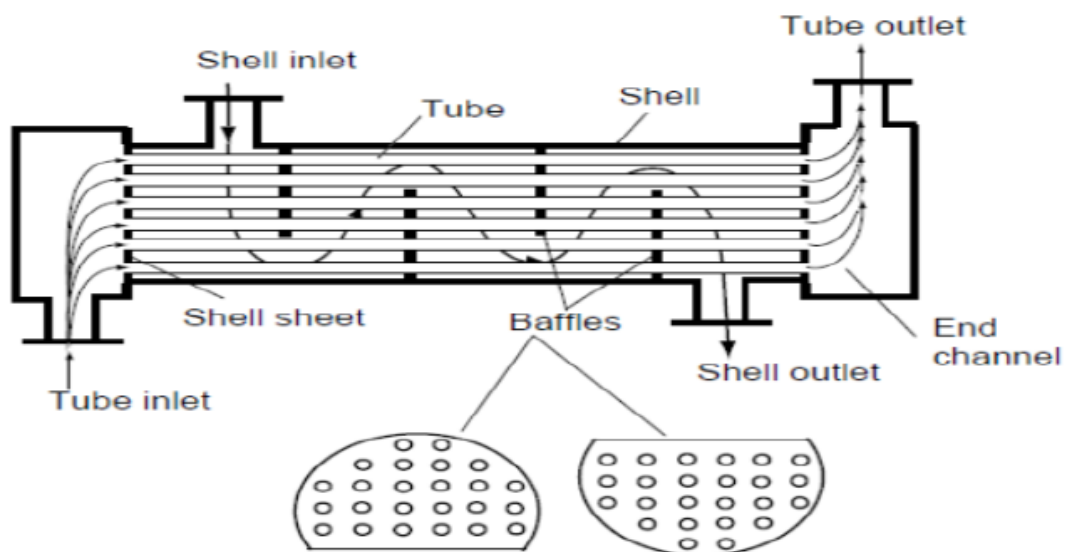


Figure 2: Shell and tube heat exchanger geometry and its main components

The design of these baffles is not confined to late straight walls. Contemplates have been coordinated on baffle geometries, for instance, rod baffles, helical baffles and flower baffles. The tube bundle housed inside the shell of an STHE could involve different tube layout arrangements of action. The inside to-focus expel between each tube in the tube bundle is controlled by the parameter known as tube pitch. The tube pitch is ordinarily a little partition since many tubes could be permitted inside the shell by growing the open surface region for heat transfer. The stream inside these types of Shell and tube heat exchanger is bundled into entrance, internal and window flow regions as shown in figure 3.

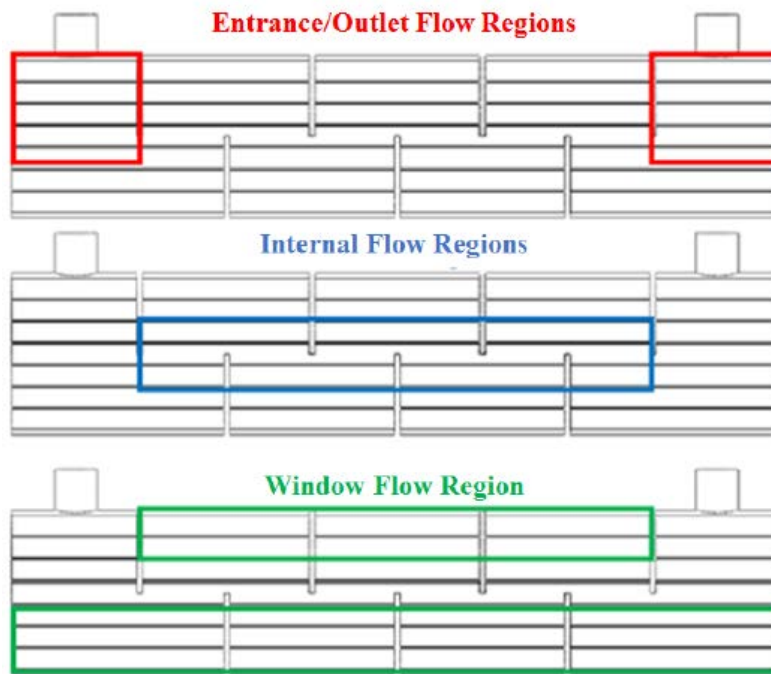


Figure 3: Entrance, internal, and window flow regions

In the entrance region, the approaching shell side fluid flow expands and flows perpendicular to the tube bundle. Likewise, the fluid flow in the outlet region flows perpendicular to the tube bundle, yet it unites towards the outlet pipe. The fluid flows in the internal region to move to the region where the fluid flow is constrained up and down the baffles.

BAFFLING

Baffles are being used to support tubes, enable a desirable velocity to be maintained for the shell side liquid, and prevent failure of tubes due to flow induced vibration. They serve the flow of direction of fluid on shell side and thus enhance the rate of heat transfer [14-16].

There are two types of baffles they are:

Plate baffles

Rod baffles

Plate baffles may be single segmental, double segmental, or triple segmental, as shown in figure 4.

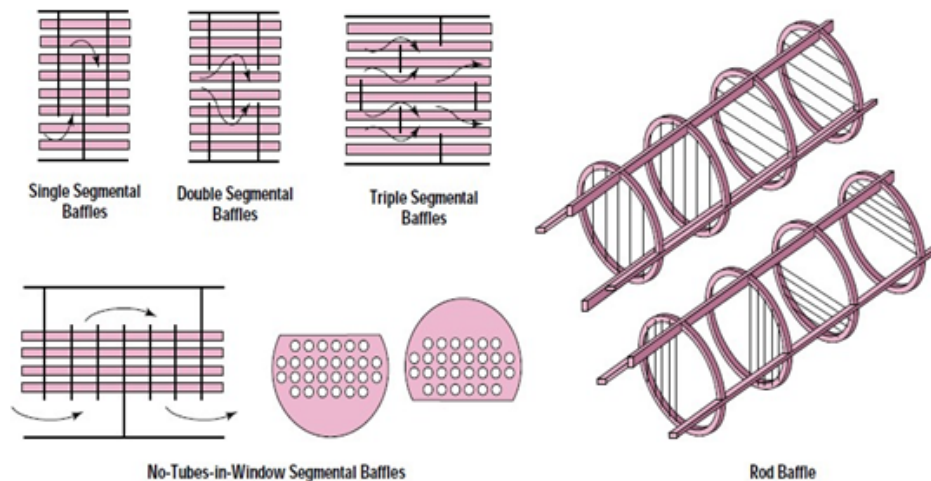


Figure 4: Plate and rod baffles

II. LITERATURE REVIEW

The related literature is promptly reviewed to comprehend the effects of heat transfer and flow characteristics of heat exchangers in general, shell and tube heat exchangers in particular.

Bao-Cun Du et al. (2017) designed a special flow layout with Ushaped tubes applied in the laboratory for testing heat transfer performances (HTPs) of molten salt in the shell side of a shell and tube heat exchanger. The experiments are done on the shell and tube heat exchanger (STHE) with segmental baffles and corresponding heat transfer relationships were fitted and validated with traditional correlation. The results demonstrate a better agreement with 2% deviations existing between the fitted correlations and the test data.

Jian-Fei Zhang et al. (2009) presented an experimental review of a few shell and tube heat exchangers, one with segmental baffles and four with helical baffles at helix angles of 20°, 30°, 40° and 50° respectively. The outcomes show that, based on similar shell side flow rate, the heat transfer coefficient of the heat exchanger with helical baffles is lower than the heat exchanger with segmental baffles while the shell side pressure drop of the previous one is even much lower than the later. Any improvement in the system ought to be incorporated by keeping in mind the end goal to upgrade shell side heat exchange based on a similar flow rate. The review of heat transfer coefficient per unit pressure drop (and pumping power) versus shell side volume flow rate modelled that (1) the heat exchanger with helical baffles have critical execution advantage over heat exchanger with segmental baffles, (2) for a similar shell inner diameter, the execution of heat exchanger with helical baffles with 30° helix angle is superior to that of 20° and the execution of 40° helix angle is greater than that of 50° helix angle. The heat exchanger with helical baffles of 40° angle shows best execution among all five heat exchangers tried.

Jie Yang & Wei Liu (2015) proposed a novel shell and tube heat exchanger with new plate baffles. It is numerically explored in correlation with a shell and tube heat exchanger with rod baffles. In business virtual products, FLUENT 6.3 and GAMBIT 2.3 are embraced for modeling and computational results. The modeling approach is tested with experimental approach. The shell side after effects of heat transfer, flow performance, and exhaustive performance are broken down. The Nusselt number for plate baffle heat exchanger is around 128–139% of the rod baffles heat exchanger. The pressure drop for the novel one is around 139–147% of the rod baffles heat exchanger. Mostly, the novel plate baffles heat exchanger shows obviously higher exhaustive performance (115–122%) than the rod baffles one. The temperature field, pressure field and path lines are examined to show the upside of the novel shell and tube heat exchanger.

Hamed Sadighi Dizaji et al. (2017) studied the effects of corrugated shell and corrugated tube developed rather than flat shell and flat tube throughout a shell and tube heat exchanger in this paper. Particular courses of action of concave and convex type of corrugated tubes were examined. Exergy misfortune due to synchronous utilizing of corrugated tubes as the internal and the external tube (shell) of a shell and tube heat exchanger has not been examined some time recently. In reality, past examinations have

concentrated on just warm qualities of corrugated tubes and its impact on layering of exergetic attributes has not been tested. Thus, in the present work, exergetic parameters were temporarily concentrated on a shell and tube

heat exchanger made of corrugated shell and corrugated tube. Said parameters were assessed for various plans of corrugated tubes. Corrugated tubes were delivered by a unique machine which was produced for this reason. The outcomes demonstrated that, grooves caused addition of both exergy misfortune and NTU. In the event of both tube and shell getting corrugated, the exergy misfortune and NTU increment around 17% - 81% and 34% - 60% separately. Most extreme exergy misfortune was observed for a heat exchanger made of convex corrugated tube and concave corrugated shell.

Jin Qian et al. (2017) experimentally investigated two shell and tube molten salt heat exchangers, both a gas cooled one with finned tubes and a molten salt to salt one with segmental baffles in the shell side. According to a nonlinear regression scheme, heat transfer coefficients in both tube and shell sides are attained and compared with three empirical correlations. When comparing the outcome, the Wu's Equation has shown better agreement with experimental data than Gnielinski's and Hausen's Equations.

Ambekar et al. (2016) concentrated on the effects of various arrangements of baffles in shell and tube heat exchanger on heat transfer coefficient and pressure drop. Baffles used as a part of shell and tube heat exchanger enhanced the heat move additionally resulting in extended pressure drop. Shell and Tube Heat Exchanger with segmental baffles, helical baffles and flower baffles are laid out and the eventual outcomes of diversions show same shell side mass flow rate, heat transfer coefficient, pressure drop and heat transfer rate obtained to be most phenomenal with single segmental baffles.

Anas et al. (2016) registered and assessed the thermo-hydraulic performance of shell and tube heat exchangers with different baffle types. The heat transfer is upgraded while utilizing trefoil hole baffles. On the other hand, this change is done to the hindrance of an immense pressure drop. Further, to evaluate the effect of the shell side thermo-hydraulic performance under fluctuating different design parameters, the performance factors with an essentially not too bad exactness are anticipated by numerical model predicts with assistance of experimental data for segmental baffles.

Bala Bhaskara Rao J & Ramachandra Raju V (2016) studied a single shell and multiple pass heat exchangers with various tube geometries like circular tubes to elliptical tubes through experimental and numerical analysis. The hot fluid in tube side and the cold fluid in shell side with circular tubes at 600 tubes and 25 % baffle cut are considered for experiment. The outcomes are heat transfer rates and pressure drops for various Reynolds numbers from 4000 to 20000. The numerical analysis is done through fluent software. For that analysis, both circular and elliptical tube geometries with 450,600 and 900 orientations are carried out. The outcomes of experimental results and numerical analysis of 25 % baffle cut, quarter baffle cut and mirror quarter baffle cut arrangements are used for comparison.

III. METHODOLOGY

A conventional shell and tube heat exchangers (STHX) with segmental baffle is utilized as a part of the investigation, the hot water flows in the tube side, while the cold-water flows in the shell side in a counter current configuration. The geometrical parameters for experimental setup are carried out for numerical analysis. The numerical results are validated with experimental results. If the percentage of error is at an acceptable level, then the new design configuration of the STHE is varied under the Tube layout, Baffle cut and number of Baffles. These new models are analyzed for existing boundary conditions [17].

It is very much essential to know the technical terms during design and optimization of a shell and tube exchanger

- Rating: Determination of heat transfer and pressure drop of a heat exchanger.
- Sizing: Determination of physical size, flow arrangement, tube material, fins and construction type.

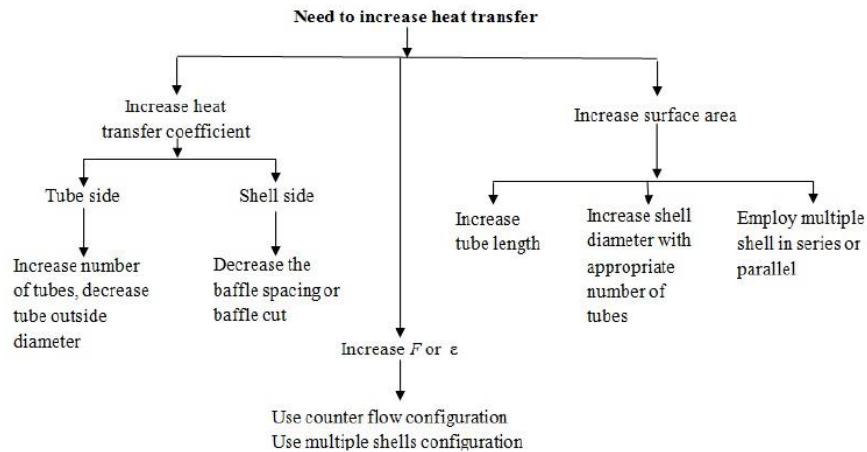


Figure 5: Effects of geometrical variables on heat transfer in STHX

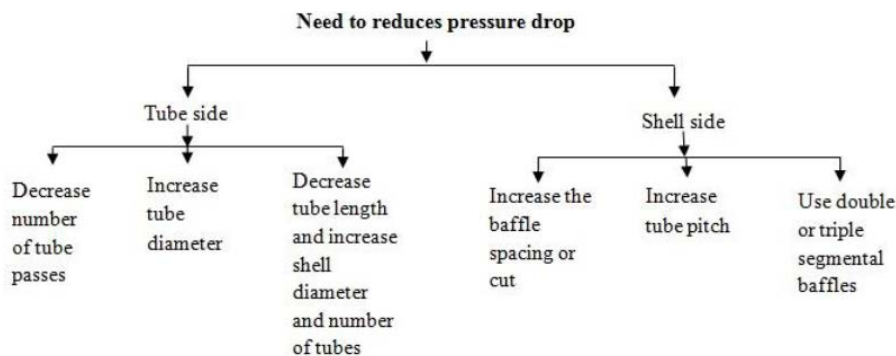


Figure 6: Effects of geometrical variables on pressure drop in STHX

The main objective of any shell and tube heat exchangers is to increase heat transfer and decrease pressure drop. From the above figures 5 and 6, it is revealed that in order to increase heat transfer, the tubes diameter should be decreased. On the other hand, in order to reduce pressure drop, it is found that tube diameter should be increased. This leads to contradiction of the variables in achieving the objective functions. Hence, we need optimization to find the optimal values so as to maximize an objective function and minimize another objective function simultaneously. The design of a shell and tube heat exchanger involves several variables like shell diameter, tube diameter, tube layout angle, baffle cut, tube layout pitch, length of the tube, baffle spacing, number of tubes etc. subjected into contradictory situation.

Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CFD) is the science of forecasting fluid flow, heat transfer, mass transfer, chemical responses, and related phenomena by solving mathematical equations, which govern these processes by using a numerical process. CFD applies numerical techniques called discretization to progress approximation of the governing equations of fluid mechanics in the fluid region of interest [18].

CFD provides information about important flow characteristics such as pressure loss, flow distribution and mixing rates by solving fundamental equations and by restraining fluid flow processes. CFD analysis complements traditional testing and experimentation and provides added insight and confidence in your designs. It consumes lesser time. This results in better design, lower risk and faster time to the marketplace for product or processes.

The Navier Stokes Equation

The Navier-Stokes equation describes the motion of fluid over time. Here we will derive the Navier-Stokes equation as it is seen most commonly in fluid simulation papers in computer graphics. Modern fluid simulation

literature in computer graphics is often daunting at first, as the techniques presented are often building on decades of research. Similarly, general fluid mechanics texts are often highly mathematical, and texts aimed at fluid simulation are often geared towards mechanical engineers, focusing on specific forms of the Navier-Stokes equation that often arise in engineering applications, such as modeling airflow over a wing. The goal of this section is to provide the reader with a solid mathematical reference on how the fully general Navier-Stokes equation is derived, with annotations along the way to correct common misconceptions, and provide the mathematical intuition behind physical quantities like pressure and viscosity [19].

Now that we have derived the full incompressible Navier-Stokes equation, let us break it down term by term. We will see that due to the separability of differential equations, we can solve each term independently and apply these operations in serial, therefore it is useful to obtain and intuitive mathematical and physical understanding of each term and any additional constraints, such as incompressibility: Recall equations (3.29, 3.18) which comprise the incompressible Navier-Stokes equation:

$$\frac{\partial \mathbf{u}}{\partial t} = \mathbf{f} - \frac{1}{\rho} \nabla p + \nu \nabla^2 \mathbf{u} - (\mathbf{u} \cdot \nabla) \mathbf{u}$$

$$\nabla \cdot \mathbf{u} = 0 \quad (1)$$

Advection: $-(\mathbf{u} \cdot \nabla) \mathbf{u}$. This is likely the most complicated term, as we will see when we discuss methods of solution, and in fact it is what makes the Navier-Stokes equation a non-linear differential equation since it contains two factors of \mathbf{u} . Advection is the transport of any quantity through a vector field. For example, particles moving through a vector field are being advected, scalar quantities such as temperature may also be advected through a vector field. Advection may also be conducted on vector as well as scalar fields. Even further, a vector field can advect itself. This is called self-advection, and is exactly what the advection term in the Navier-Stokes equation describes. It is difficult to provide further intuition, other than to say that this forms the basis of how to establish a rule to advance from one timestep to the next, as we are modeling future velocity as some function of the current velocity [93].

Diffusion/Viscosity: $\nabla^2 \mathbf{u}$, is responsible for simulating the viscosity of a fluid. Intuitively this type diffusion can be thought of as iteratively applying a smoothing filter. Velocities close together will tend towards the same value. The higher the viscosity, the faster the velocities will diffuse. This explains why viscous fluids come to rest much sooner once disturbed, and have less 'lively' behavior.

Pressure: $-1/\rho \nabla p$ accounts for the velocity due to differences in pressure of the fluid. Consider two adjacent fluid volumes: if the pressure is very high in one fluid volume, and low in all the adjacent fluid volume, fluid will want to move out to these low pressure areas (this is why it is the negation of the divergence field, which points in the direction of highest pressure increase).

Body Force: \mathbf{f} , last term is the free body force which represents any external force applied to the fluid. This is often gravity, but it need not be constant; it can be an arbitrary function over space, time, a parameter of the simulation (such as temperature or density), or a forcing function used for artistic control.

Continuity/Incompressibility: $(\nabla \cdot \mathbf{u}) = 0$. While not part of equation 3.29, in order to simulate an incompressible fluid, this condition must be enforced. It states that the divergence of the velocity field is zero everywhere. This means that for any fluid volume, the amount of fluid coming in and the amount of fluid going out is conserved. This equation is exactly what enforces the incompressibility constraint. Empirically this is what causes a vector field to be 'swirly', when forces are applied inside the fluid; the reason for this is that when a force is locally applied to a uniform field, it inherently causes divergence. Since the field must be divergence free everywhere, it is often that vortex patterns emerge as they are the only way large velocities can exist and still maintain a locally divergence free field; each fluid volume in a vortex has an equal amount of fluid coming in as it does going out.

KERN METHOD

This method is very simple and allows rapid calculation of shell-side coefficients and pressure drop. This method cannot be adequately used because it does not account leakages between baffle-to-shell and tube-to-baffle and is limited to fixed baffle cut (25%). The model-1, model-2 and model-3 are deals with Kern method. The governing equations and the input parameters are remain same for model-4, model-5 and model-6. This

method used by Hadidi et al. [20], Mohanty et al. [21] and Asadi et al. [22-25] as single objective function. In the present work the model-1, model-2 and model-3 are deals with single objective optimization.

THERMAL AND ANALYTICAL MODELLING

The heat exchanger surface area is given by [19]

$$A = \frac{q}{U \Delta T_{LM} F} \quad (2)$$

Where q is the heat quantity, U is the overall heat transfer coefficient, ΔT_{LM} is the logarithmic mean temperature difference, F is the correction factor.

The heat transfer rate is given by,

$$q = \dot{m}_s c_{ps} (T_{hi} - T_{ho}) = \dot{m}_t c_{pt} (T_{co} - T_{ci}) \quad (3)$$

$$U = \frac{1}{\frac{1}{h_o} + R_{o,f} + \frac{d_o}{d_i} \left(R_{i,f} + \frac{1}{h_i} \right)} \quad (4)$$

Where $R_{o,f}$ and $R_{i,f}$ are the fouling resistance taken from the literature.

$$d_i = 0.8 d_o \quad (5)$$

PRESSURE DROP AND OBJECTIVE FUNCTION

For a fixed heat capacity heat exchanger, increasing the flow velocity will cause a rise of heat transfer coefficient and will cause more pressure drop which results in extra running cost.

$$\Delta P_t = \Delta P_{tubelength} + \Delta P_{tubeelbow} = \frac{\rho_t v_t^2}{2} \cdot \left(\frac{L}{d_i} f_t + p \right) \cdot N_p \quad (6)$$

Assumed $p = 4$ from Kern et al. [19] and assumed $p = 2.5$.

$$\Delta P_s = f_s \left(\frac{\rho_s v_s^2}{2} \right) \cdot \left(\frac{L}{B} \right) \cdot \left(\frac{d_s}{D_e} \right) \quad (7)$$

Where f_s is the friction factor.

$$f_s = 2 b_0 Re_s^{0.15} \quad (8)$$

$$b_0 = 0.72 \quad [28] \text{ valid for } Re_t < 40000.$$

$$P = \frac{1}{n} \left(\frac{\dot{m}_t}{\rho_t} \Delta P_t + \frac{\dot{m}_s}{\rho_s} \Delta P_s \right) \quad (9)$$

$$C_{inc} = 8000 + 259.2 A_{t,t}^{0.91} \quad (10)$$

Where C_{inc} is the capital investment for exchangers both shell and tubes made out of stainless steel.

$$C_{oc} = P k_{ell} \tau \quad (11)$$

$$C_{opc} = \sum_{k=1}^{ny} \frac{C_{oc}}{(1+i)^k} \quad (12)$$

$$C_{totc} = C_{inc} + C_{opc} \quad (13)$$

Where C_{totc} is total cost taken as the objective function, which includes energy cost ($kell$), capital investment (C_{inc}), total discounted operating cost (C_{opc}) and annual operating cost (C_{oc}).

IV. SIMULATION RESULTS

A shell and tube heat exchanger was simulated in Matlab software. The geometrical specifications used in shell and tube heat exchanger are as follows.

Table 1: Geometrical Specifications

Parameters	Specifications
Material	Stainless steel
Tube internal diameter	4 mm
Tube external diameter	6 mm
Tube arrangements	Triangular
Number of tubes	7
Tube effective length	184 mm
Shell internal diameter	44 mm
Baffle number	4
Baffle cut	~22%

In the design of shell and tube heat exchangers, the pressure drop is an extremely significant issue to consider because it is directly related to the running costs and efficiency of the system. Pressure drop reduction leads to a reduction in pumping power, which in turn results in a gain in system overall efficiency. According to the above pressure contours, the trend in pressure decrease can be noted, and it can be determined that higher pressure at the inlet is required in order for the fluid to reach the outlet. The pressure drop for segmental baffles is greater than the other two types of baffles, and it continues to decrease as the baffle type progresses towards helical baffles, as shown in the graph.

It can be seen from the pressure contours that pressure drop fluctuates with the amount of mass flow that is being transported. The following graph depicts the change in shell side pressure drop as a function of mass flow rates ranging from 0.0104 kg/s to 0.032 kg/s as seen in the previous graph. The variance in pressure drop for all three baffles is relatively small when the mass flow rate is very low, as can be seen in this graph. In proportion to the rise in mass flow rate, the variance in pressure drop is enhanced to a greater extent. As a result, it is recommended that heat exchangers operating at higher mass flow rates make use of helical baffles rather than segmental or double segmental baffles.

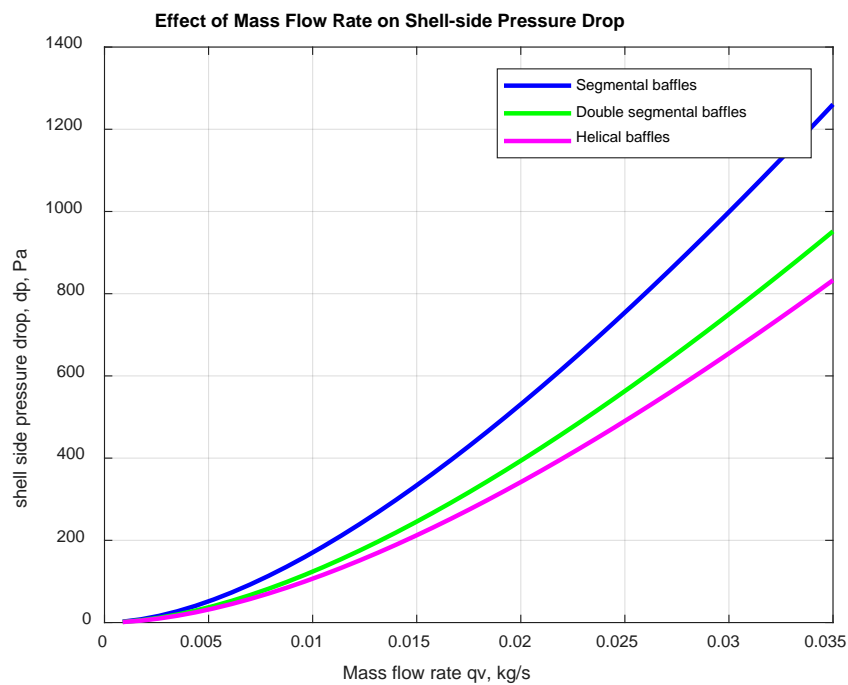


Figure 7: Shell-side Pressure Drop vs mass flow rate

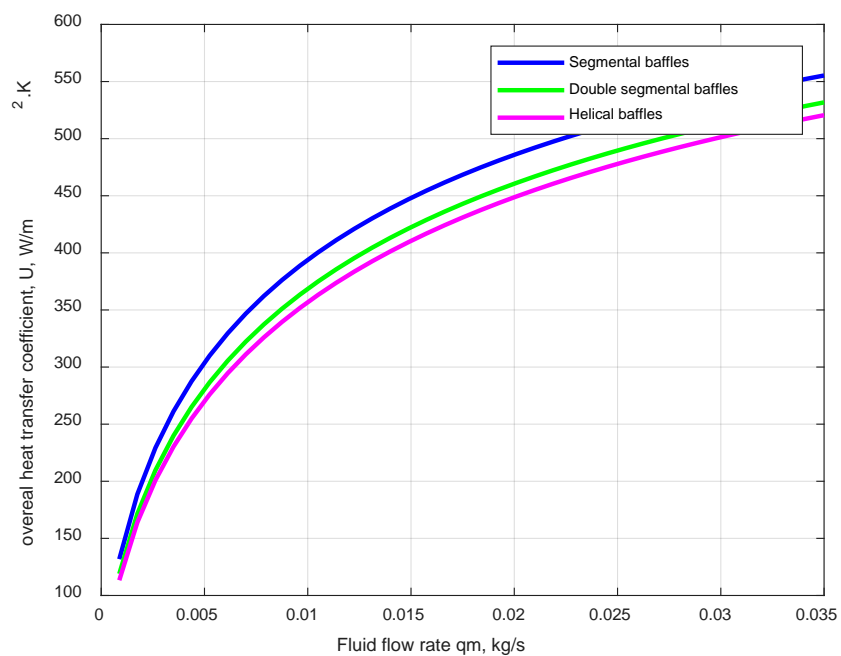


Figure 8: overall heat transfer coefficient fluid flow rate

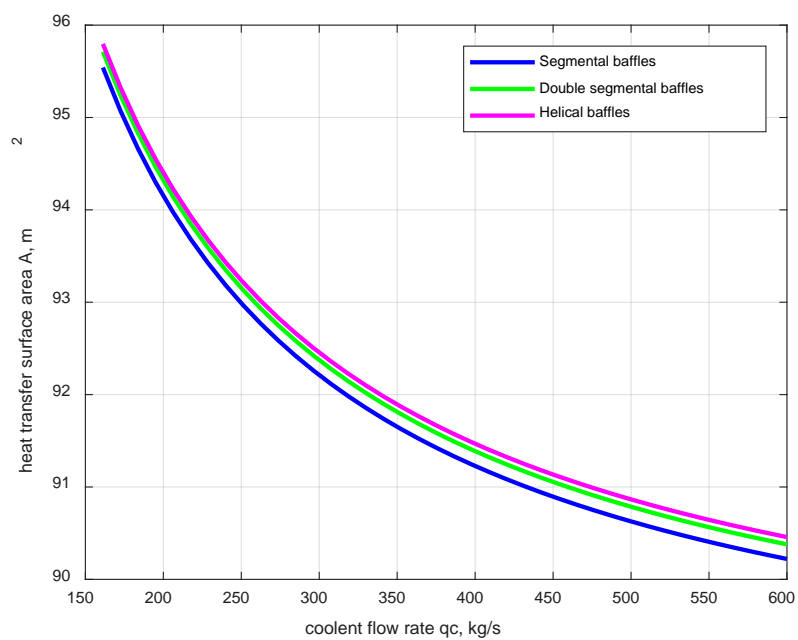


Figure 9: heat transfer surface area vs coolant flow rate

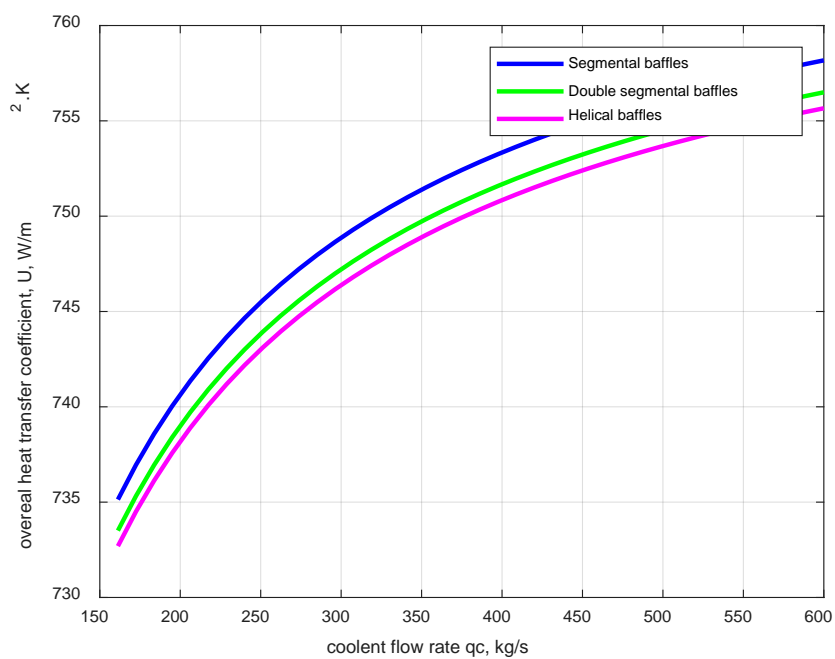


Figure 10: overall heat transfer coefficient vs coolant flow rate

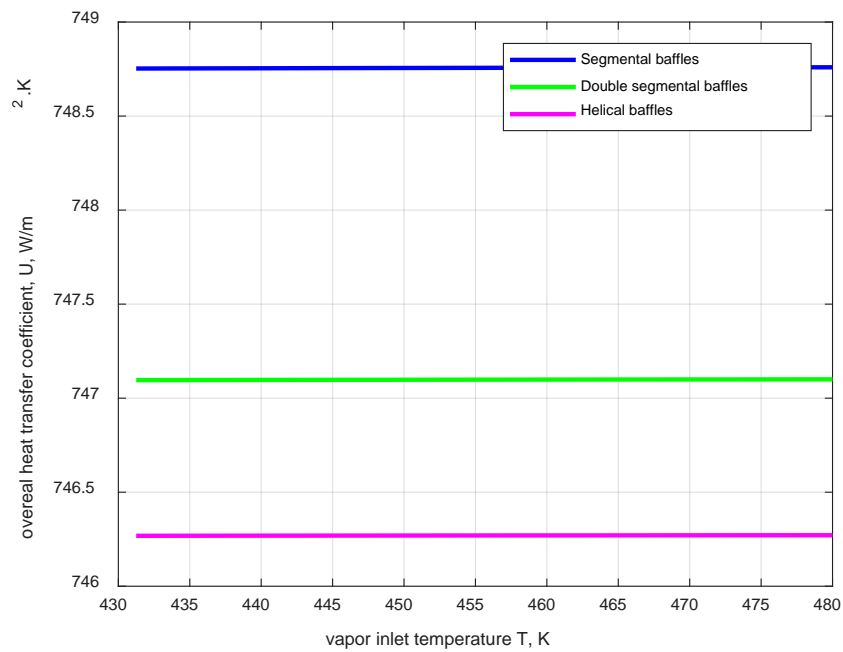


Figure 11: overall heat transfer coefficient vs vapor inlet temperature

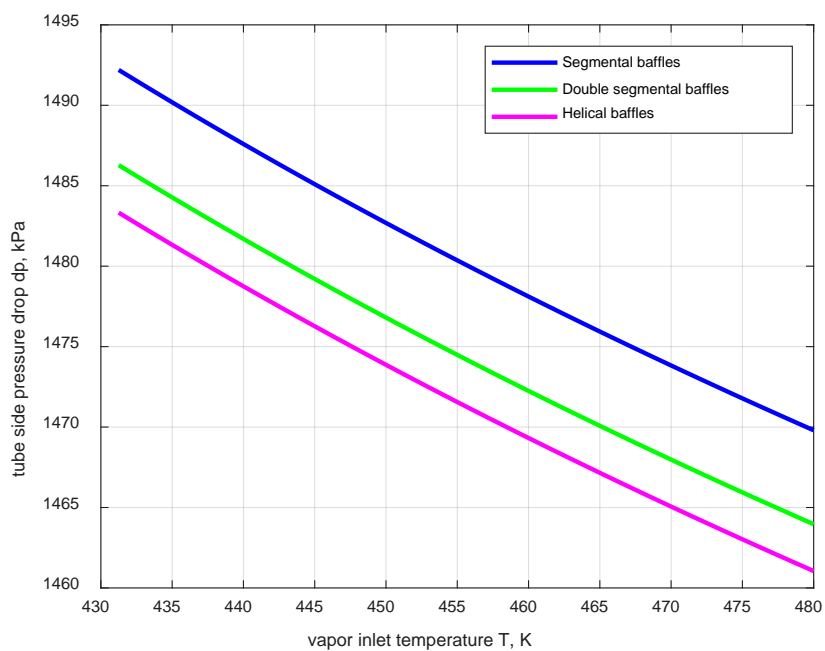


Figure 12: Tube side pressure drop vs vapor inlet temperature

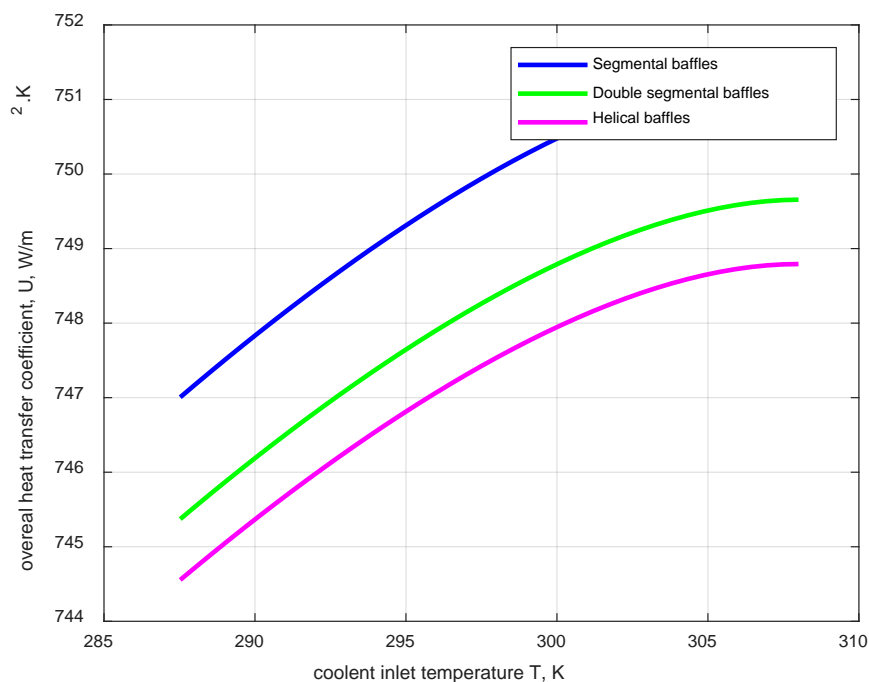


Figure 13: overall heat transfer coefficient vs coolent inlet temperature

V. CONCUSLION

The shell side fluid performance of shell and tube heat exchangers is computed and compared using a numerical model in this work. Different baffles, such as segmental, double segmental, and helical baffles, are used in numerical simulations to explain how baffles affect pressure drop in shell and tube heat exchangers. When the number of baffles is increased beyond a certain point, the pressure reduction is significant. By varying the types of baffles without affecting the other dimensions, it was discovered that single segmental baffles produce the most pressure decrease, while helical baffles produce the least.

Single segmental baffles demonstrate the establishment of dead zones when heat transport is impeded. Double segmental baffles are used to alleviate this problem. When compared to single segmental baffles, it also reduces vibrational damage. However, using helical baffles instead of the other two reduces pressure drop, increasing total system efficiency. As a result, it has been established that helical baffles are superior than the other two forms of baffles.

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