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Performance Analysis of Shell and Tube Heat Exchanger: Parametric Study

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Abstract-Refrigeration, air conditioning, and chemical plants all use heat exchangers. It's utilised for a variety of things, including transferring heat from a hot to a cold fluid. They're commonly employed in a variety of industrial settings.Researchers had worked on a variety of projects in attempt to increase performanceIn this study shell and tube heat exchanger with 10 different baffles are placed along the shell in alternating orientations with cut facing up, cut facing down, etc., in order to create flow paths across tube bundle. The geometric modelling is done using CAD software called CATIA V5R21 because it is easy to model Heat exchanger in 3D modelling software.

Keywords-Shell and tube heat exchanger, CFD, performance, analysis.

I. INTRODUCTION

Heat exchangers are also used to transfer heat between two fluids that would be at various temperatures along a solid surface. The nonlinear dynamics of this process, notably the varying steady-state gain or time constant with process fluid [1,], make it complicated. The shell-and-tube heat exchanger is the most popular form of heat exchanger, with uses in refrigeration, power production, heating, air conditioning, chemical processes, manufacturing, and medicine [2]. It really is made up of a bundle of tubes contained in a cylindrical shell, including one fluid flowing thru the tube and another running between both the tubes as well as the shell.A heat exchanger may be defined as a device that transmits thermal energy between two or more fluids of varying temperatures. Several industrial processes would indeed be impossible to complete without this equipment.

Refrigeration, air conditioning, and chemical plants all use heat exchangers. It's utilised for a variety of things, including transferring heat from a hot to a cold fluid. They're commonly employed in a variety of industrial settings.Researchers had worked on a variety of projects in attempt to increase performance. The velocity and temperature contour fields upon that shell side, on the other hand, are much more complicated, and their performance is influenced by baffle elements such as their arrangement the spacing scheme.

Round tubes were put in cylindrical shells having their axes aligned with the shell axis to create this. Shell side refers to the region surrounding the tubes, whereas tube side refers to the inside tubes. The primary function of baffles would be to produce turbulence, which increases the convective heat transfer coefficient of the shell side fluid.

The following methods are used to evaluate the performance of the heat exchanger: I Outlet temperature of the hot stream (Tho) profile, ii) Approach temperature (Tho - Tci) profile, iii) Log Mean Temperature Difference (LMTD) with time, iv) Heat load profile, and v) Time series of overall heat transfer coefficient.

The first four approaches are commonly utilised, however they are poor at distinguishing the net effect of fouling of process disturbances. The total heat transfer coefficient technique, on the other hand, necessitates comprehensive computations and knowledge of the exchanger shape [3].Fouling causes the heat exchanger's performance to decrease over time. It tends to rise with time, with a particularly site-specific trajectory. As both a result, a predictive model of evaluating heat exchanger performance is required.

II. REVIEW OF PAST STUDIES

Sundaram et al (2016) examined the prediction of an outlet liquid temperature of a saturated steam heat exchanger from its liquid flow rate, 4 distinct neural networks are considered: Elman Recurrent Neural Networks (ERNN), Time Delay Neural Networks (TDNN), Cascade Feed Forward Neural Networks (CFFNN), and Feed Forward Neural Networks (FFNN). To train, validate, and evaluate the performance of each neural network model, a benchmark dataset of 4000 tuples is employed.

Shrikant (2016) the impacts of various baffle designs on the heat transfer coefficient and pressure drop in a shell and tube heat exchanger (STHX) were investigated. The use of baffles in shell and tube heat exchangers improves heat transmission while simultaneously increasing pressure drop.

SOLIDWORKS Flow Simulation software is used to design shell and tube heat exchangers featuring single, double, triple segmental baffles, helical baffles, and flower baffles, as well as fluid dynamic simulations (ver.2015).Simulation studies revealed how single segmental baffles had the highest heat transfer coefficient, pressure drop, or heat transfer rate for much the same shell side mass flow rate.

Kamble et al (2014) The use of artificial neural network (ANN) modelling in different heat transfer applications, such as constant and dynamic thermal issues, heat exchangers, gas-solid fluidized beds, and so forth, was examined. Several crucial issues in thermal engineering cannot always be solved using typical analysis methods such as basic equations, conventional correlations, or trial and error to build unique designs from experimental data.

The use of the ANN tool using various methodologies and structures reveals that the findings provided using ANN and experimental data are in good agreement.The aim of this paper is to highlight current improvements in ANN and how it has been successfully used to a number of key heat transfer challenges. According to the literature, the feed-forward network with back propagation approach has been effectively utilised in various heat transfer investigations.

Kwang-Tzu Yang (2008) The goal of this work is to showcase recent advances in ANN and how it has been effectively applied to a variety of major heat transfer problems. The feed-forward network incorporating back propagation technique has already been successfully used in many heat transfer experiments, per the literature.

Singh et al. (2011) The performance of three training functions (TRAINBR, TRAINCGB, and TRAINCGF) utilised for training NN to forecast the value of the specific heat capacity of both the working fluid, LiBr-H2O, employed in a vapour absorption refrigeration system were evaluated. The percentage relative error, coefficient of multiple determination, RMSE, and sum of a square owing to error were employed as comparison metrics. The input parameters include vapour quality and temperature, with specific heat capacity as being one of the output parameters.The training is maintained until the least mean square error (MSE) at a specific number of epochs was found. The TRAINBR function outperformed the other two training functions based on findings of performance parameters.

Gerardo Diaz et al (2001) Apply the artificial neural network (ANN) approach to the modelling of a heat exchanger's time-dependent behaviour and use it to manage the temperature of air travelling through it. Inside an open loop test facility, the tests are carried out. To begin, an approach for training and predicting the dynamic behaviour of thermal systems including heat exchangers was provided. Then, using two artificial neural networks, somebody to mimic the heat exchanger the other as a controller, an internal model strategy for controlling the over-tube air temperature is devised.

To avoid a steady-state offset, an integral control is performed in tandem with the neural network controller's filter. The findings correspond to PI and PID controllers that are commonly used. The neural network controller has less oscillating behaviour, allowing the system to attain steady-state operating conditions in areas where the PI and PID controllers are not quite as effective.

III. RESEARCH METHODOLOGY

The design and prediction of heat exchanger behaviour are too complicated to mathematically mode land solve using analytical solution. Closed form solutions are available only in situations where the model has several simplifying assumptions (Gvozdenac and Mitrovic, 2012).

Heat exchanger design based on these assumptions has errors that make the prediction of thermal behavior challenging. The design challenges are multiple objectives with several constraints to be fulfilled simultaneously.

In this study shell and tube heat exchanger with 10 different baffles are placed along the shell in alternating orientations with cut facing up, cut facing down, etc., in order to create flow paths across tube bundle. The geometric modelling is done using CAD software called CATIA V5R21 because it is easy to model Heat exchanger in 3D modelling software.

A STHX with different baffle geometries is designed [15, 16, and 17] to study the effects of variations in baffle geometry. A water-water shell and tube heat exchanger is designed considering the data in the following table 1. Fig.1 shows single segmental baffle respectively. Fig.2 shows flower-A and flower-B type baffles respectively.

Table 1. Dimensions of the shell side and tube side of the heat exchanger.

Specification	Dimensions
Length of heat exchanger , L	610 mm
Shell outer diameter, DS	160 mm
Tube length, l	610 mm
Tube outer diameter, do	16 mm
No. of tubes, Nt	21
Baffle spacing, ΔBt	100 mm
Baffles thickness, t	2.5 mm
No. of baffles Nb	10

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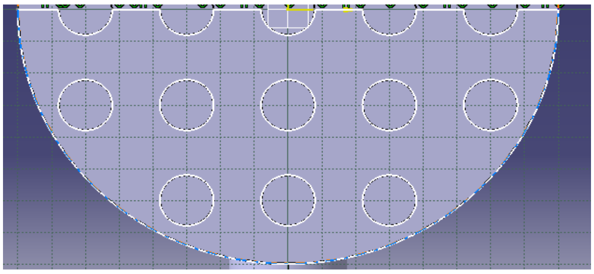


Fig 1. Single segmental baffle.

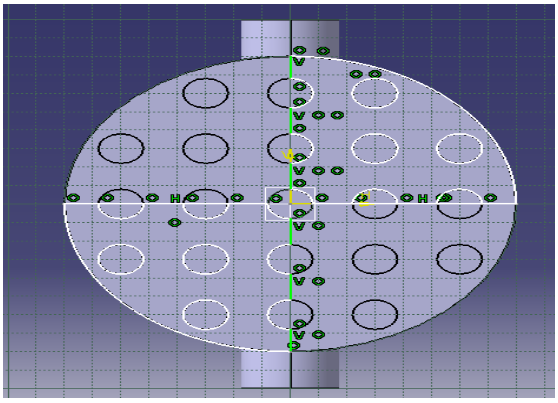
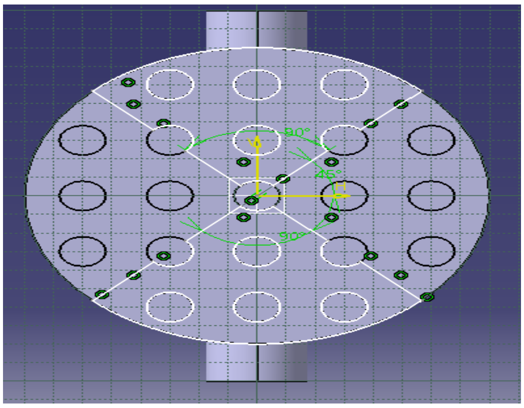


Fig 2. Flower ‘A’ baffle.



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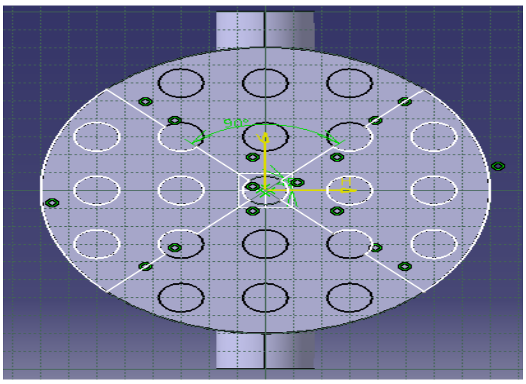


(b)

Fig 3. Flower ‘B’ baffle.

1. Geometry Modeling:
First the geometry of the model is created in CATIA V5R21. The model is saved in IGS. format. The external geometry file is imported in the design modeller of the ANSYS fluent. The geometry has totally 22 parts. One shell and 21 tubes bundle.

2. Meshing:
In free meshing a relatively coarse mesh is generated. It contains both tetrahedral and hexahedral cells having triangular and quadrilateral faces at the boundaries. Later, a fine mesh is generated using edge sizing. In this, the edges and regions of high pressure and temperature gradients are finely meshed.

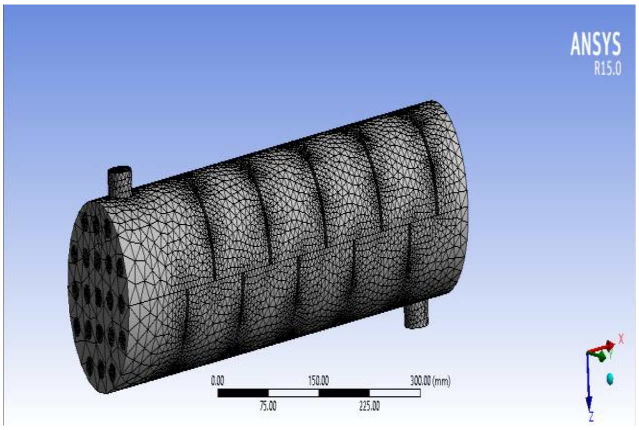


Fig 4. Mesh model.

3. Boundary Conditions:
Different boundary conditions were applied for different zones. Since it is a shell-and-tube heat exchanger, there are two inlets and two outlets. The inlets were defined as velocity inlets and outlets were defined as pressure outlets.

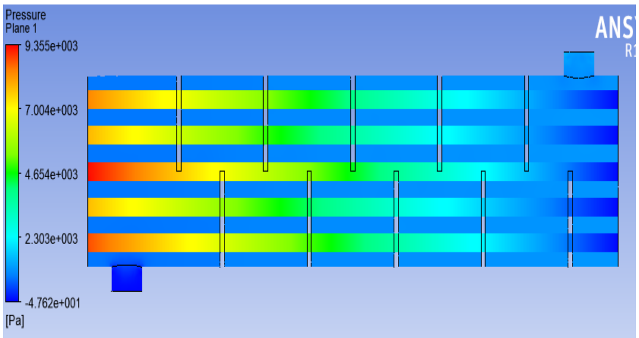
The water inlet boundary conditions are set as Flow opening inlets and outlet boundary conditions are set as Pressure opening outlets. The exterior wall is modelled as adiabatic. The simulation is solved to predict the heat transfer and fluid flow characteristics by using k-ε turbulence model.Shell side inlet is set as flow opening the mass flow rate varied from 0.7533 kg/s for different simulations and temperature is set to 303 K.Tube side inlet is set to flow opening the mass flow rate is varied from 0.7 kg/s to 1.2 kg/s and the temperature is set to 363 K.

IV. RESULTS AND DISCUSSION

CFD simulations of pressure, temperature and velocity profile in STHX with different baffle configurations have been discussed. Pressure drop and overall heat transfer coefficient has been compared to conclude the best design parameters.In order to better explain this situation, it must be noted that lower mean velocity gives lower velocity gradient among the fluids and channel walls, which in turn reduces the wall shear stress. The reduced friction results in lower pressure difference required to move the fluid along the channels, which is indicated by the pressure drop values.

Pressure drop is depends on many factors such as viscosity, geometry etc. In segmental heat exchanger fluid is settled in between the baffle, so pressure drop is increased.

Pressure Distribution across the shell and tube heat exchanger is given below in Fig. 5. Pressures vary largely from inlet to outlet. The contours of static pressure are shown in the entire figure to give a detail idea.



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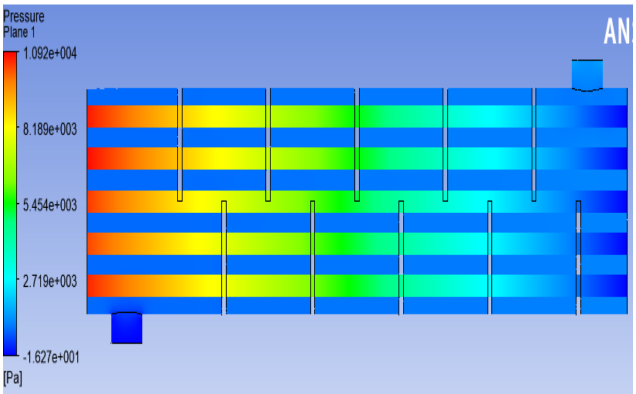

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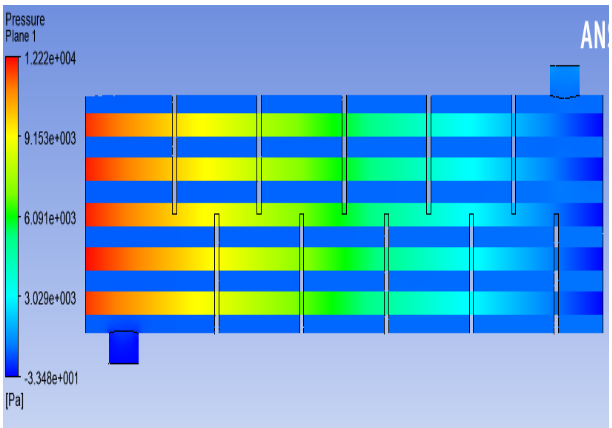

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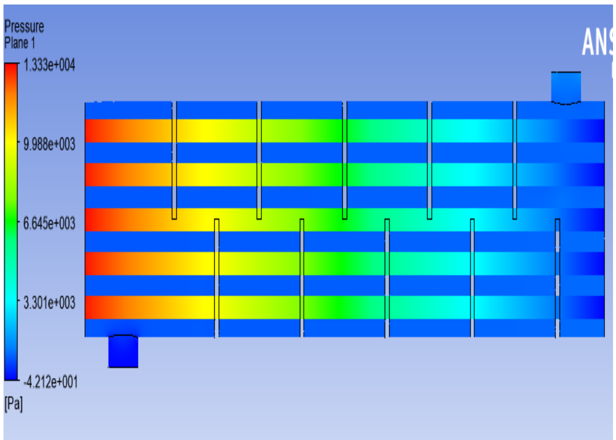

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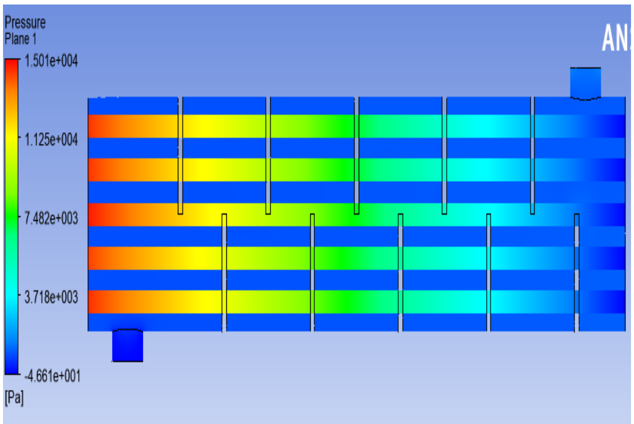

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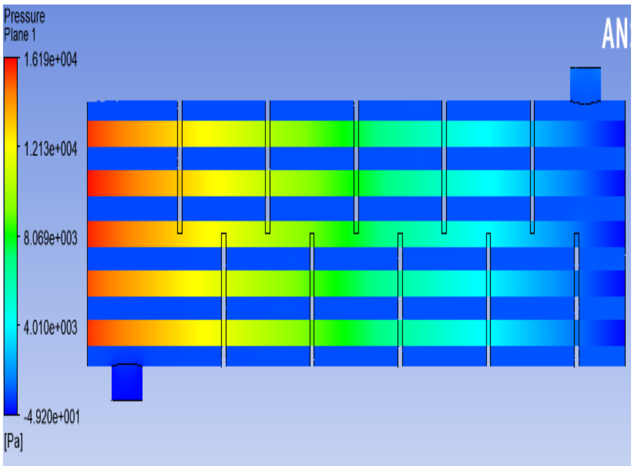

(f)

Fig 5. Pressure variations in STHX with single segmental baffles for 6 simulations

1. Variations in Heat Transfer Coefficient for Single Segmental Baffle in Sixth.

As the volumetric flow rate of the tube side fluid is increased from 0.7 to 1.2Kg/s, the overall heat transfer coefficient increased from 2325.3 to 2888.6 W/(m^2/K). This is because increase in the volumetric flow rate increases the mass flow rate in a much faster rate than over all heat transfer coefficient or the heat energy transferred. Since the specific heat remains almost constant, tube outlet temperature should decrease to comply with law of conservation of energy.As the flow rate of tube side fluid is increased, the tube side heat transfer coefficient increases, which in turn decreases fin effectiveness and surface effectiveness.

V. CONCLUSION

CFD simulation studies on Shell and Tube Heat Exchanger has been carried with single, flower 'A' type, and flower 'B' type baffle configurations.

The following are the conclusions arrived from these simulation studies:

- Single Segmental Baffles provide good heat transfer coefficient but with large pressure drop and thus consume large pumping power.
- Flower Baffles are the most effective baffles as they reduce the pressure drop by 46 % - 51 % while the heat transfer coefficient is lowered to 13 % -21 % of that produced with single segmental baffles.
- Flower 'B' Baffles are more effective than Flower 'A' Baffles as they reduce the Pressure Drop to the same extent as that of Flower 'A' baffles but with a better thermal performance associated.

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