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Shell and Tube Heat Exchanger And Their Study

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Abstract-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.

Keywords- Shell and tube heat exchanger, CFD, baffles, ANSYS, thermal performance, efficiency

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 them 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 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.

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)

"examine the prediction of a 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 behaviour challenging. The design challenges are multiple objectives with several constraints to be fulfilled simultaneously.

This work will be complete with following steps:-

- First, we will prepare shell and tube heat exchanger model of different baffles arrangement in CATIA V5 and save as this part in IGES format and after that in ANSYS Workbench 14.5 Environment.
- Then we will apply material for shell and tube heat exchanger model.
- After that we will mesh the model.
- Define type of analysis: fluent analysis
- Define boundary condition for analysis boundary conditions play an important role in finite element calculation.
- Run the analysis using design of experiment.
- Get the results
- Compare all the results obtained

Specification of Shell and Tube Heat Exchanger

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.

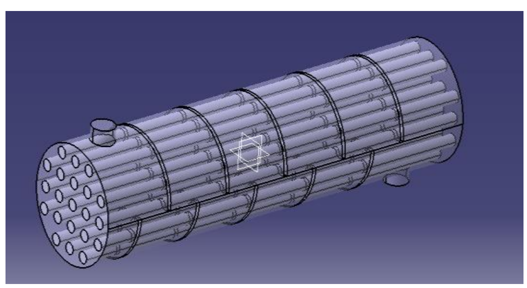
A STHX with different baffle geometries is designed [15, 16, and 17] to study the effects of variations in baffle geometry. A water-water shell and tube heat exchanger is designed considering the data in the following table 1.

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

IV. 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.



the model

V. 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.

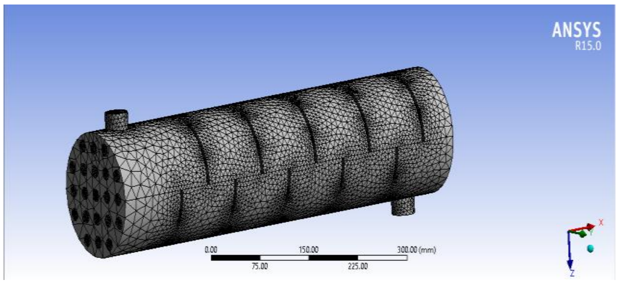


Fig. 3: Mesh model

VI. 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.

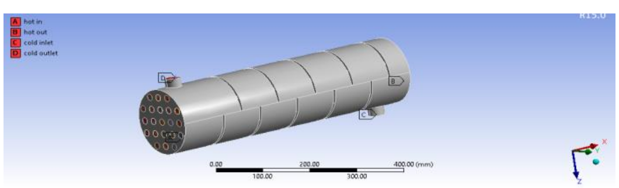
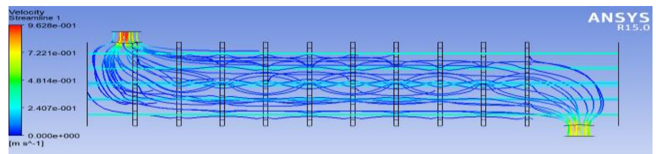


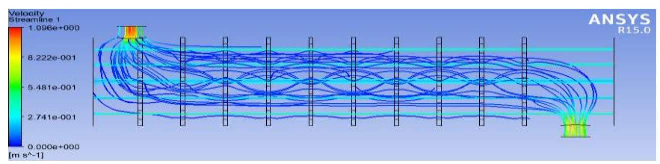
Fig. 4: Boundary condition in the model having single segmental baffle

VII. RESULT & DISCUSSION

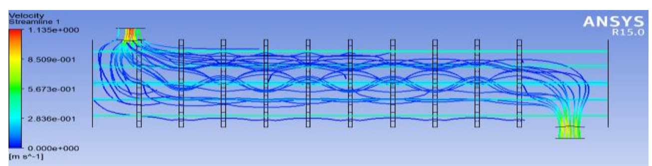
From simulation, it is inferred that the fluid velocity magnitude on the shell side changes periodically in the central part of the heat exchanger. When the fluid passes a baffle, it is firstly accelerated rapidly and then flows across the breaches with large velocity. After rushing out of the breaches, the fluid is expanded suddenly and the velocity is decreased gradually. This periodic flow pattern is caused by the periodic changes of flow area which is induced by arrangement of flower baffles. Moreover, it is also noticed that in the downstream just behind a baffle, two recirculation flow regions are generated, where the velocity magnitude is very small.



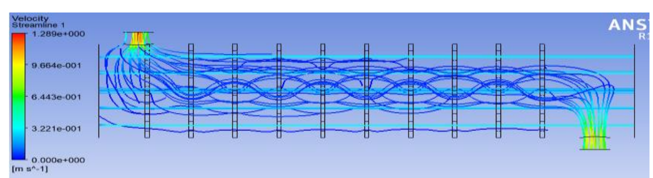
(a)



(b)



(c)



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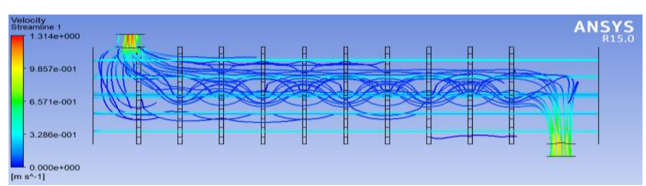

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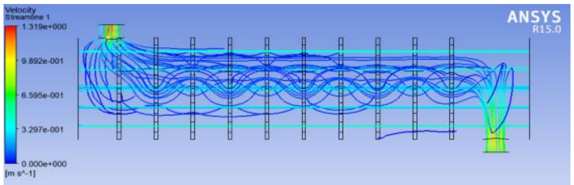

(f)

Fig. 5: Velocity variation in shell and tube heat exchanger

VIII.CONCLUSION

Shell and tube exchangers have been widely employed in a variety of engineering applications for decades, including chemical engineering processes, power generation, petroleum refining, refrigeration, air-conditioning, and the food sector [1]. Especially compared to other types of heat exchangers, shell and tube heat exchangers are very easy to produce but have a wide range of applications [2]. Shell-and-tube heat exchangers have been shown to account for more than 30% of all heat exchangers in operation [3, 4].

Baffles serve an important part in the construction of Shell and Tube Heat Exchangers (STHX). They offer tube support, let the shell-side fluid flow can retain a desired velocity, and keep the tubes form wobbling. The shell-side flow is additionally guided forward through the tube bundle by baffles, boosting fluid velocity and heat transfer coefficient. Heat transfer was boosted with the most widely used single segmental baffles because the baffles direct the shell side fluid to flow inside a zigzag pattern between both the tube bundle, increasing turbulence intensity and local mixing [5]. The single segmental baffles, but at the other hand, have several intrinsic flaws due to the structure's limitations:

- Fouling forms with in stagnation zone along the shell wall and also the back of baffle plates;
- When baffles obstruct fluid flow, a large pressure drop occurs, and flow separation occurs towards the baffle edge. As a result, additional pumping power is frequently required to compensate for the increased pressure loss under the same heat load.
- Significant bypass streams and leakage streams due to manufacturing tolerances;
- Flow-induced tube vibration causes short operating lifespan [6, 7].

As a result, various baffles must be investigated in order to reduce the shell side pressure drop and hence the heat exchanger's operating cost.

STHX with single segment baffles, helical baffles at varied helix angles, and flower baffles was researched and compared in enhancing performance, according to the literature review. Furthermore, simulations involving single, double, triple segmental baffles, helical baffles, and flower baffles have not been compared using the same STHX specification and input circumstances. As a result, a unique idea was developed to investigate the impacts of multiple baffle designs in shell and tube heat exchangers (STHX), including such single, double, triple segmental baffles, helical baffles, and flower baffles, on heat transfer coefficient and pressure drop.

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