Effect of Fin Cross Section on Shell and Tube Heat Exchanger using CFD

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Abstract- Heat transfer rate and cost significantly affect designs of shell and tube heat exchangers. To increase the heat transfer rate and to minimize the cost we are proving the radial fins on the tube surface, by doing this convective heat transfer surface is increased. By providing fins we can reduce the tube count which can transfer the same amount of heat as that of heat exchanger without fins, which reduces the diameter of shell and cost of the heat exchanger. The objective is to analyse the performance of a shell and tube heat exchanger with fins on tube surface. Numerical analysis is carried out using commercially available software FLUENT. The model of shell and tube heat exchanger was designed using CATIA V5. The convective heat transfer process is analyzed for rectangular finned and bare tube type heat exchanger. Boundary conditions have been applied to both shell and tubes, at inlet, velocity with energy condition is assigned and outlet is treated as pressure outlet. The convection boundary condition is applied for tube walls in terms of heat transfer coefficient and ambient temperature. The flow of temperature, pressure and velocity has been observed to evaluate the overall heat transfer.

Keywords – CFD, Heat exchanger, Shell, Tube

I. INTRODUCTION

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, petro chemical plants, chemical plants, petroleum refineries and natural gas processing. The classical example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Shell and tube heat exchangers consist of series of tubes. One set of these tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required. A set of tubes is called the tube bundle and can be made up of several types of tubes: plain, longitudinally finned, etc. Shell and tube heat exchangers are typically used for high-pressure applications (with pressures greater than 30 bar and temperatures greater than 260 °C). This is because the shell and tube heat exchangers are robust due to their shape. There can be many variations on the shell and tube design. Typically, the ends of each tube are connected to plenums (sometimes called water boxes) through holes in tubesheets. The tubes may be straight or bent in the shape of a U, called U-tubes. Figure 1shows the typical configuration of U tube heat exchanger.

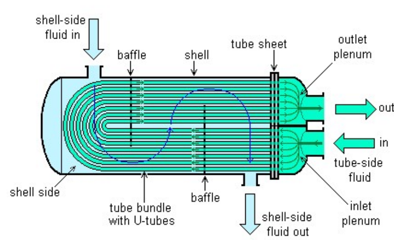

Figure1. U tube heat exchanger

1.1 Material Selection

To be able to transfer heat well, the tube material should have good thermal conductivity. Because heat is transferred from a hot to a cold side through the tubes, there is a temperature difference through the width of the tubes. Because of the tendency of the tube material to thermally expand differently at various temperatures, thermal stresses occur during operation. This is in addition to any stress from high pressures from the fluids themselves. The tube material

also should be compatible with both the shell and tube side fluids for long periods under the operating conditions (temperatures, pressures, pH, etc.) to minimize deterioration such as corrosion. All of these requirements call for careful selection of strong, thermally conductive, corrosion-resistant, high quality tube materials, typically metals, including copper alloy, stainless steel, carbon steel, non-ferrous copper alloy, nickel and titanium. Fluoropolymers such as perofluoroalkoxy alkane (PFA) and Fluorinated ethylene propylene (FEP) are also used to produce the tubing material due to their high resistance to extreme temperatures. Poor choice of tube material could result in a leak through a tube between the shell and tube sides causing fluid cross contamination and possibly loss of pressure.
An STHE is divided into three parts: the front head, the shell, and the rear head. The TEMA nomenclature for the various construction possibilities of a shell and tube heat exchangers are available in literature. Exchangers are described by the letter codes for the three sections — for example; a BFL exchanger has a bonnet cover, a two-pass shell with a longitudinal baffle, and a fixed-tube sheet rear head.

1.2 Parameters consider in construction of shell and tube heat exchanger
The following parameters have been considered for shell and tube heat exchanger.

- Tube diameter
- Tube thickness
- Tube length
- Tube pitch
- Tube Layout
- Baffle Design

The principal components of an STHE are:

- Shell
- Shell cover
- Tubes
- Channel
- Channel cover
- Tube Sheet
- Baffles

Other components include tie-rods and spacers, pass partition plates, impingement plate, longitudinal baffle, sealing strips, supports, and foundation. The Standards of the Tubular Exchanger Manufacturers Association (TEMA) describe these various components in detail.

II. LITERATURE

Shiv Kumar Rathore, Ajeet Bergaley , et al [1], The aim of this paper is to identify the advantages of low-finned tube Heat Exchangers over Plain tube (Bare Tube) units. To use finned tubes to advantage in this application, several technical issues were to be addressed. (1) Shell side and tube side Pressure, (2) Cost, (3) Weight and (4) Size of Heat Exchanger, Enhanced tubular heat exchangers results in a much more compact design than conventional plain tube units, obtaining not only thermal, mechanical and economical advantages for the heat exchanger, but also for the associated support structure, piping and skid package unit, and also notably reduce cost for shipping and installation of all these components. S.Rajasekaran, et al [2], The objective of this paper is to Develop and Test a model of optimizing the early design phase of shell and Tube Heat Exchangers via the application of modified Genetic Algorithm (MGA).The Modified Genetic Algorithm is based on the integration of classical genetic algorithm structure and a systematic neighborhood structure. Swapnaneel Sarma, et al [3], The energy present in the exit stream of many energy conversion devices such as I.C engine gas turbine etc. goes as waste, if not utilized properly. The present work has been carried out with a view to predicting the performance of a shell and finned tube heat exchanger in the light of waste heat recovery application. The performance of the heat exchanger has been evaluated by using the CFD package fluent 6.3.26 and has been compared with the existing experimental values. Heidar Sadeghzadeh, et al [4], Heat transfer rate and cost significantly affect designs of shell and tube heat exchangers. From the viewpoint of engineering, an optimum design is obtained via maximum heat transfer rate and minimum cost. Here, an analysis of a radial, finned, shell and tube heat exchanger is carried out, considering nine design parameters: tube arrangement, tube diameter, tube pitch, tube length, number of tubes, fin height, fin thickness, baffle spacing ratio and number of fins per unit length of tube. Manasa Kishtapati et al [5], Heat exchange devices are the most essential components in every process industry. Among them the widely used are shell and tube heat exchangers due to their robust geometry construction, easy maintenance and possible improvements. There is a continuous effort for increasing the film coefficients tube side and shell side so as to improve the overall heat transfer coefficient. The improvement in overall heat transfer coefficient decreases the size of the exchanger resulting in savings in space and cost of the exchanger.

III. MATERIALS & METHODOLOGY

The following tables 1 and 2 gives the material properties of steel, water and steam simultaneously that are used for the simulation.

Table 1. Material Properties

Properties	Stainless Steel (Grade 304)
Density (1000 kg/m3)	7.75-8.1
Elastic Modulus (GPa)	190-210
Poisson's Ratio	0.27-0.3
Thermal Expansion (10-6/K)	9.0-20.7
Melting Point (°C)	1371-1454
Thermal Conductivity (W/m-K)	11.2-36.7
Specific Heat (J/kg-K)	420-500

Table 2. Properties of steam at 350 oC, 1 atm

Properties	Steam
Density (kg/m3)	114
Kinematic viscosity (m2/s)	0.233 x 10-6
Specific heat (J/kg-K)	16425
Thermal conductivity (W/m-K)	0.107

3. Modeling

3.1 Bare tube type shell and tube heat exchanger

The geometry is created using CATIAV5 and imported to ANSYS Workbench that is shown in Figure 2.

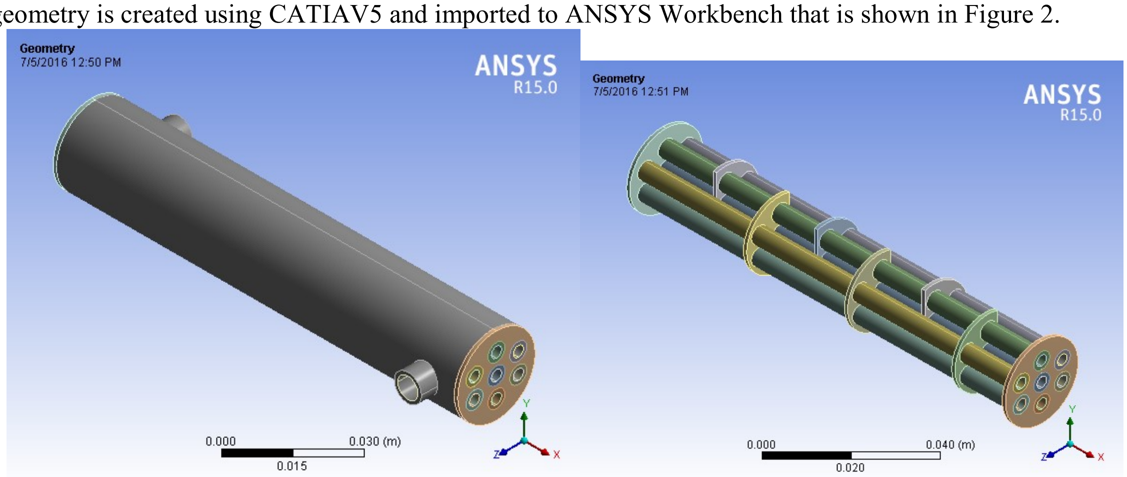

Figure 2. Model of bare tube type shell and tube heat exchanger

3.2 Heat Exchanger with Rectangular Fins

Rectangular fins on tube surface are created as shown in Figure 3.

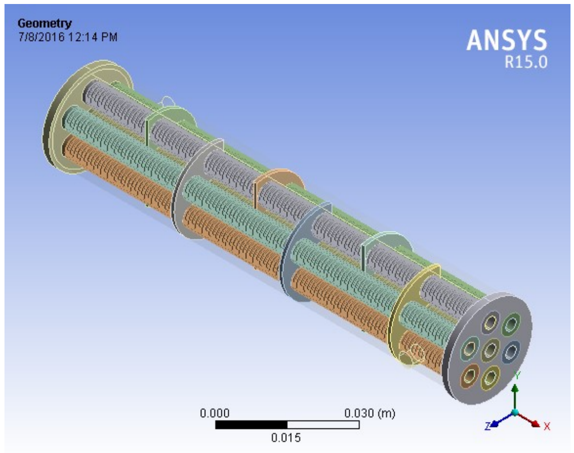

Figure 3. Internal view of rectangular finned shell and tube heat exchanger

IV. RESULTS AND DISCUSSION

4.1 Bare tube results

The following results has been observed from simulation using CFD-FLUENT and it is observed that the tube side fluid temperature drop is high than the temperature rise shell side fluid, it is because there is a loss of heat to tube wall and thermal conductivity of steel is low by which heat transfer to surrounding from tube outer surface is decreased.

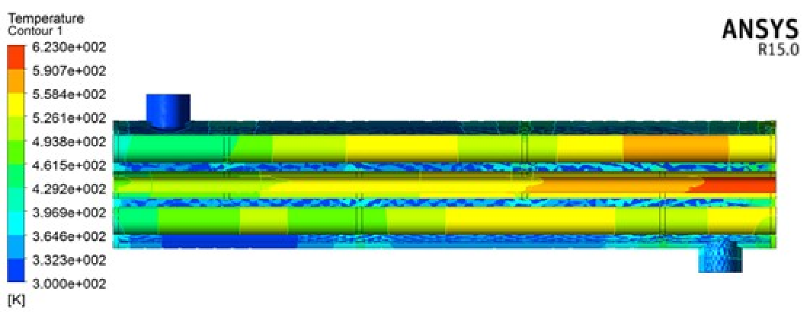

Figure 4. Temperature distribution across tube

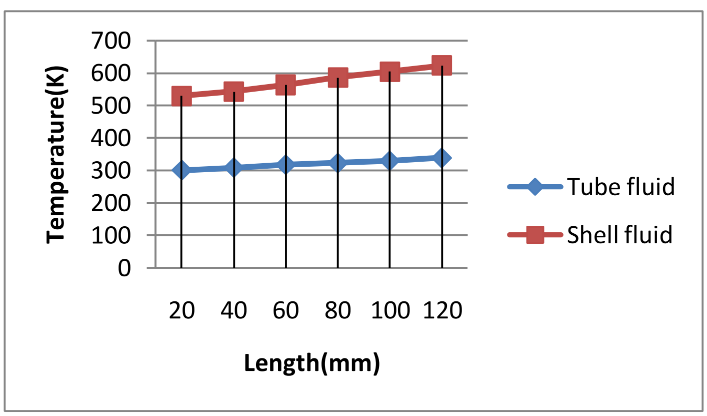

Figure 5. Temperature variation along length

4.2 Tube with Rectangular fins results

The following figure shows that the temperature drop is more in tube side fluid of rectangular finned heat exchanger when compared to the bare tube heat exchanger.

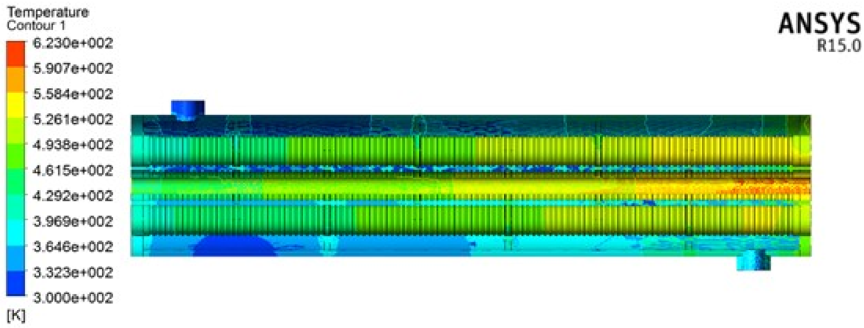

Figure 6. Temperature distribution across tube

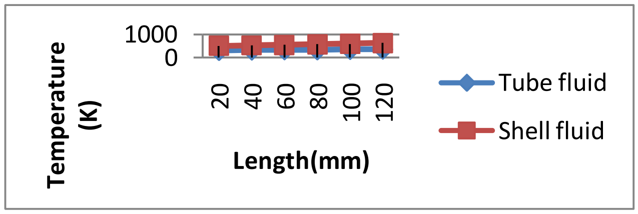

Figure 7. Temperature variation along length

The following table shows the overall results comparisons between bare tube and tube with rectangular fins.

Table 3. Comparison between bare and finned tube

S. No	Parameter	Bare tube heat exchanger	Rectangular finned heat exchanger
1	Shell Inlet temperature (K)	623	623
2	Shell outlet temperature (K)	529	508
3	Tube inlet temperature (K)	300	300
4	Tube outlet temperature (K)	338	353
5	Shell inlet pressure (bar)	0.00656	0.00685
6	Shell outlet pressure (bar)	0	0
7	Tube inlet pressure (bar)	0.000365	0.000368
8	Tube outlet pressure (bar)	0	0
9	Shell inlet velocity (m/s)	0.85	0.85
10	Shell outlet velocity (m/s)	0.86	0.863
11	Tube inlet velocity (m/s)	0.0709	0.0709
12	Tube outlet velocity (m/s)	0.0709	0.0709

IV.CONCLUSION

It is concluded that temperature drop is more in racangular finned heat exchanger than the bare tube heat exchanger where as pressure drop across the shell side and tube side is almost same. Heat transfer is more in rectangular finned heat exchanger when compared to that of bare tube heat exchanger, it is required less number of tubes in rectangular finned heat exchanger for same heat transfer rate.

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