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Parametric Optimization & CFD Analysis of Shell And Tube Type Heat Exchanger

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Abstract — *In modern day shell and tube heat exchanger is widely used in industries as a chillers plant for transfer waste heat from the injection molding machine to the cooling water for improve the efficiency of the injection molding machine. The transformations of the waste heat from injection molding machine to the cooling water is dependent on the heat exchange capacity of heat exchangers. So in now a day the industries are facing the problem for improving the heat exchange capacity of the heat exchanger by improving the heat exchanger's efficiency for increase production capacity and efficiency of injection molding machine.*

Keywords*-heat exchanger, cfd analysis of shell and tube heat exchanger, shell and tube, experimentation of heat exchanger, analysis of shell and tube type heat exchanger.*

I. INTRODUCTION

A heat exchanger is a device built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, cryogenics applications and sewage treatment. One common example of a heat exchanger is the radiator in a car, in which the heat source, being a hot engine-cooling fluid, water, transfers heat to air flowing through the radiator (i.e. the heat transfer medium).

II. OBJECTIVE OF THE PAPER

The objective of work is to increase the efficiency of the shell and tube heat exchanger. The efficiency of the heat exchanger is basically depends on the geometric parameters (tube diameter, pitch length, types of the baffles, angle of the baffles etc.) as well as process parameters (mass flow rate, inlet and outlet temperature of the cooling water etc.) of heat exchangers. So the objective is to optimize some of these parameters (tube diameter, pitch length, mass flow rate) for improve the efficiency of the heat exchanger. The steps needs for perform optimization of parameters are:

- Modeling of shell and tube heat exchanger.
- CFD analysis of shell and tube heat exchanger in ANSYS.

III. LITRATURE SURVEY

3.1 CFD analysis of a shell and finned tube heat exchanger for waste heat Recovery applications

(Author: Apu Roy, D.H.Das & Journal: ScienceDirect)

Work:-The energy available 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 6.3.16 and has been compared with the available experimental values.

An attempt has also been made to predict the performance of the above heat exchanger by considering different heat transfer fluid and the result so obtained have been compared. The performance parameters pertaining to heat exchanger such as effectiveness, overall heat transfer coefficient, energy extraction rate etc, have been reported in this work.

An investigation was carried out to study the shell and finned tube heat exchanger computationally. The analysis has done and pressure drop and temperature rise along the tube surfaces has been investigated. Based on the obtained result it can be concluded as follows,

1) Temperature variation with same velocity of castor oil and water is greatly noticeable. This is due to better thermal properties of castor oil than the water.

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2) All dimensionless parameters are changes for their own properties such as specific heat, viscosity, density, and thermal conductivity properties.

3) Better effectiveness can be achieved by using castor oil as heat transfer fluid whereas water gives the traditional effectiveness. The effectiveness of the finned tube heat exchanger is quite comparable with other conventional heat exchanger.

4) The results from the computational analysis appear to be in good agreement with the available experimental results.

5) Energy extraction rate is also quite significant .That means a sufficient amount of heat can be recovered by the using of finned tube heat exchanger.

3.2 CFD and experimental studies on heat transfer enhancement in an air cooler equipped with different tube inserts *(Author: S.R. Shabanian, M. Rahimi, M. Shahhosseini, A.A. Alsairafi S.R. Shabanian, M. Rahimi, M. Shahhosseini, A.A. Alsairafi & Journal: ScienceDirect)*

Work: This paper reports the experimental and Computational Fluid Dynamics (CFD) modelling studies on heat transfer, friction factor and thermal performance of an air cooled heat exchanger equipped with three types of tube insert including butterfly, classic and jagged twisted tape. In the studied range of Reynolds number the maximum thermal performance factor was obtained by the butterfly insert with an inclined angle of 90°.

The results have also revealed that the difference between the heat transfer rates obtained from employing the classic and jagged inserts reduces by decreasing the twist ratio. The CFD predicted results were used to explain the observed results in terms of turbulence intensity. In addition, good agreements between the predicted and measured Nu number as well as friction factor values were obtained.

In the present study the thermal performance factor of an insert called butterfly has been compared with that of classic and jagged twisted tape tube inserts. The studied tube inserts including the butterfly inserts with inclined angles of 45°, 90° and 135°, and the jagged and classic twisted tape inserts with twist ratios of 1.76, 2.35, 2.94 and 3.53, were placed in a bent tube of the air cooled heat exchanger.

The enhancement percentages of Nu/Nu0 of all studied inserts have been calculated. The ratio of Nu/Nu0 values for the jagged inserts with various twist ratios with respect to the classic ones have been measured. The average value of 17.24%, 22%, 26.02% and 28.11% were found for twist ratios of 1.76, 2.35, 2.94 and 3.53, respectively. From these results it has been concluded that the effect of edging of the classic insert on heat transfer rate reduces by decreasing the twist ratio.

In addition, in comparison between the jagged inserts and butterfly inserts, it was found that there were higher performances by the butterfly inserts in terms of thermal performance factor. In the studied range of Reynolds number, the thermal performance factor of butterfly insert varied between 1.28 and 1.62, while it was between 1 and 1.23 for the jagged inserts.

The CFD modeling was employed to explain the experimental observations. In the modeling, the MFR method was used to model the fan rotation and the RNG $\kappa-\varepsilon$ turbulence model was employed to predict the turbulence effects. The three dimensional CFD modeling results showed that an increase in turbulence intensity could be one of the reasons for higher performance of butterfly compared with the jagged and classic ones.

3.3 CFD application in various heat exchanger designs *(Author: Muhammad Mahmood Aslam Bhutta, Nasir Hayat, Muhammad Hassan Bashir, Ahmer Rais Khan, Kanwar Naveed Ahmad, Sarfaraz Khan & Journal: ScienceDirect)*

Work: Nasir hayat present the research paper on CFD application in various heat exchanger designs. The main objective of this research paper is that CFD is employed for the following areas of study in various type of heat exchanger, fluid flow maldistribution, fouling and pressure drop and thermal analysis in the design and optimization phase. Finally he concluded that conventional methods are used for the design and development of the heat exchangers are largely tedious and expensive in today's market.

CFD has emerged as cost effective alternative and it provides speedy solution to heat exchanger design and optimization.

3.4 Analysis on flow and heat transfer characteristics of EGR helical baffled cooler with spiral corrugated tubes *(Author:* lin liu *& Journal: ScienceDirect)*

Work: lin liu present the research paper on analysis on flow and heat transfer characteristics of EGR (exhaust gas recirculation) helical baffled cooler with spiral corrugated tubes .the main objective for this work is that exhaust gas recirculation which reduces the exhaust gas temperature for reduction of NOx.

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He used helical baffled tube cooler with spiral corrugated tubes. Finally he concluded that heat performance of spiral corrugated tube is significantly higher than that of smooth tube.

IV. MODELLING OF SHELL AND TUBE TYPE HEAT EXCHANGER
V.

After performing simple calculation, the modeling has been performed on the Solid works 2009 version and then after the analysis work has been performed on the ANSYS 12.0 version.

5.1 FUNCTIONS OF SOLID WORKS

- **Part design**
  - Create sketch of the parts.
  - Sketch cosmetic features,
  - Create geometric tolerances and surface finishes on models.
  - Assign the properties like density, mass, units, materials etc.

- **Assembly design:**
  - Create full product assembly.
  - Disassemble components from assembly.
  - Modify part dimensions.
  - Additional functionality is also available,

- **Design documentation (drawings):**
  - Create detailed, exploded, auxiliary, cross-sectional prospective drawing views,
  - Perform extensive view modifications.
  - Modify dimension values and number of digits.
  - Include existing geometric tolerances.

- **General functionality**
  - Database management commands.
  - Larger control of placing items.
  - Measurement commands.
  - Viewing capabilities.

5.2 SPECIFICATIONS

1) Shell – 150 NB, 750 mm long provided with end boxes.
   a) One end box with divider plate.
   b) 25 % cut baffles – 4 nos., in the shell.

2) Tubes 7.525 I.D., 9.525 O.D., 750 mm copper tubes with triangular pitch (32 nos.)

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Figure 1. Set Up Image of Shell & Tube Type Heat Exchanger

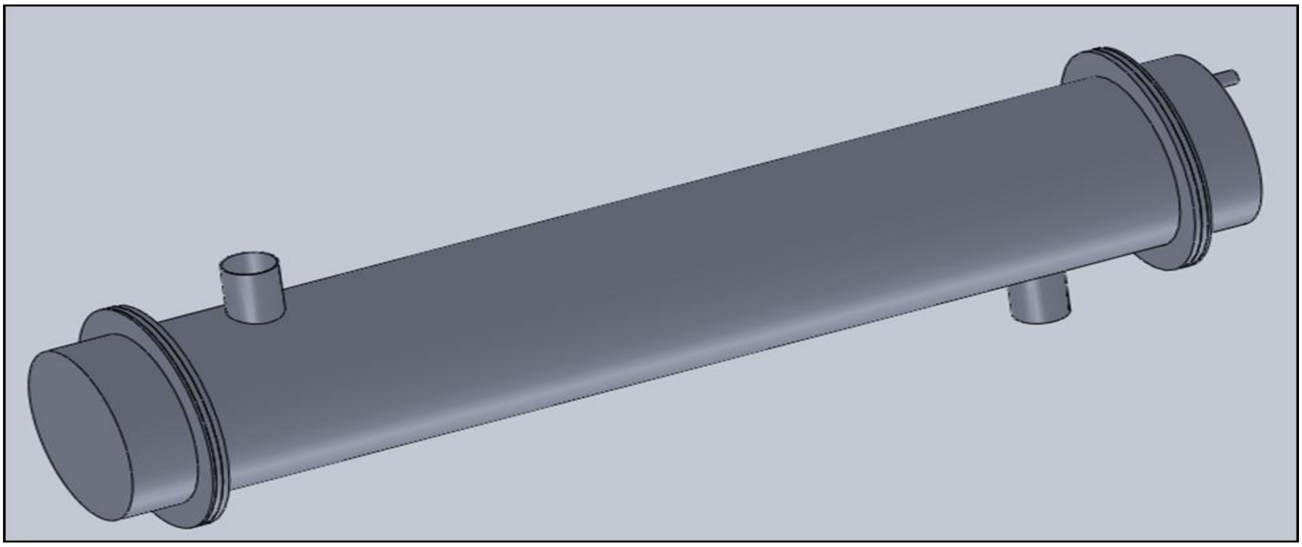

Figure 2. Solid Work Model Of Shell & Tube Type Heat Exchanger

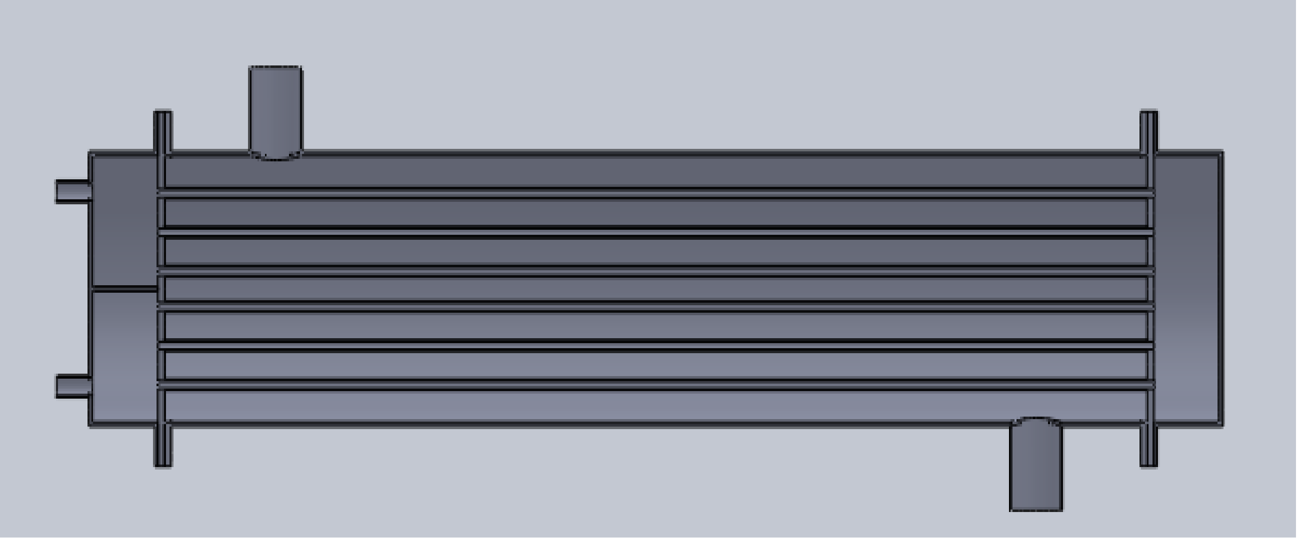

Figure 3. Sectional View Of Shell & Tube Type Heat Exchanger

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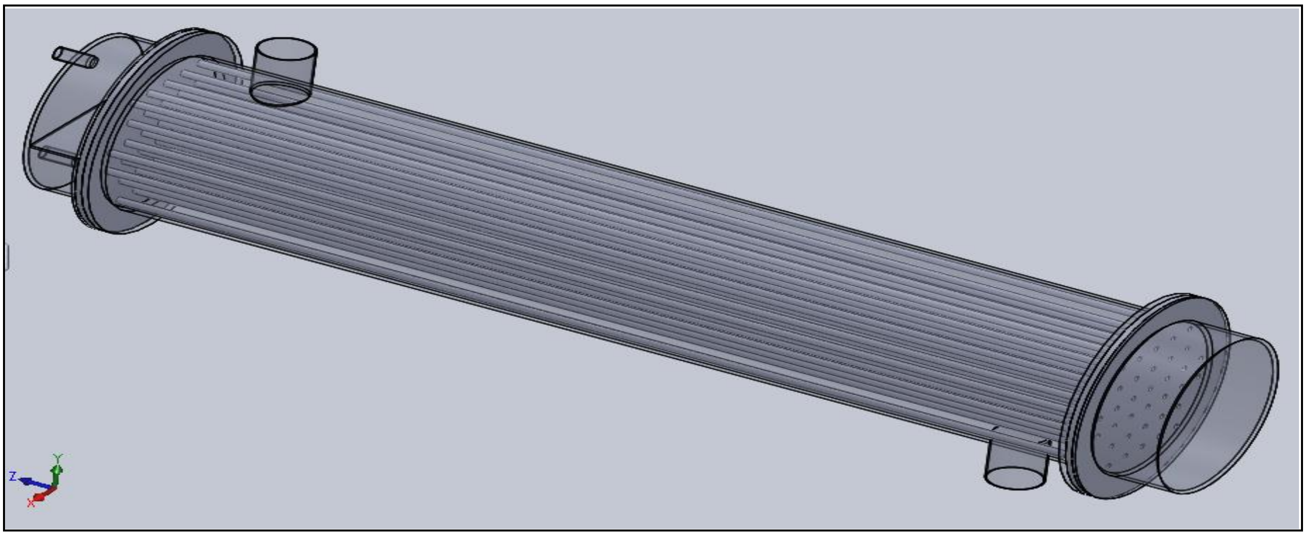

Figure 4. Transparent Model Of Shell & Tube Type Heat Exchanger

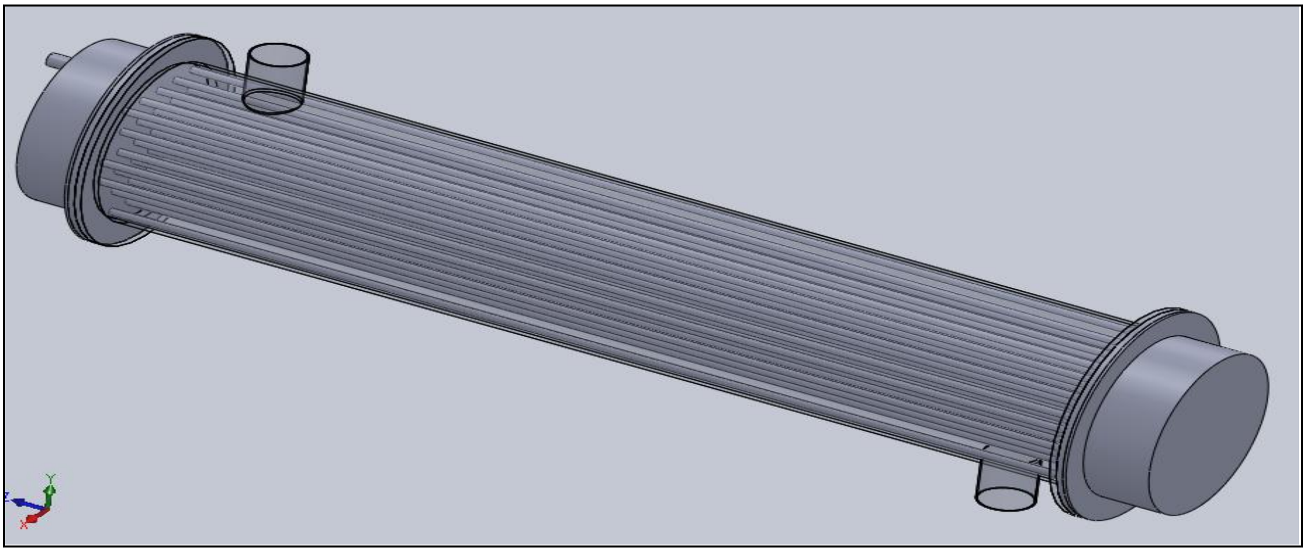

Figure 5. 3D Model Of Shell And Tube Type Heat Exchanger

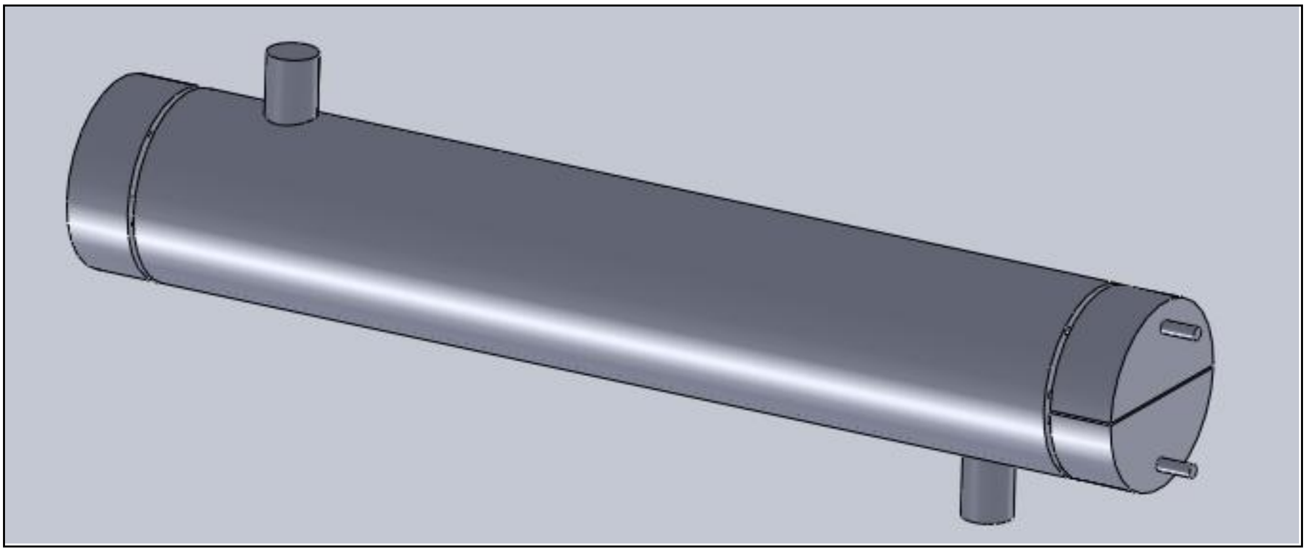

Figure 6. Cavity Models Of Shell And Tube Type Heat Exchanger

VI. PROCEDURE OF CFD ANALYSIS FOR SHELL AND TUBE TYPE HEAT EXCHANGER

The equations of fluid mechanics which have been known for over a century are solvable only for a limited no. of flows. The known solutions are extremely useful in understanding fluid flow but rarely used directly in engineering. Analysis or design. CFD makes it possible to evaluate velocity, pressure, temperature, and species concentration of fluid flow throughout a solution domain, allowing the design to be optimized prior to the prototype phase.

Availability of fast and digital computer makes techniques popular among engineering community. Solutions of the equations of fluid mechanics on computer has become so important that it now occupies the attention of a perhaps a third of all researchers in fluid mechanics and the proportion is still is increasing. This field is known as computational fluid dynamics. At the core of the CFD modeling is a three-dimensional flow solver that is powerful, efficient, and easily extended to custom engineering applications.

In designing a new mixing device, injection grid or just a simple gas diverter or a distribution device, design engineers need to ensure adequate geometry, pressure loss, and residence time would be available. More importantly, to run the plant efficiently and economically, operators and plant engineers need to know and be able to set the optimum parameters.

A. Create 3d Model Of Shell And Tube Type Heat Exchanger In Solid Works 2009.

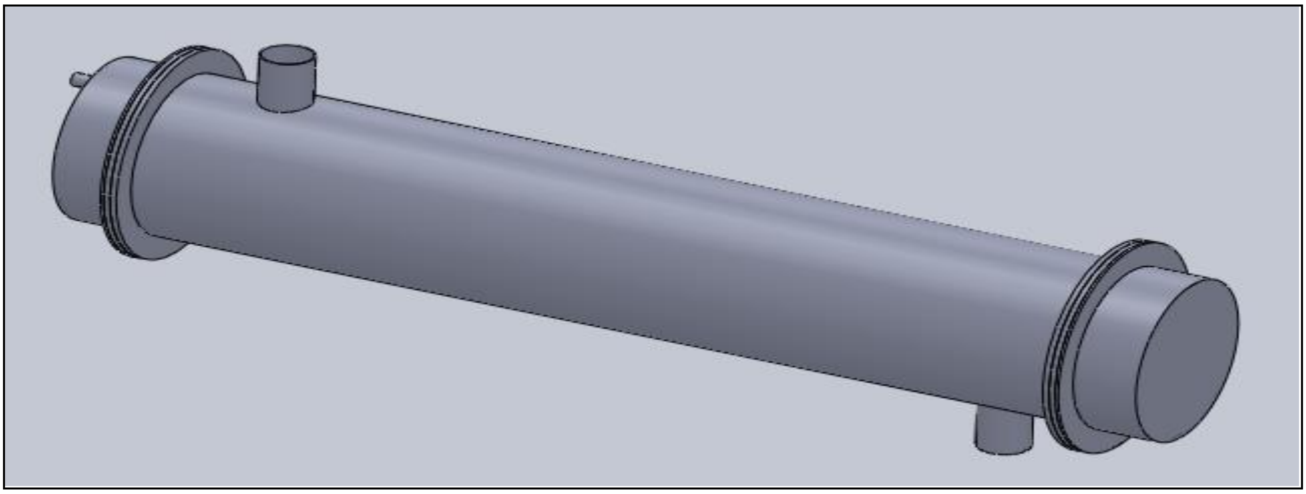

Figure 7. Shell and Tube Type Heat Exchanger Single Path

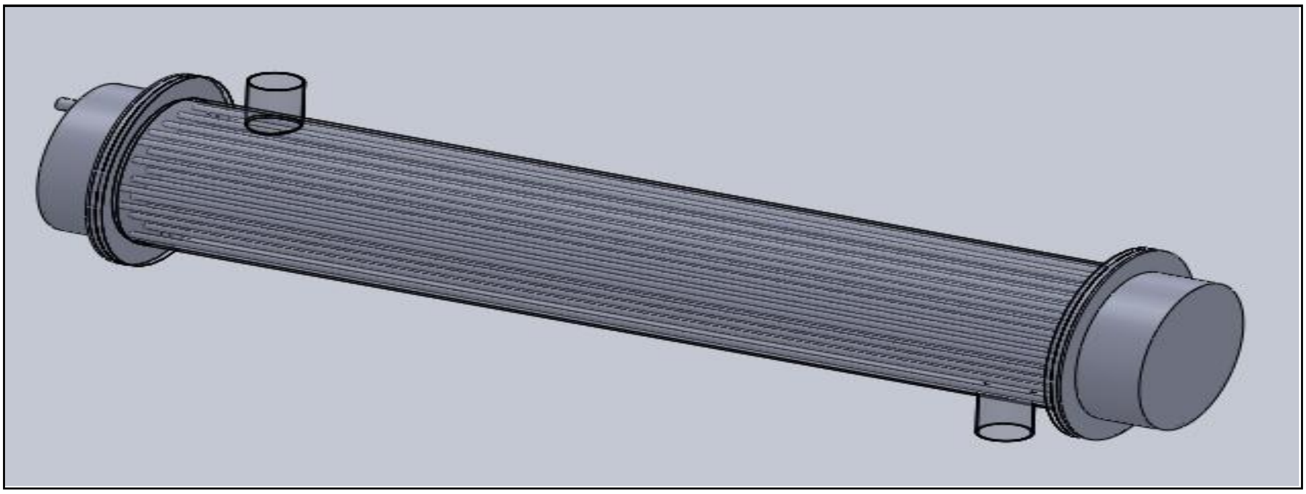

Figure 8. Porous Domain for Air

B. Create Cavity Domain for CFD Analysis.

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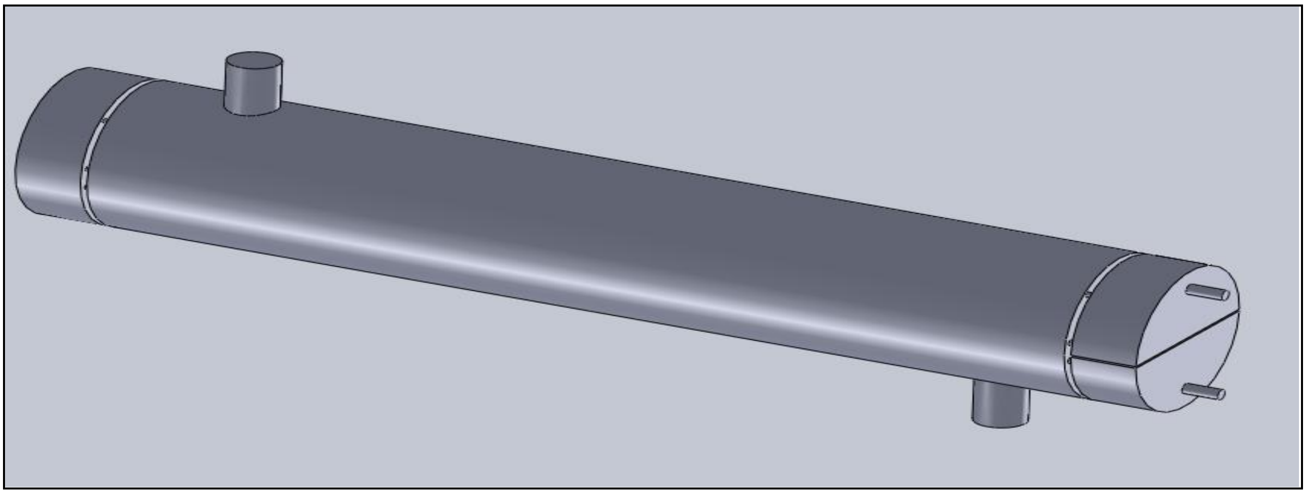

Figure 9. Cavity Domain for Inner and Outer Fluid

C. Save Above Model In *.IGES Format for Importing into ANSYS Workbench Mesh Module.

D. Import above Saved *.IGES File in ANSYS Workbench.

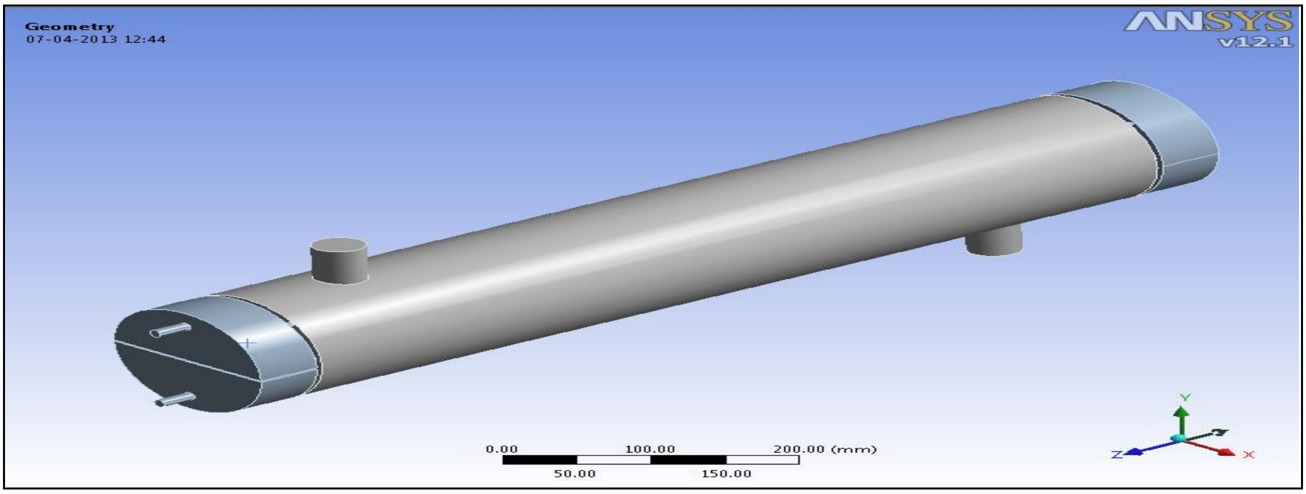

Figure 9. Import Model

E. Create Mesh.
Type of Analysis: - 3D
Type of Element: - Tetrahedral (10 Node)

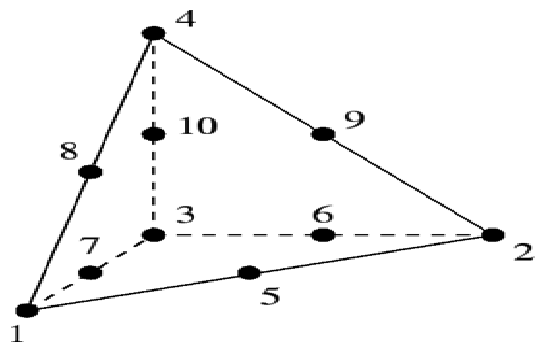

Figure 10. Tetrahedral

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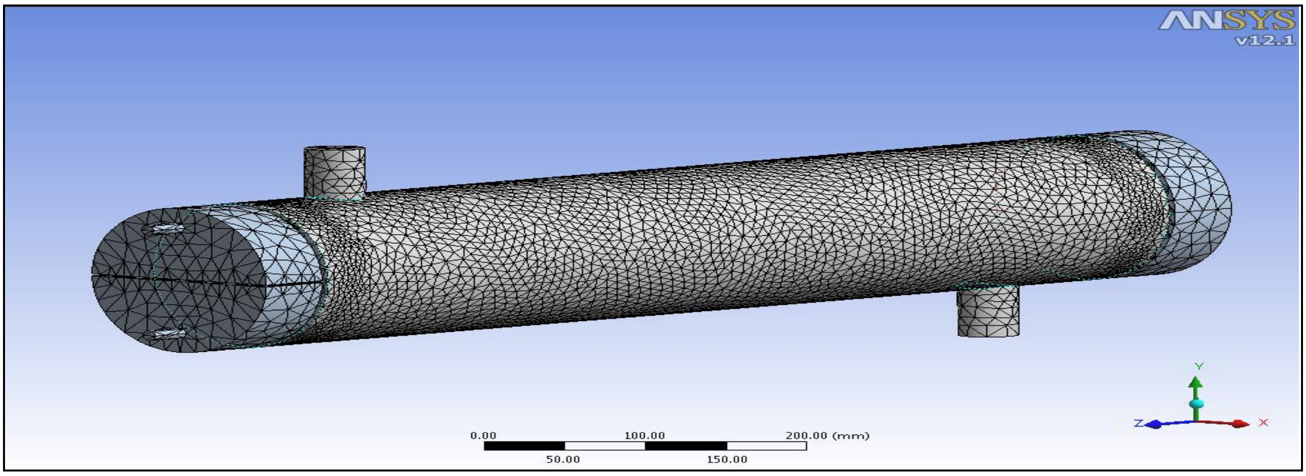

Figure 11. Meshing

Number of Nodes: - 553071
Number of Element: - 340908

F. Save Above Meshed Model In *.Cmdb Format for Importing into Ansys Cfx.

G. Import above *.CMDB File in ANSYS CFX PRE.

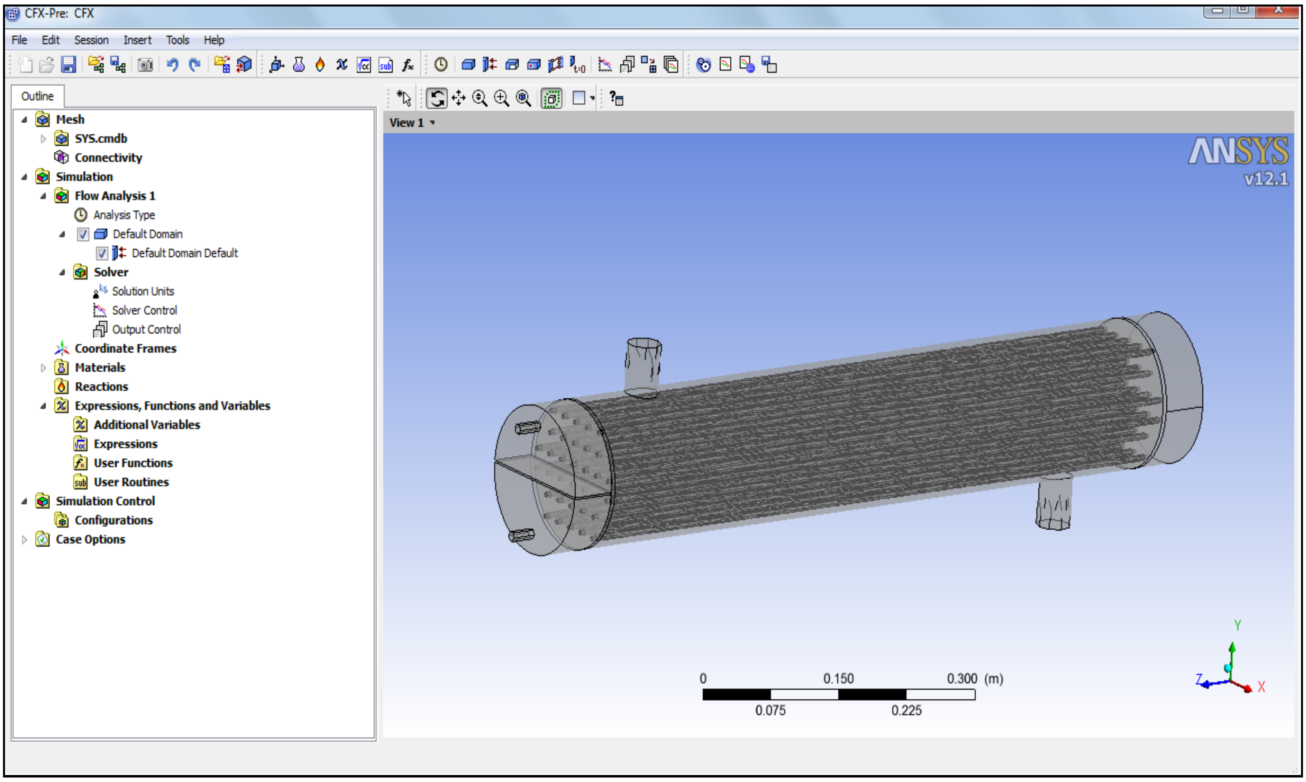

*Figure 12. Import *.CMDB File in ANSYS CFX PRE*

H. Define Type of Analysis.
Type of Analysis: - Steady State

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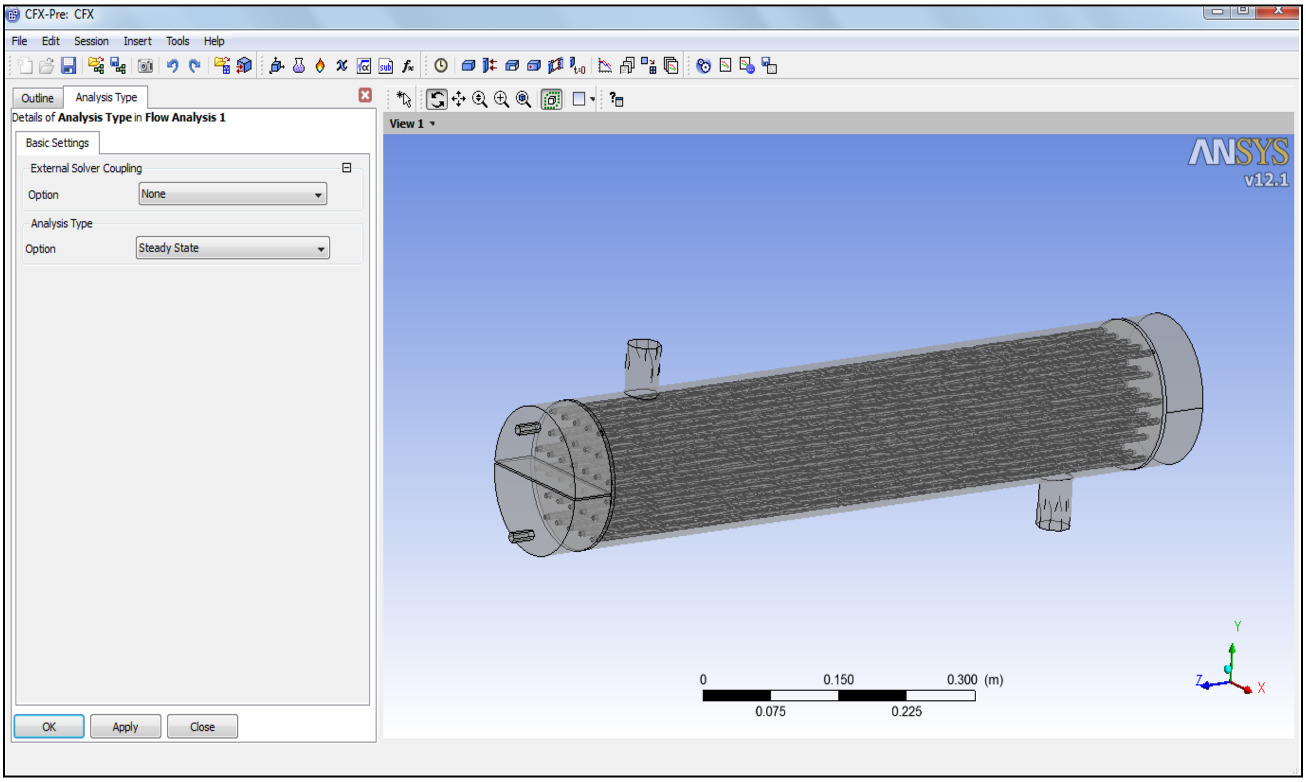

Figure 13. Steady State of Analysis

I. Define Tube Side Fluid Domain for Water.
Domain Type: - Fluid
Domain Material: - Water
Domain Motion: - Stationary

J. Define Heat Transfer and Turbulence model for Fluid Domain.
Heat Transfer Model: - Thermal Energy
Turbulence Model: - K-Ɛ

Where k is the turbulence kinetic energy and is defined as the variance of the fluctuations in velocity. It has dimensions of (L2 T-2); for example, m2/s2.
ε is the turbulence eddy dissipation (the rate at which the velocity fluctuations dissipate), as well as dimensions of k per unit time (L2 T-3) (e.g., m2/s3).
The k-ε model introduces two new variables into the system of equations. The continuity Equation is then:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho U) = 0;$$

And the momentum equation becomes,

$$\frac{\partial \rho U}{\partial t} + \nabla \cdot (\rho U \otimes U) - \nabla \cdot (\mu eff \nabla U) = \nabla P' + \nabla \cdot (\mu eff\ \nabla U)T + B\ ;$$

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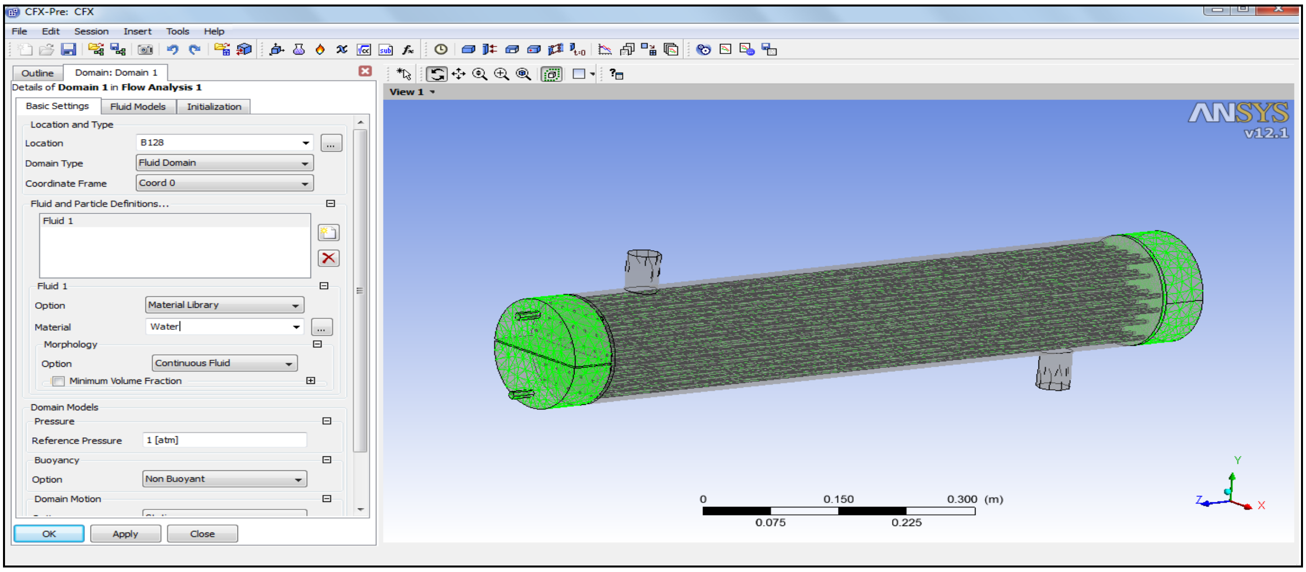

Figure 13. Tube Side Fluid Domain for Water

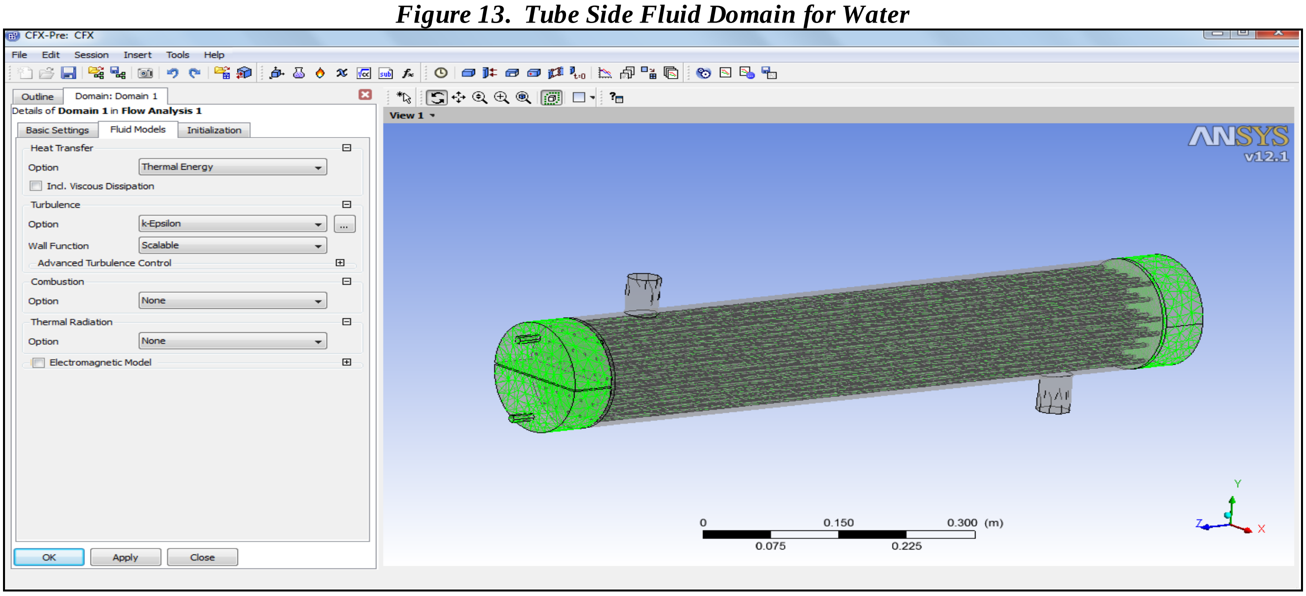

Figure 14. Heat Transfer and Turbulence model for Fluid Domain

K. 11) Same way Define Domain for Shell Side Water.

L. 12) Define Inlet for Shell Side.

Mass Flow Rate: - 0.318 Kg/s
Temperature: - 26 C

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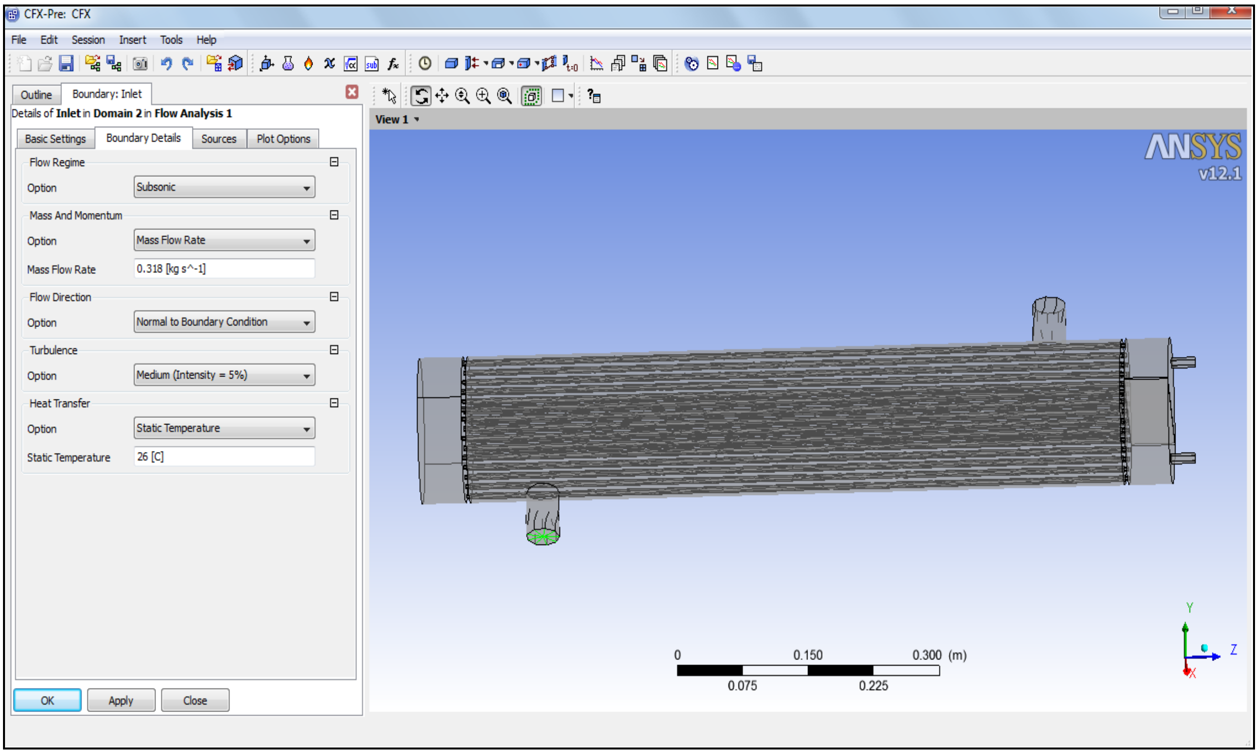

Figure 15. Define Inlet for Shell Side

M. Define Outlet For Shell Side.

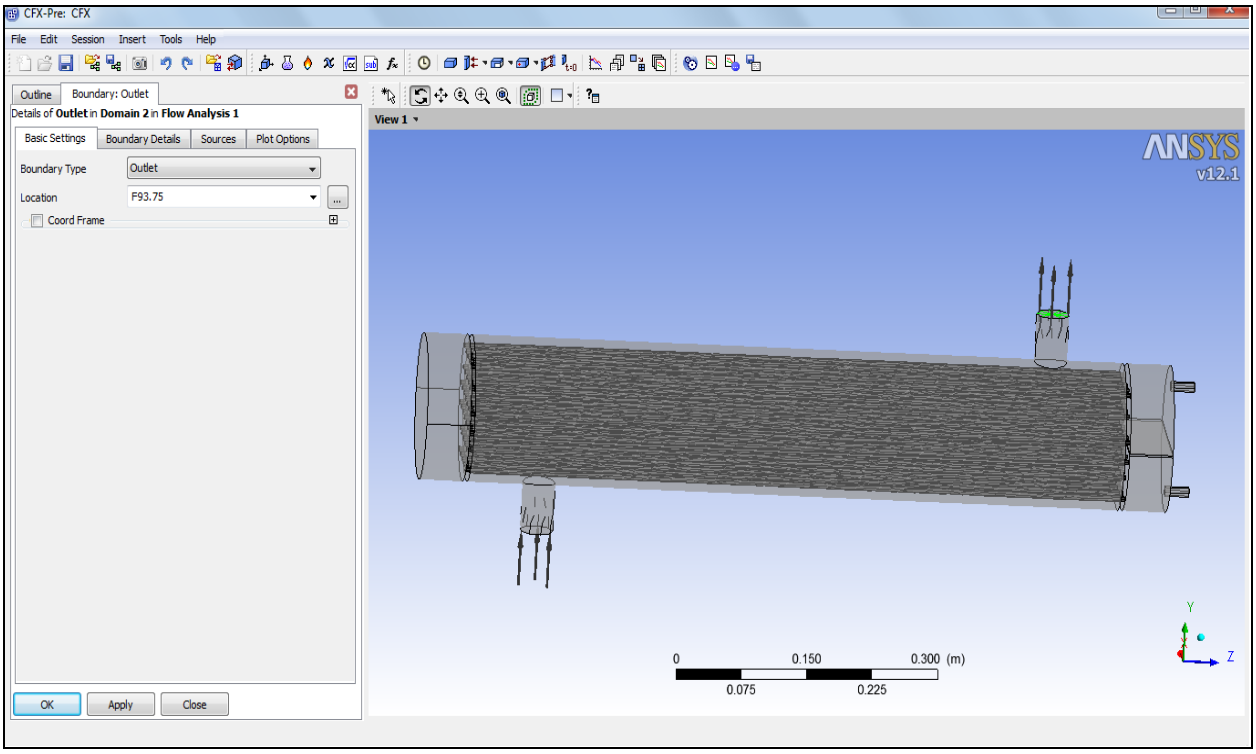

Figure 16. Define Outlet for Shell Side

N. Define Inlet for Tube Side Water.

Mass Flow Rate:- 0.062 Kg/s
Inlet Temparature:- 40 C

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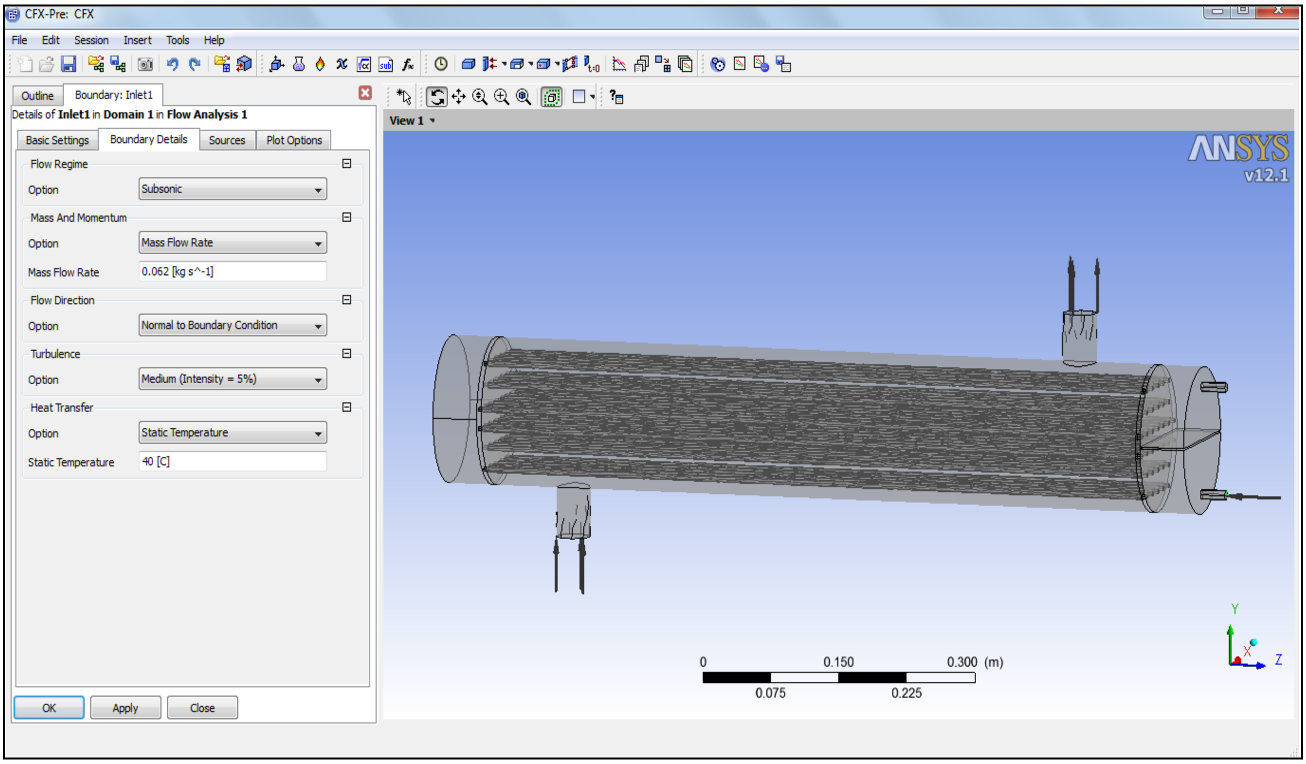

Figure 16. Define Inlet for Tube Side Water

O. Define Outlet for Tube Side Water.

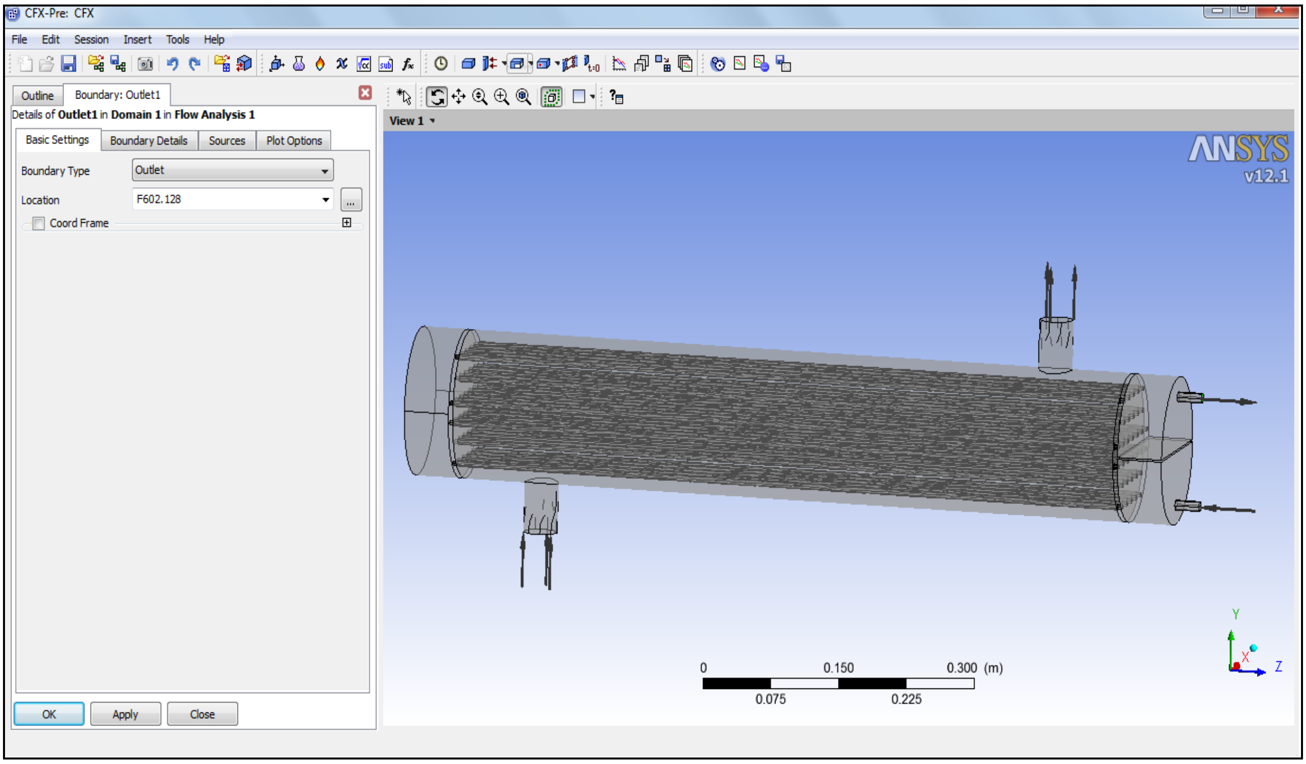

Figure 17. Define Outlet for Tube Side Water

P. Define Solver Control Criteria.

Convergence Criteria

Residual Target: - 1e-4

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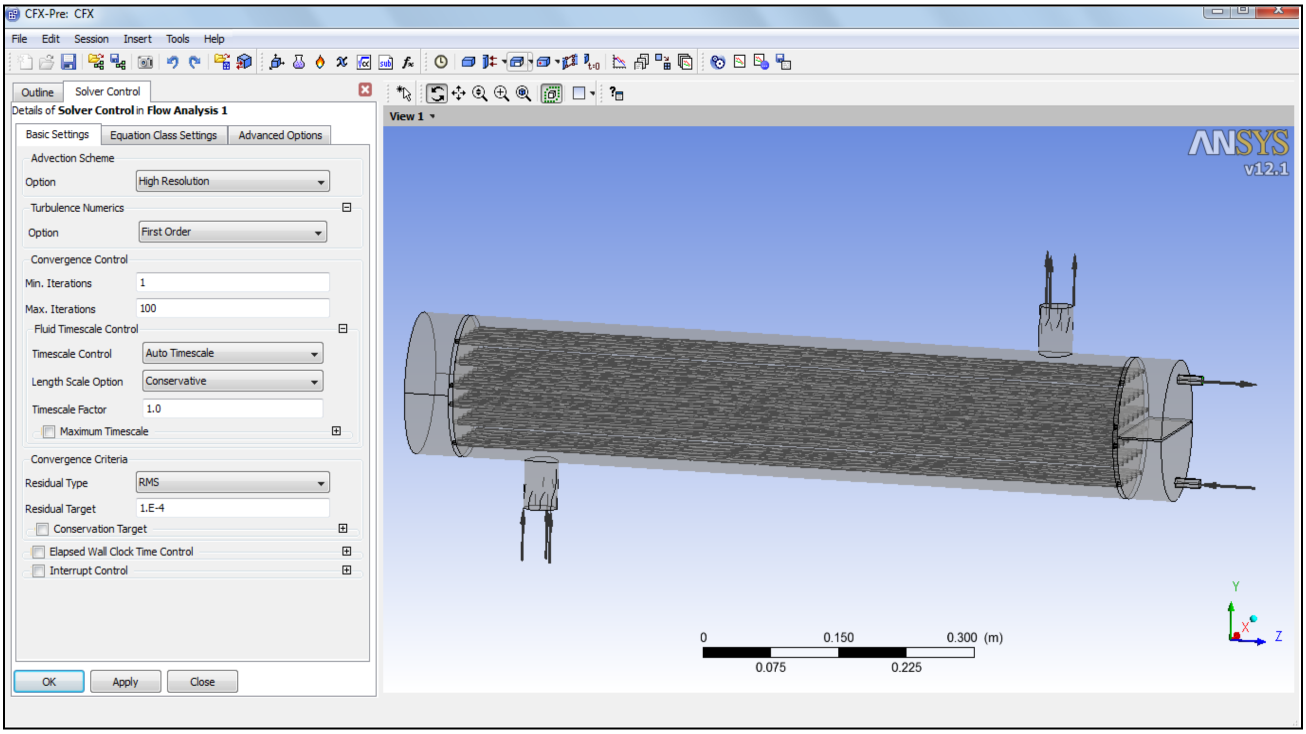

Figure 17. Define Solver Control Criteria

Q. Run the Analysis

R. Get the Results

VII. RESULTS

Shell and tube heat exchanger is widely used in industries. Today the main problem of industries is effectiveness of the heat exchanger.There are various heat exchanger performance parameters like tube diameter, mass flow rate, pitch length, longitudinal pitch, tube material, shell material, types of baffles, baffles angles etc.

Based on the practical and ANSYS results, it is found that the mass flow rate is the Primary parameter and pitch length is the secondary element that has an effect of improvement of effectiveness of heat exchanger. Also from results and analysis it can be concluded heat optimum parameter to increase the effectiveness of the heat exchanger are tube diameter are 8.52 mm, pitch length of tube 27 mm and mass flow rate 1.8 kg/s.

ANSYS and experimental result are compared and found in good agreement, thus proving the strength of model. After completing CFD Analysis Results, we can say that CFD Analysis is a good tool to avoid costly and time consuming Experimental Work.

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