CFD Analysis of Shell and Tube Heat Exchanger With and Without Fins for Waste Heat Recovery Applications

Priyanka G¹, M. R. Nagraj²

¹Assistant Professor, Mechanical Engineering Department, Guru Nanak Dev Engineering College Bidar, Karnataka, India ²Associate Professor Mechanical Engineering Department, PDA Engineering College Gulbarga, Karnataka, India

Abstract: 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 ANSYS13.0. An attempt has been made to predict the performance of the 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, heat transfer, energy extraction rate etc., have been reported in this work.

Keywords: Waste heat recovery, Heat transfer Fluid, finned tube heat exchanger, Diesel engine exhaust

1. Introduction

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved. Large quantity of hot flue gases is generated from boilers, kilns, ovens and furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered. At present scenario the rapid industrial growth is the main reason for the crisis of energy and also for pollution. Diesel engine are now widely used device in all industrial application starting from gas turbine power plant .Nearly about 2/3 rd. of energy are now wasted through the exhaust gas which is indirectly cause of global warming and overall energy requirement. Depending on the temperature level of exhaust stream and proposed application, different heat exchanger devices, heat pipes combustion equipment's has been employed to facilitate the use of recovered heat. Previously Shell and tube heat exchanger was widely used as industrial heat transfer equipment's. Here both plain tube and with fins are been analyzed. But now a day's modified tube are using for proper exchanging of heat just like finned tube. Selecting the castor oil as HTF is that it has higher heat transfer coefficients than the gasses. And also it minimizes the size of the heat exchanger. Castor oil is a one type of bio- fuel which is formed from Veranda trees. It has better thermal properties than the water. Relative to other vegetables; it has a good shelf life. Finned tube heat exchanger has selected as it has high compactness. Extended surfaces has provide for better heat transfer rate in the exchanger. The present work is been done with view to predicting the performance of a shell and tube heat exchanges with and without fins by using waste heat.

2. Geometric Modeling and Data Input

The geometry of shell and tube heat exchanger and fins have been modeled on ANSYS design modeler .The heat exchanger specification used for present work has been shown in the Table 1 given below.

1	Shell outer diameter	323 mm
2	Shell thickness	6mm
3	Fin thickness	2 mm
4	Fin height	6mm
5	Tube outer diameter	12.5 mm
6	Tube thickness	1.65mm
7	Length of the shell	500 mm
8	No of tube inside the shell	36
9	Transverse pitch	37.5 mm
10	Longitudinal pitch	37.5 mm

The shell material, fin and tube materials is mild steel, and copper respectively. Longitudinal type of fin tube has been used and inline square arrangement has been adopted. In this analysis tetrahedral mesh is used with prism boundary layer. The total no of elements used is 2 millions without fins and 3.2millions with fins. The shell side exhaust is exhaust gas which is coming from 15HP exhaust and having temperature of 120°C.the tube side fluid is taken 35°C for both fluids. Keeping shell side fluid velocity constant and only varying the tube side velocity at various conditions, analysis has been done.

3. Properties of Working Fluid

Castor oil having better thermal properties than water is used as heat transfer fluid. As boiling point of water is 100°C whereas for castor oil it is 313°C. For shell side fluid exhaust gas from 15 HP diesel engine has been considered.

4. Results and Discussion

After the exporting the model into analysis has done in two steps. In first step water is taken into consideration. All the analysis has been done at three different fluid velocities to both with and without fins. Similarly for castor oil same thing is done.

4.1. Analysis with Water

Taking the inlet velocity condition the temperature rise along the tube surfaces along the tube has been observed by some of the temperature contour and plot are given in the following figure.







Figure.4.2: Temperature contours on heat exchanger-tube



Figure.4.3: Velocity contours on symmetry plane of heat exchanger

All these results are obtained from the analysis using water as heat transfer fluid at 0.85 m/s velocity. Similarly three times analysis has taken. From all above figure it is clearly observed that temperature increases along the tube and in case of shell the temperature is decreasing. All result has been shown in various the graph and plots.



Figure 4.4: Temperature contours on symmetry plane of heat exchanger with fins



Figure.4.5: Temperature contours on heat exchangersectional view



Figure.4.6: Temperature contours on heat exchanger-fin temperature



Figure.4.7: Temperature contours on heat exchanger-tube temperature



Figure 4.8: Velocity contours on tube of heat exchanger

Above figures shows the temperature and velocity contours on tube of heat exchanger with inlet velocity 0.85m/s. and increase in velocity along the tube side. After increasing the velocity both fluids temperature of shell side fluid decreases and tube side fluids increases after exchanging the heat with each other's. Since shell side fluid become mixed along the path of the flow therefore shell side fluid's exit temperature become nearly uniform. Pressure drop is observed quite high which indicates the necessity the large pumping power.

4.3 Analysis with castor oil



Figure 4.8:Temperature contours on heat exchanger-tube temperature



Figure 4.9: Temperature contours on heat exchangersectional view

Figure 4.8 aand 4.9 shows temperature contours of heat exchanger.Temperature rise along the tube surfaces has been observed. From the above analysis it is evident that heat transfer is higher in castor oil than water when used, and has better thermal properties than water as heat transfer fluid.

 Table 4.1: CFD analysis of shell and tube heat exchanger

output without fins.										
velocity m/s	0.85		1.25		1.75					
	Water	Oil	Water	Oil	Water	oil				
Shell inlet K	393	393	393	393	393	393				
Shell outlet K	390.7	390.5	390.2	389.7	389.7	389.3				
Tube inlet K	308	308	308	308	308	308				
Tube outlet K	357.4	364.6	348.3	355.2	341.3	347.5				

 Table 4.2: CFD analysis of shell and tube heat exchanger output with fins.

output with fills.										
velocity m/s	0.85		1.25		1.75					
	Water	Oil	Water	Oil	Water	oil				
Shell inlet K	393	393	393	393	393	393				
Shell outlet K	390.	389.9	389.7	389.5	389.4	389.				
Tube inlet K	308	308	308	308	308	308				
Tube outlet K	364.	372.6	356.1	364.2	347.3	352.5				

Table 4.1 and 4.2 shows results of CFD analysis of shell and tube heat exchanger with and without fins by comparing both results it is evident that tube side outlet temperature with fins has higher temperature than that of without fins . And with castor it has better heat transfer than water. This is due to better thermal properties of castor oil than the water.

5. Conclusions

An investigation was carried out to study the shell and finned tube heat exchanger computationally using ANSYS fluent 13.0. The geometric modeling of the shell and tube heat exchanger is done by using ANSYS design modeler. And CFD meshing is carried out using ANSYS meshing. The analysis is carried out and pressure drop and temperature rise along the tube surfaces has been investigated. Based on the obtained result it can be concluded as follows;

- Temperature variation with same velocity for castor oil and water is greatly noticeable. This is due to better thermal properties of castor oil than the water.
- Better effectiveness can be achieved by using castor oil as heat transfer fluid. The effectiveness of the finned tube heat exchanger is quite comparable with other conventional heat exchanger.
- Energy extraction rate is also quite significant .that means a sufficient amount of heat can be recovered by using the finned tube heat exchanger.

6. Future Scope of Work

- CFD provide alternative to cost effectiveness speedy solution to heat exchanger design and optimization.
- Conventional methods used for the design and development of Heat Exchangers are expensive.
- CFD results are the integral part of the design process and it has eliminated the CFD is still a developing art in prediction of erosion/ corrosion due to lack of suitable mathematical models to represent physical process. New flow modeling strategies can be developed for flow simulation in shell and tube heat exchanger

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