Optimization of fin thickness used in heat exchanger through Computational fluid dynamic Analysis

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Abstract

The performance of heat exchanger is depending on different parameter. The design of heat exchanger depends on the use, area availability, space required, and rate of heat transfer and depends on the working fluid. In order to increase the performance of heat exchanger different input parameters and boundary conditions were enhance or optimize. In order to increase the heat transfer rate different flow pattern were used. Here in this work tube type heat exchangers are selected for the present research it has a plain finned tube configuration. Hot air coming from compressor flows across the tube bank while here in this analysis cold fluid that may be fuel oil flows inside the tubes. The two configurations have the same tube geometry which is a staggered tube arrangement.it numerically investigates the heat transfer and pressure variation characteristics of such exchangers with consideration of the air property variability which caused the air temperature changes. Here it also analyzed the effect of fin thickness and for that here it considered three different fin thicknesses.

1. INTRODUCTION

A heat exchanger is a device used to transfer heat between a solid object and a fluid, or between two or more fluids or gases. It is device in which heat is transferred from one fluid to another fluid .the hot fluid gets cooled, and the cold fluid is heated. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. Many of the heat exchanger models have been designed forlarge-scale power plants and refrigeration systems. For small-scale applications characterized by highly dynamic conditions, e.g. automotive applications, only a few studies have been reported. A dynamic heat exchanger model has been developed and validated for a passenger car application. The model represents a tube-finned heat exchanger based on the MB principle. The studied heat exchanger is non-modular meaning the two flows travel the complete heat exchanger length uniformly. In contrast, we consider a modular heat exchanger design, in which the working fluid side is divided into three sections called modules. These modules are shifted along the heat exchanger length to improve the heat transfer between the flows and to avoid high temperatures in the wall material. In such a design, multiple phase transitions in a singlepipe flow can occur, especially during transients. As a result, the modeling of modular heat exchangers using only the MB approach is not straightforward.

1.1 Leoni et.al. This work presents an analysis of the shell side flow in a shell and tube heat exchanger usingComputational Fluid Dynamics (CFD). The heat exchanger has been designed with the software HTRI Xchanger Suite,while CFD simulations have been performed with the computational. Starace et.al. Despite their limitations, the cross flow compact heat exchangers are generally modeled by the e-NTU and LMTD methods and this mainly leads to the absence of effective consideration on the heat transfer geometry at the micro scale. Quintero et.al.Multilayered, counter flow, parallel-plate heat exchangers are studied theoretically and numerically. The analysis, carried out for constant property fluids, assumes a fully developed laminar flow with moderately large Peclet numbers in the flow channels, so that longitudinal conduction can be neglected in the fluids in first approximation. Gómez et.al.The present paper presents a theoretical analysis of a cross flow heat exchanger with a new flow arrangement comprehending several tube rows. The thermal performance of the proposed flow arrangement is compared with the thermal performance of a typical counter cross flow arrangement that is used in chemical. Starace et.al. Despite their limitations, the cross flow compact heat exchangers are generally modeled by the e-NTU and LMTD methods and this mainly leads to the absence of effective consideration on the heat transfer geometry at the micro scale.

2.Material Used

For the initial analysis it has taken the material same as that of taken by Lingdong et.al [1]. So here is considering the GH3044 alloy (Fe-25Ni-15Cr) is chosen as the fin material, whose thermal conductivity is set as 14.2 W/ (m^2-K). The material properties of GH3044 is shown in the below table

Table.1 Properties of material GH3044

Properties	values
Density	8.89 g/cm^3
Specific heat	440 J/kg-k
Thermal conductivity	11.7 W/m-C

3.CFD Model

In order to develop the CFD model of the heat exchanger analysis different sub method or steps have to be performed. Different steps required for the development of CFD model is perform in this section. To increase the performance of heat exchanger used in aero engines here in this work it find out and calculate the effect of change in thickness of fins used for heat transfer. It takes three different thickness that is 0.07, 0.1, 0.2 mm and find out the optimum thickness of fins for increase the temperature drop.

3.1 Solid Model

In order to achieve the above objective here first it has to develop the solid model of heat exchanger based on the geometry used given in Lingdong et.al [1] the geometric specification of heat exchanger used in the analysis is defining the tube bank configurations include the tube outside diameter (D), transverse tube pitch (P_t), longitudinal tube pitch (P_l), and number of tube rows (N). They are taken to be D = P_l = 3.0 mm, P_t = 6.0 mm and N = 12 in this research. The plain finned tube configuration involves additional parameters including the fin pitch (F_p) and fin thinkness (d_f), which are specified to be F_p = 1.1 mm and d_f = 0.1 mm. due to the periodicity and symmetry of the heat exchanger geometry for numerical analysis it considered the two dimensional that is 2D airflow passage as shown in the fig. here the solid model of the heat exchanger is prepared in the design modular of Ansys.

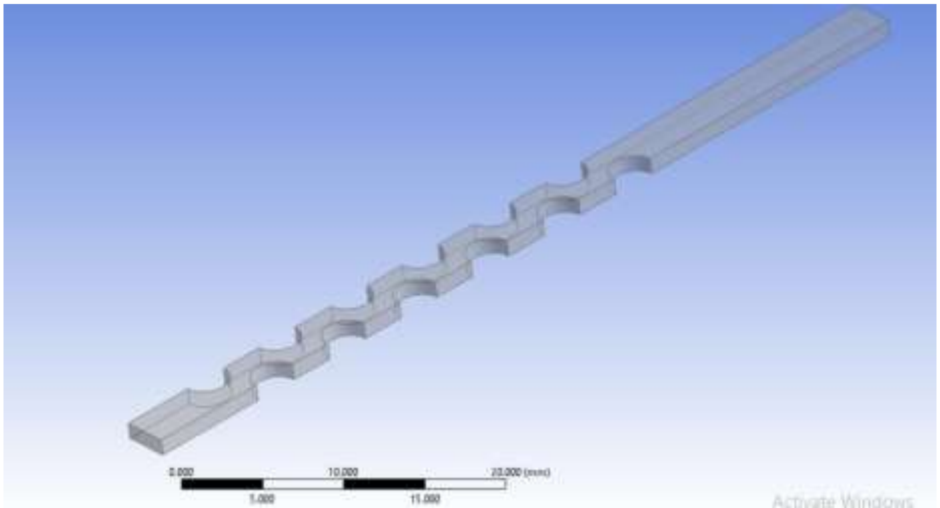

Fig.1Geometric 2D model used for analysis

3.2Physical Properties

Air coming from the compressor and entering the heat exchanger in the aero engine operation assume to operate at altitude of 11 km and flies at mach 0.8 as given in Lingdong et.al [1]. During the analysis it considered the local atmospheric temperature and pressure that is calculated as 216.65 K and 22.63 kPa[17]. The inlet total pressure recovery coefficient is assume to be 0.97, the compressor compression ratio considered during the analysis is 25, the compressor efficiency is 0.90, and the air adiabatic index is 1.4, the air temperature and pressure at the inlet of heat exchanger is considered to be same as those at the compressor outlet, and it is considered as 653.99 K and 0.84 MPa.

3.3 Meshing

After developing the solid model of given geometry, it is then discretizing in to number of elements and node because the numerical analysis is completely depends on the number of elements and number of nodes.

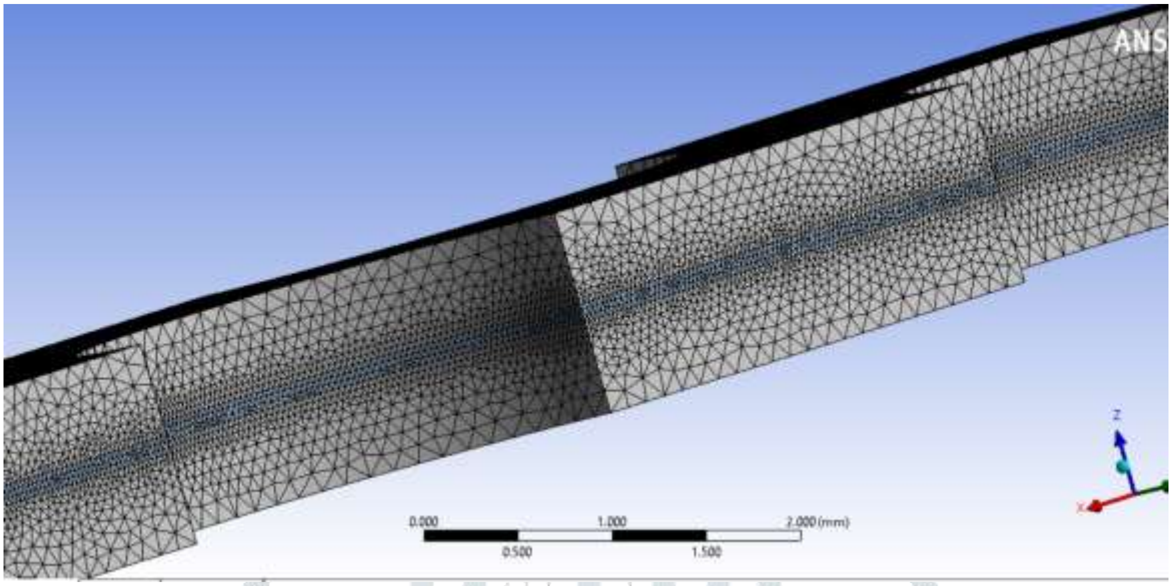

Fig.2 Front view of the meshed solid model

After analyzing the mesh with different number of element and finding the temperature of air at the exit it is observed that the property of heat transfer is independent of number of element in mesh. There is a slide variation in the temperature of air which is not that much of concern.

3.4 Boundary Condition

Here in this analysis the frontal air entering the heat exchanger is at different speed because it considered four different velocity of air that is 5, 10, 15 and 20 m/s. but for the initial analysis it is taken as 10 m/s. and the pressure is near about 0.84 MPa. The input of boundary condition in to the numerical analysis is shown in the fig; the temperature of air at the inlet of heat exchanger is 653.99 K.

4. Result

After finding out the effect of material on the heat transfer rate, here it has also analyzed the effect of tube fin thickness on the heat transfer rate and the temperature of heat exchanger. In order to find out the effect of fin thickness, here it considered the three different fin thicknesses solid model and find out the temperature of air at the exit. Here it considered 0.07, 0.1 and 0.2 mm thickness fin during the numerical simulation. Model having fin thickness 0.1 is already analyzed in chapter four.

4.1 Fin having 0.07 mm thickness

In this section of analysis here it considers the solid mode of computational domain having the fin thickness 0.07 mm. To find out the effect of thickness analysis were performed on this model and then temperature of air at the exit is calculated. The temperature contour for this model analysis is shown in the fig. during the analysis of this model velocity of frontal air is taken as 10 m/s and the other boundary conditions is same as that of case 1 in chapter 4 and the material is GH3044.

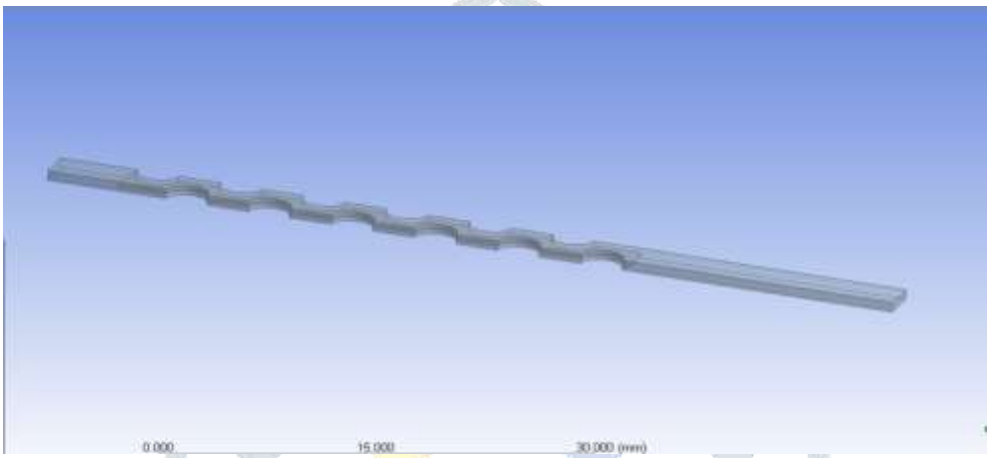

Fig.3 Solid model of computational domain having fin thickness 0.07 mm

During the analysis of this model only thickness of fin get change whereas the thickness of Computational fluid domain cannot change and it remains constant as 1.1 mm

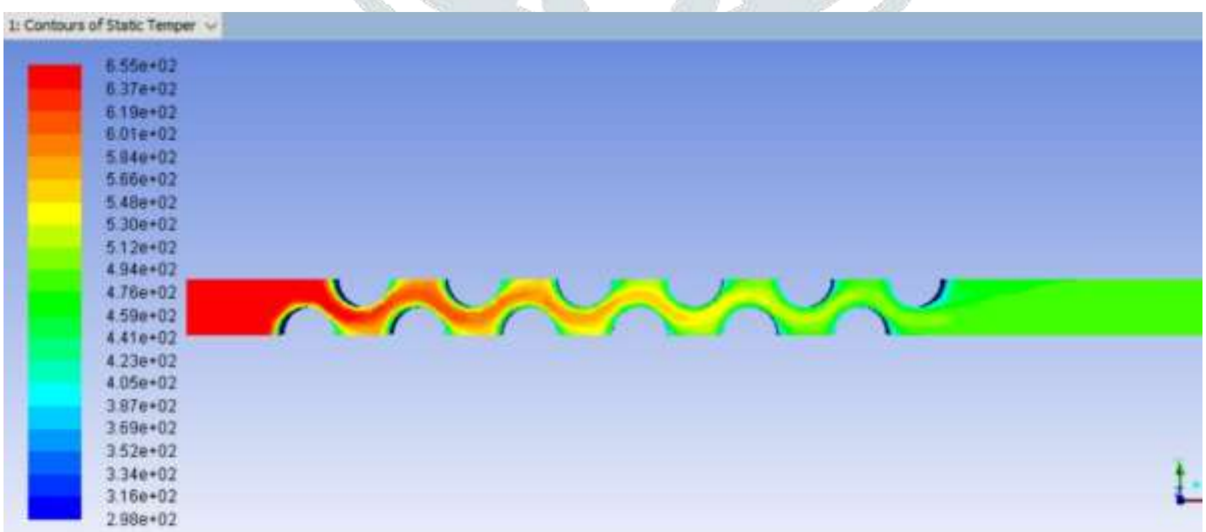

Fig.4 Contours of temperature at model having fin thickness 0.07 mm

The temperature of air at the exit for fin 0.07 mm is near about 460 K. After analyzing the above case having fin thickness 0.07 mm it is observed that as the thickness if fin decreases the temperature of air at the exit get increased, which means the reduction of fin thickness reduces the heat transfer rate.

4.2 Fin having 0.2 mm thickness

Here in this model the computational domain have fin of thickness 0.2 mm. whereas the material and boundary conditions were same as considered for model having fin thickness 0.07 mm. it calculate the temperature of air at exit. The contour plot of temperature for this domain is show in the fig. 5.8

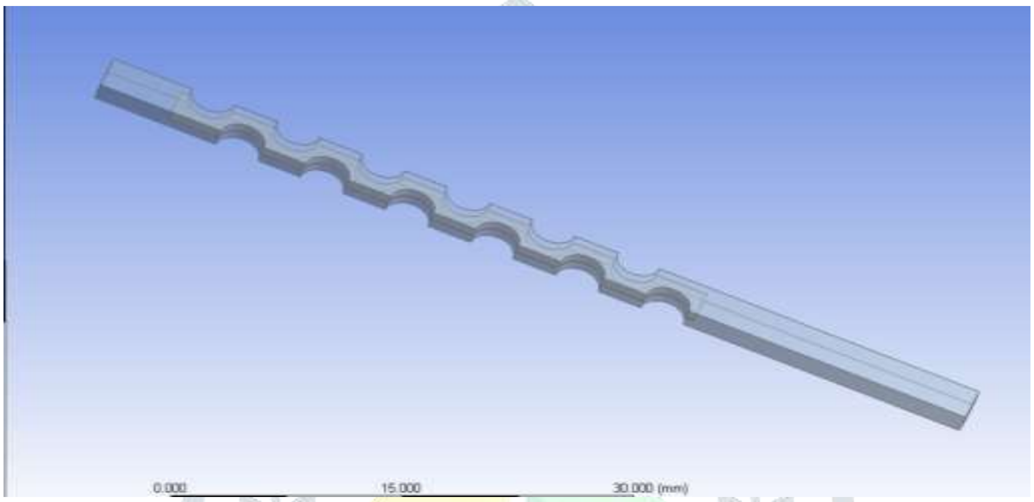

Fig.5 Solid model of computational domain having fin thickness 0.2 mm

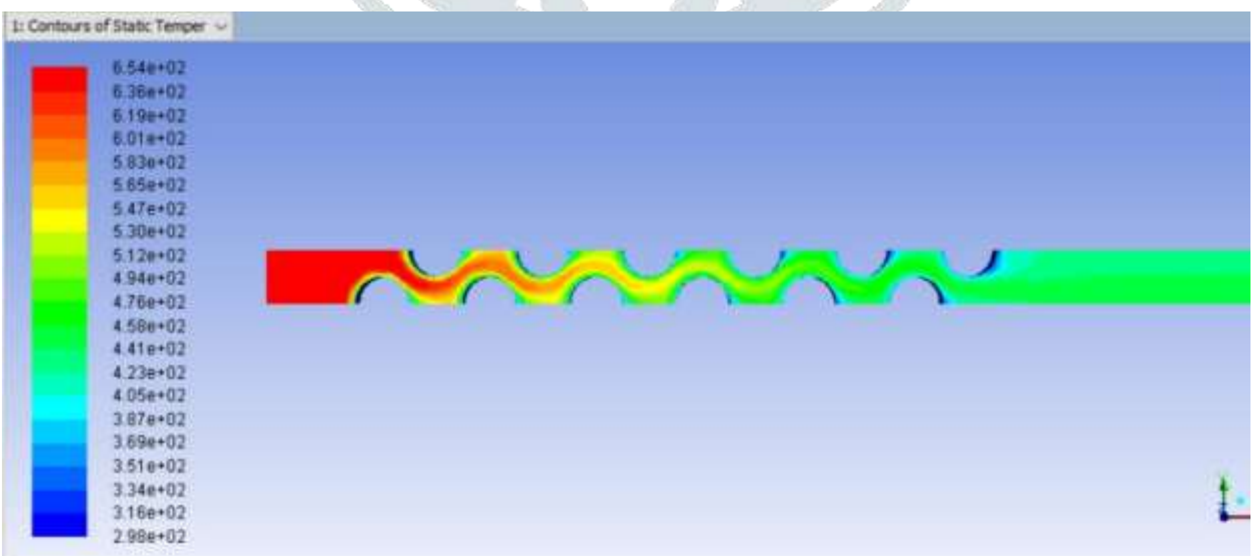

Fig.6 Contour of temperature having fin thickness 0.2 mm

The temperature of air at the exit of heat exchanger is near about 439 K. which is less as compare to the fin having thickness 0.07 mm and 0.1 mm. so it is analyzed that as the thickness of fin increases up to certain limit the heat transfer rate get increased and as thickness get decrease the heat transfer rate get also decrease.

4.3 Comparison of Model having Different Fin Thickness

In order to optimize the fin thickness here it compares the entire model having different fin thickness as find the best one.

Table.2 Comparison of temperature for model having different fin thickness

S.N	Thickness of Fin (mm)	Temperature of air at the exit
1	0.07	460
2	0.1	444
3	0.2	439

5. Conclusion

From the above table 2 it is concluded that the temperature of air is minimum in the case having fin thickness 0.2 mm, where as it is maximum in the case having fin thickness 0.07. Here it is analyzed that as the thickness of fin decreases the temperature of air get increase and as the thickness get increased the value of temperature get decrease. With the help of this analysis it can predict the material which is best suitable for the heat transfer without doing any experimental work. It also helps in the design of heat exchanger. After finding out the effect of material it also analyzed the effect of fin thickness on heat transfer or temperature variation. To observe the variation here it consider three different fins having thickness 0.07, 0.1, 0.2 mm. through analysis it is find that as the fin thickness decreases the temperature of air get increased whereas as the thickness of fin increases air temperature get reduce. Due to the above analysis of material and thickness variation design of heat exchanger get optimize during designing.

6. References

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