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CFD ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER FOR PRE-HEATING OF BIODIESEL

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ABSTRACT

The objective of this work is to improve the performance characteristics of a high viscous non-edible vegetable oil as alternative fuel to diesel fuel. The pre-heating process of fuel is used to reduce the viscosity of high viscous fuels. A double pipe heat exchanger is used to operate using the heat of engine exhaust. A bypass valve is used to control the mass flow rate of exhaust gas to heat exchanger. A single cylinder diesel engine is used for testing. The necessary arrangements are done to attach the heat exchanger to engine. The engine is tested with biodiesel. The heat exchanger design is made using CATIA V5 software. The heat exchangers are analyzed using ANSYS FLUENT. The results are compared and the suitable heat exchanger is proposed.

Keywords: Preheating, heat exchanger, CFD simulations, double pipe heat exchanger.

I. INTRODUCTION

The fossil fuels are our main source for producing energy. The rapid depletion of usage of fossil fuels has initiated many to find other forms of sources. Not only that, the side effects of using fossil fuels like global warming has also made us to look for an Eco-friendly source. There are lot of options to consider like solar, wind, hydro, etc. But among, these one of the major source is bio fuels. These oils have similar properties to diesel fuel and have high cetane value and produce low emissions compared to the traditional fuels. It can be produced easily and relatively faster compared to the fossil fuels which take centuries to be produced.

Though bio fuel seems to be a viable replacement for the traditional fuels but there is a problem of high viscosity when compared to that of diesel and petrol. Due to this high viscosity, the mixing of fuel and air wouldn't take place properly which results in improper combustion, ignition delay period and poor cold start-up of the engine. The previous study on the increasing the temperature and its effect on the fuel properties and engine performance are determined [1 -5]. The heat exchanger in the solar collector to absorb the heat energy are discussed by Senthil and Cheralathan [6-10]. The storage integrated solar system is discussed by Arunasalam et al. [11].

Different heat exchanger and storage for the solar thermal systems are discussed [12 -16]. In this work heat exchanger is designed for preheating of the alternate fuels so that its viscosity can be further reduced. The reduced viscosity of oil may decrease the pump work and better atomization of fuel. The CFD simulation of shell and tube heat exchanger is designed and tested in the ANSYS-FLUENT and the results are reported.

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II. DESIGN OF HEAT EXCHANGER

Preheating vegetable oil is done by using a shell and tube type heat exchanger. The exhaust of the engine is sent into pre-heater where hot exhaust gases circulate around a tube containing no edible high viscous fuel. As copper had thermal conductivity it is used for tube. The shell should be strong enough to withstand high temperature and pressure of exhaust gases, and have strong sheet metals like stainless steel is used. We will insulate the shell by air gap.To design heat exchange following data is required:Temperature of engine exhaust which varies from 130 °C to 470 °C. Mass flow rate of fuel is 0.127 to 0.35 gm/sec. Exhaust flow rate 8 to 10 gm/sec. Temperature of oil heated is 30 °C to 100°C.Properties of neat oils such as viscosity, density and calorific value are determined with the suitable tests.Tube material for oil is copper and heat exchanger is made of 316 grade stainless steel.Based on the engine requirement the shell tube diameter was selected to be 38 mm, the tube inner and outer diameter was taken as 5mm and 6mm. Shell material is stainless steel and tube material is copper.Calculation of Reynolds number was carried out. But the Reynolds number is greater than 2300. Hence, we used the Dittus-Boelter correlation. CFD Post Processing Result Heat Dissipation for the respective heat exchangers are shown in Figures 1 – 5.

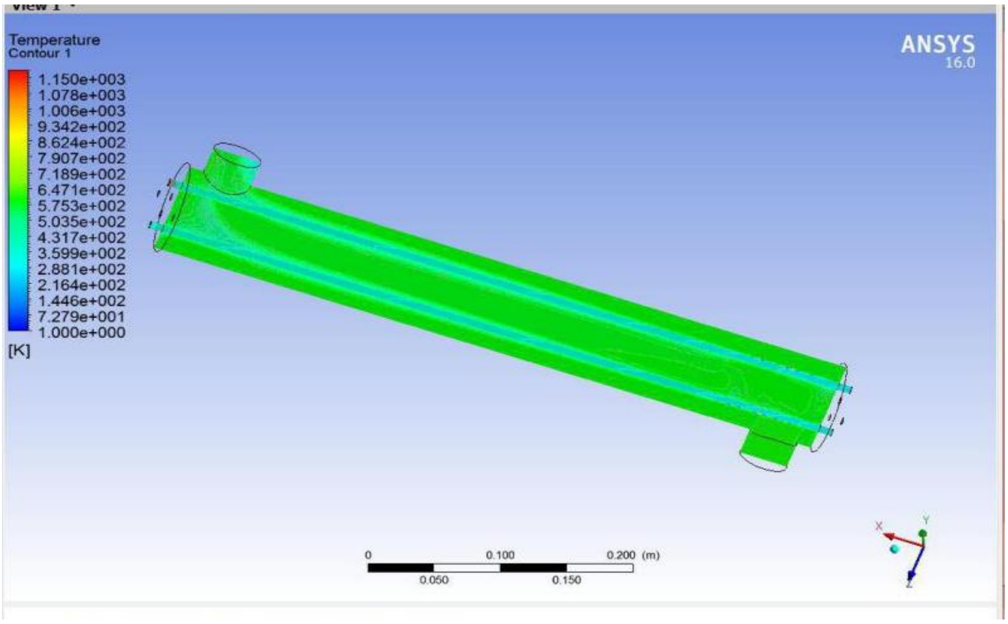

Fig.1. Heat Dissipation for Multi Pass Heat Exchanger

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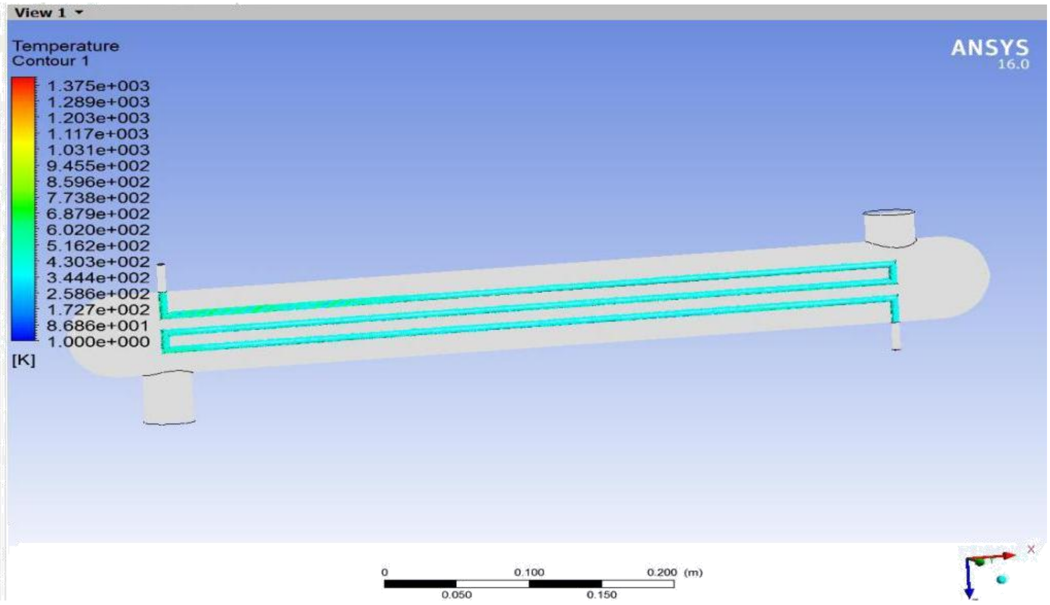

Fig.2.Heat Dissipation Single Pass Parallel Flow

The heat transfer coefficient was found to be 44.265 W/m^{2}K.Tube side heat transfer coefficient is found similarly. Since, the flow inside the tube is laminar, Nusselt number is fixed and as the heat transfer is assumed to be constant heat flux, heat transfer coefficient from this is 131.76 W/m^{2}K.The overall heat transfer coefficient is 31.5428 W/m^{2}K. The LMTD for this type comes out to be 252.65 C Then, the heat transfer rate q is found out to be 72 W. Hence, the length of the tube is found out to be 53cm.The input conditions for each and every design are same so that the different tubescan be studied and compared.The input conditions are inlet temperature of gas is 600 K and air temperature is 300 K.

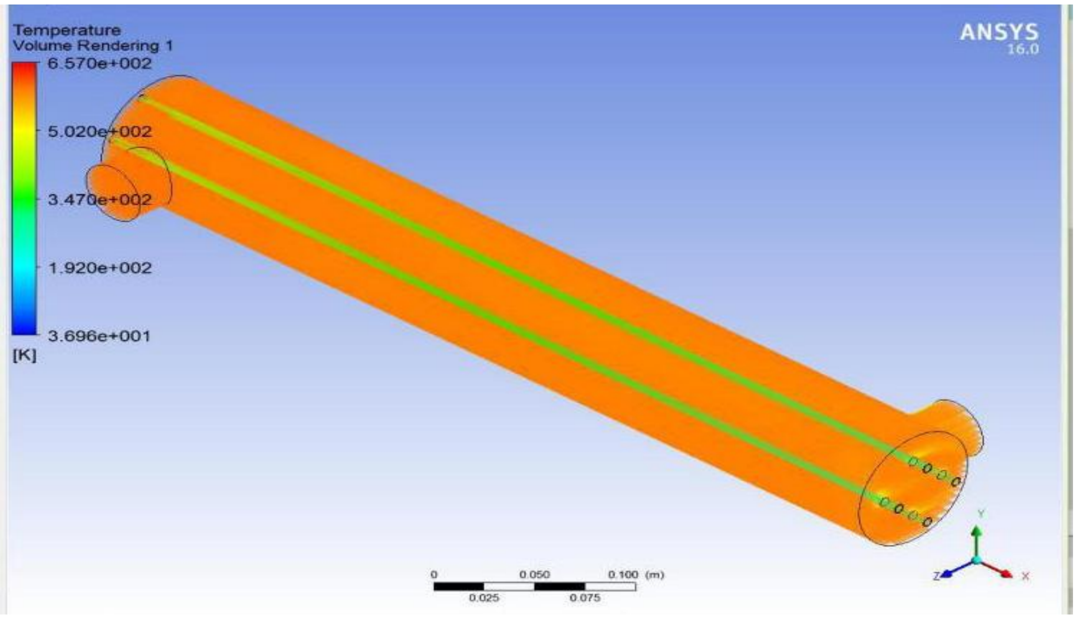

Fig. 3. Heat Dissipation Single Pass Counter Flow

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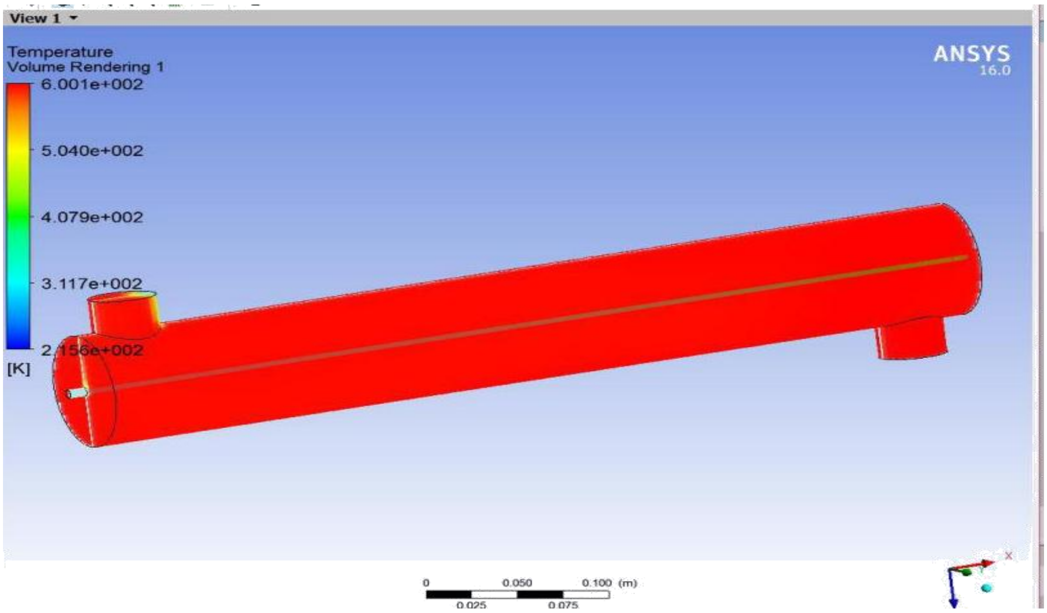

Fig. 4. Heat Dissipation for Counter Flow Heat Exchanger

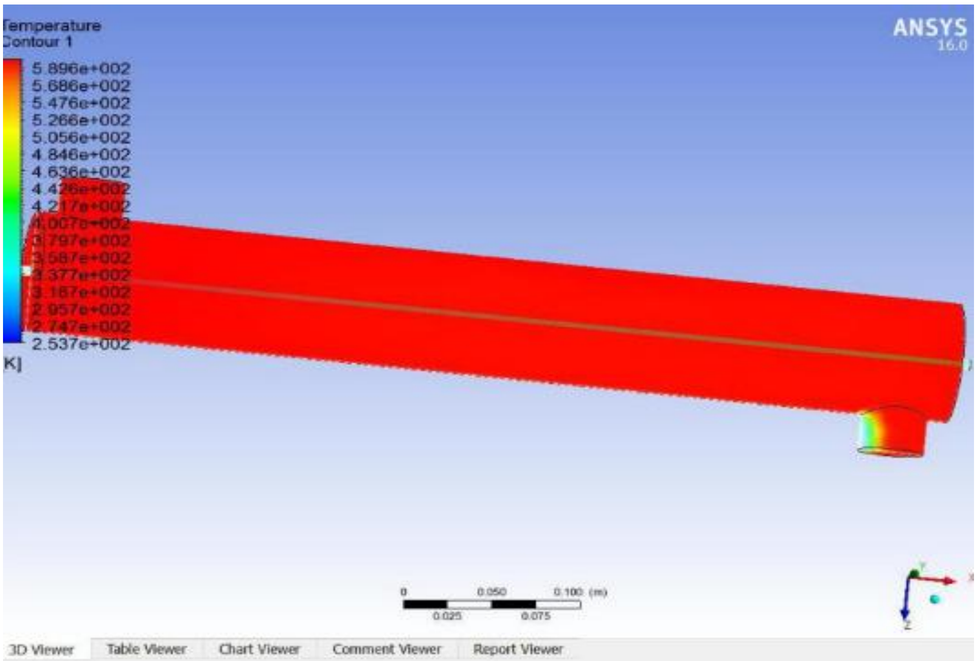

Fig. 5. Heat Dissipation for Parallel Flow Heat Exchanger

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Table 1. Heat dissipation results of heat exchangers

Type of heat exchangers	Point at which temperature is measured	Measured temperature
Multi-pass	Cold inlet - outlet	305K -407 K
	Hot inlet - outlet	600K – 492 K
Single pass parallel flow	Cold inlet 1 -4	312K
	Cold outlet 1 -4	340K
	Hot inlet – outlet	600K -534 K
Single pass counter flow	Cold inlet 1-4	303K
	Cold outlet 1-4	341K
	Hot inlet - outlet	600K -534 K
Counter flow	Cold inlet	309K
	Cold outlet	348K
	Hot inlet - outlet	600K – 553 K
Parallel flow	Cold inlet -outlet	313K -345 K
	Hot inlet - outlet	600K -542 K

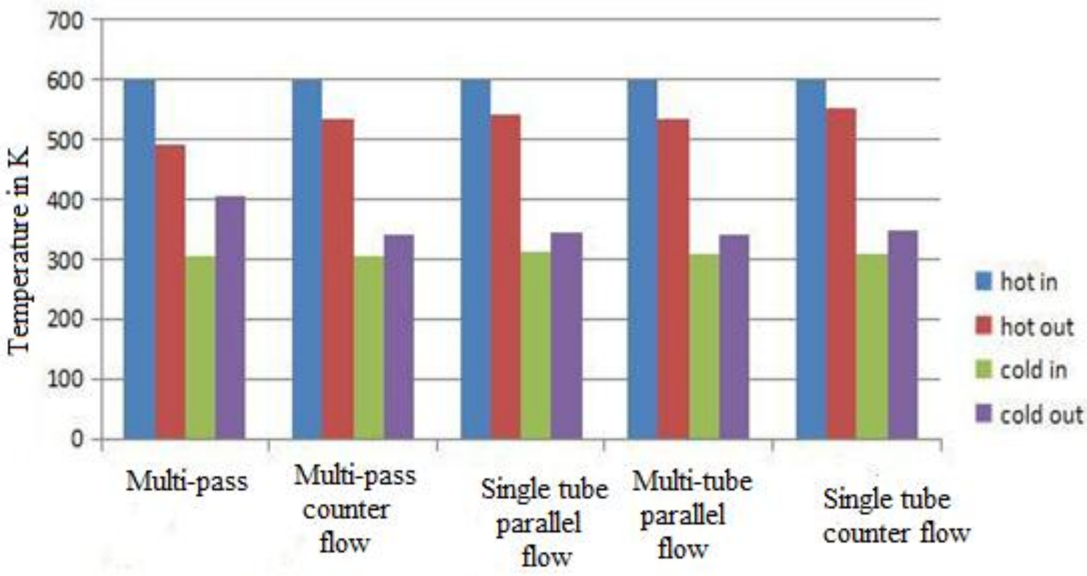

Fig.6.Comparison of Heat Distribution from all the Heat Exchangers

From the Table 1 and Figure 6, the shell tube with multi pass heat exchanger is found to be the most efficient as the temperature of the cold fluid coming out is maximum when compared to the other types of heat exchanger. The preheating of high viscous oil in a heat exchanger improves the fluidity of the oil and the increased temperature is useful in the efficient combustion in the engine. Such process is useful in the reduction of unburnt biodiesel fuel too.

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III. CONCLUSIONS

As the temperature of the bio diesel coming out is increased, the viscosity will be reduced and hence it'll have better combustion rate than bio diesel without any preheating.After performing many experiments on the heat exchangers available, we have come to an understanding that the multi-pass shell and tube heat exchanger shows comparatively better results. The maximum temperature difference observed in the bio diesel that flows in the shell and tube heat exchanger. With maximum change in temperature, significant change in the viscosity would occur. The pre-heated temperature and lower viscosity, the performance of engine is likely to improve. This is observable only when steady state is reached, as the same fuel is used initially ready for the combustion in the engine.

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