ANALYSIS OF HEAT EXCHANGER FOR AUTOMOBILE THERMOELECTRIC GENERATOR

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Abstract*—Thermoelectric generation (TEG) technology can recover waste heat from the exhaust and convert thermal energy into electrical energy with the advantages of being highly reliable, zero emission, low noise and involving no moving parts. Heat exchanger play important role in this technology, in which thermoelectric modules place on the heat exchanger and the efficiency of the heat exchanger is depend upon the thermal characteristics of heat exchanger with various heat transfer enhancement features such as different internal structure of the heat exchanger. In order to achieve uniform temperature distribution and higher surface temperature, the characteristic of the heat exchanger with enhancement features are studied in this paper, Simulation results show that a plate-shaped heat exchanger with inclined-plate internal structure achieves relatively ideal performance.

***Index Terms*— Heat exchanger, CFD simulation, internal structure.**

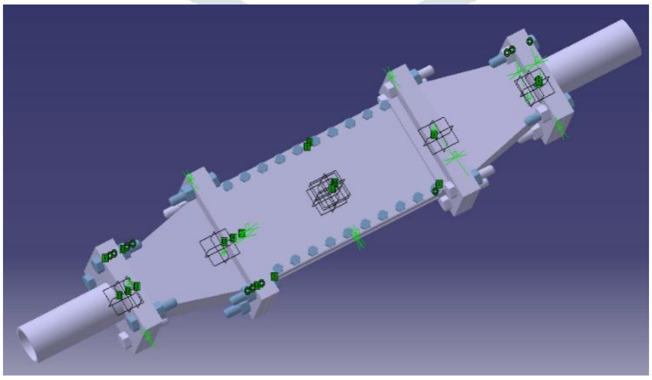
I. INTRODUCTION

In recent years, because of the forecast limitations in oil supply and increasingly stringent vehicle exhaust gas emission regulations such as Euro 6, new energy technologies are being developed to improve fuel efficiency and reduce emission; examples include hybrid vehicles as well as those powered by fuel cells and hydrogen [1]. Approximately 40% of the fuel energy is lost in exhaust gas according to energy balance of a combustion engine, which intense the energy crisis and environment pollution. [2]. As one way to recover waste heat, Thermoelectric generation (TEG) technology can recover waste heat from the exhaust and convert thermal energy into electrical energy with the advantages of being highly reliable, zero emission, low noise and involving no moving parts.[3].

Y. D. Deng et al. The thermal performance of the heat exchanger in exhaust-based TEGs is studied in this work. In terms of interface temperature and thermal uniformity, the thermal characteristics of heat exchangers with different internal structures, lengths, and materials are discussed. [7]. S. Chen et al. optimized the thermal performance of the heat exchanger in exhaust-based TEG. In terms of interface. Temperature and thermal uniformity, the thermal characteristics of the heat exchangers with different internal structures, materials and thicknesses were discussed. CFD [8]. C. R. Kumar et al. studied different shaped of the heat exchanger and also revealed that energy can be tapped efficiently from the engine exhaust and in near future thermoelectric generators can reduce the size of the alternator or eliminate them in automobiles [9]. X. Liu, et al. tried to vary the installation position of TEG and propose three different cases. Case 1: TEG is located at the end of the exhaust system; case 2: TEG is located between CC and muf; case 3: TEG is located upstream of Catalytic Converter and muffler. They developed to compare thermal uniformity and pressure drop characteristics over the three operating cases [10].

II. MODEL DESCRIPTION

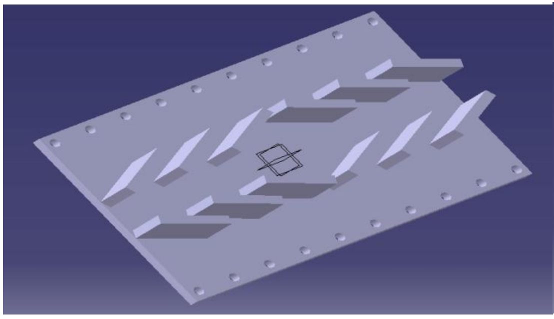
Based on the theories of thermal convection, heat conduction and turbulent flow, three-dimensional models of heat exchanger with different internal structures were designed by arranging internal baffles. Fig. 1 shows the diagram of heat exchanger which extracts waste heat energy.



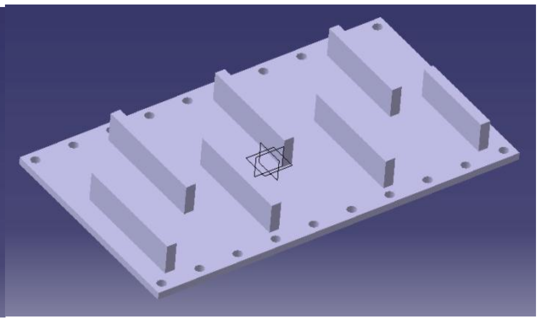
"Fig. 1" Heat exchanger model

Different Internal Structures of the Heat Exchanger.

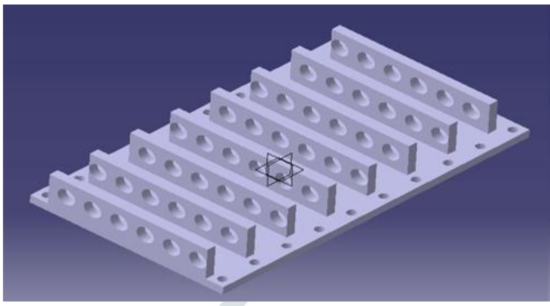
The different internal structures will be used in the heat exchanger to enhance heat transfer rate as shown in fig as given bellow. The internal structure of the heat exchanger made up of aluminium of 5 mm thickness, fin thickness is also 5 mm and 20 mm height made up of aluminium. According to the position of the fins on the plate it is divided into number of internal structure such as inclined plate structure, Fishbone-shaped structure, Serial plate structure, Separate plate with holes, Dimple structure, and Accordion-shaped structure.



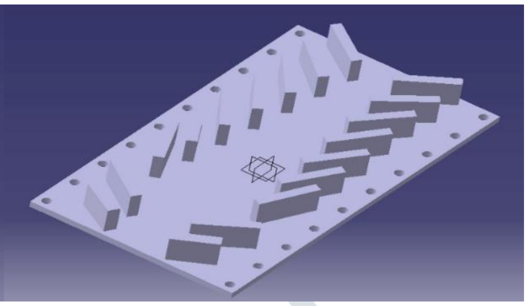
"Fig. 2" Inclined plate structure



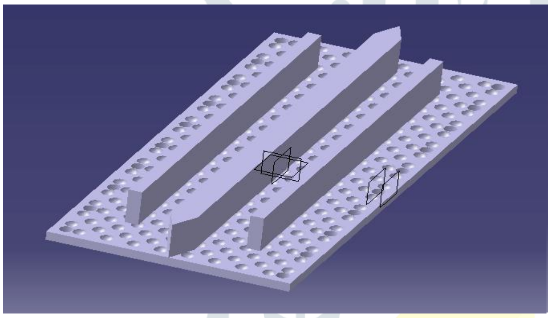
"Fig. 3" Serial plate structure



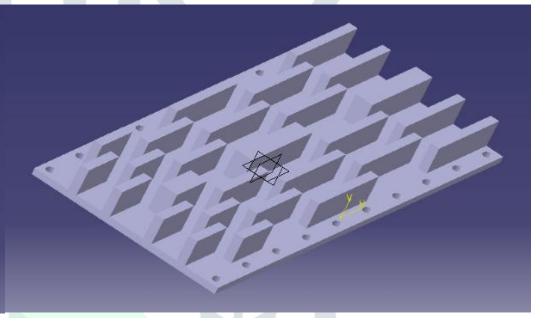
"Fig. 4" Separate plate with holes



"Fig. 5" Fishbone-shape structure



"Fig. 6" Dimple surface structure



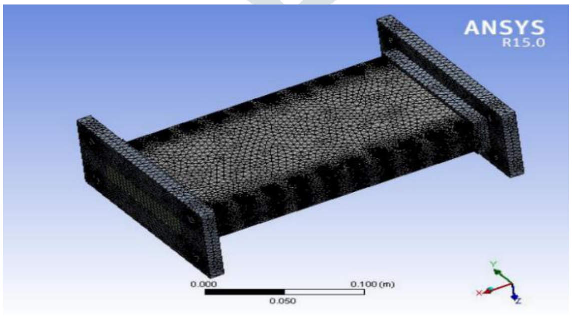
"Fig. 7" Accordion-shaped structure

III. SIMULATION ANALYSIS OF HEAT EXCHANGER

Typical software for analyzing turbulent mechanics, i.e., computational fluid dynamics (CFD), was used to simulate the exhaust gas flow within the heat exchanger, enabling simulation of the interface temperature distribution [13]. The ideal thermal field simulation results can be obtained by altering the internal structure of the heat exchanger.

Boundary conditions

Gas in the gas tank is incompressible, the flow is fully turbulent, and the molecular viscosity can be negligible in the simulation model. All of these are in line with the applications of k–ε turbulence model equations.

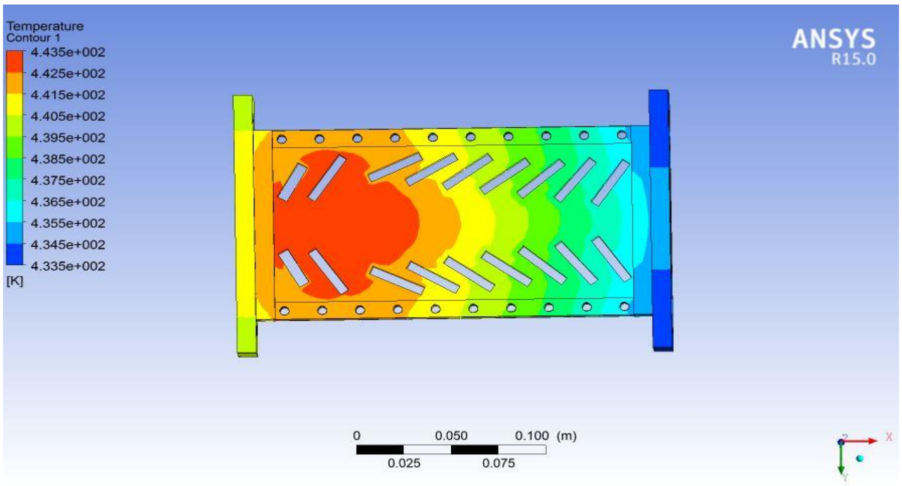


"Fig. 8" Middle part of inclined-plate heat exchanger (meshing model)

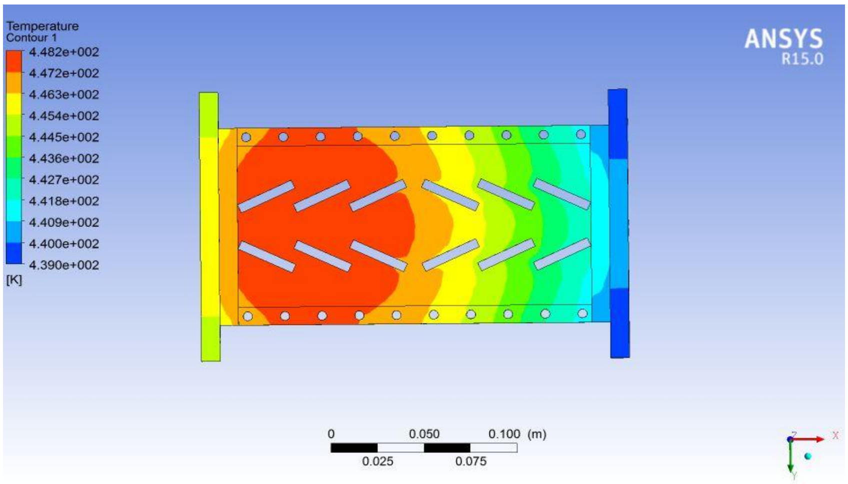
The main boundary conditions of simulation are as follows: The temperature of inlet gas is 300°C, the flow speed is 5 m/s, the back pressure of the outlet is 1 bar, the coefficient of the convective heat transfer h between the outer surface of the gas tank and the air is 10 W/m^2K

Temperature distribution on the heat exchanger with different internal structures

According to the theories of thermal convection and turbulent flow, the kinds of three-dimensional models of the internal structure of the heat exchanger is designed by changing internal baffles arrangements. Among these, the temperature distribution in the second structure (the inclined-plate) is relatively ideal, as compare to first structure (the fishbone shape).



"Fig. 9" Simulation of the heat exchanger with fishbone-shaped structure

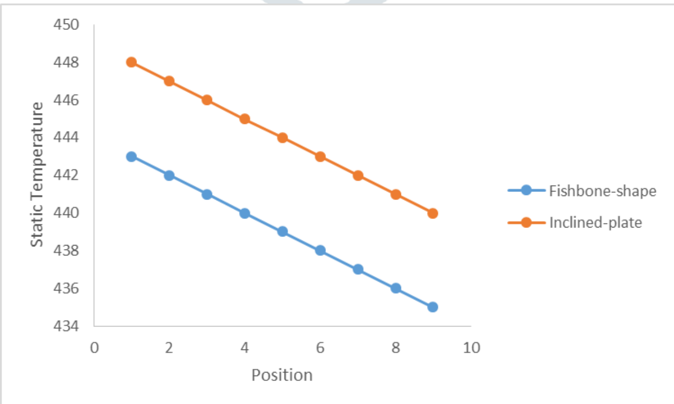


"Fig. 10" Simulation of the heat exchanger with inclined-plate structure

Considering even temperature distribution, the heat exchanger with baffles is more suitable for TEG. Although with this simulation results, the heat exchanger with the internal structure of the shape has a quite high temperature.

IV. RESULT AND DISCUSSION

Simulation result shows that, the surface temperature of the inclined-plate internal structure which used in heat exchanger is an average about 170^{o}C while the surface temperature of fishbone-shape internal structure is 165℃. So, by comparing the surface temperature of fishbone-shape internal structure is less than inclined-plate internal structure. Figure 11 presents the temperature distribution on the surface domain of the two configurations, with fins.



"Fig. 11" Temperature distribution comparison.

V. CONCLUSION

In this paper the thermal characteristics of heat exchanger with various heat transfer enhancement features are studied. Simulation results of the heat exchanger with inclined-plate internal structure shows an uniform temperature distribution over the surface of heat exchanger than fishbone-shape heat exchanger. The internal structure of the heat exchanger creates turbulence in fluid flow, which can improve overall thermal performance of the heat exchanger which is integral part of thermoelectric generator.

The current study focusses on the internal structure of the heat exchanger to improve effectiveness of the heat exchanger. In the later study the way of simulation modeling and experimental evaluation of a heat exchanger.

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