Analysis of Internal Structure used in Heat Exchanger

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Abstract: Today everywhere pollution is occurring due to continuous increasing number of vehicles, so that reduced that pollution and recover the waste heat from the exhaust which is present in the atmosphere. As one way, 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. In order to achieve uniform temperature distribution and higher interface temperature, the characteristic of the heat exchanger with enhancement features are studied in this paper, such as different internal structure of the heat exchanger. Simulation results of the heat exchanger with internal structure shows an uniform temperature distribution over the surface of heat exchanger than empty 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.

Keywords: **Automotive exhaust, Heat exchanger, Thermal characterization, CFD simulation.**

I. INTRODUCTION

In current 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 hydrogen as well as those powered by fuel cells and hybrid vehicles [1]. According to energy balance of a combustion engine near up to 40% of the fuel energy is lost in exhaust gas, 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 benefits of being highly secure, zero emission, low noise and including no moving parts.[3].

In order to receive higher thermoelectric efficiency and generation capability, the heat exchanger's geometry, mounted location, contact area with thermoelectric modules; operating conditions and so on were optimized by numerical analyses and experiments. C.Q. Su et al. studied to achieve higher interface temperature and uniform temperature distribution, the thermal characteristics of heat exchangers with various heat transfer enhancement features, such as internal structure, material and surface area. [4]. Shengqiang Bai et, al. designed six different exhaust heat exchangers within the same shell, and they also designed computational fluid dynamics (CFD) models to compare heat transfer and pressure drop in typical driving cycles for a vehicle with a 1.2 L gasoline engine.[5]. X. Liu. et al. Studied the thermal performance of different heat exchanger in exhaust based TEGs. They discussed the thermal characteristic of heat exchangers with a different internal structure and thickness. They also carried out CFD simulations, Infrared experiments and output power testing on a high performance production engine with a dynamometer. [6].

Y. D. Deng et al. The thermal performance of the heat exchanger in exhaust-based TEGs studied in this work. In terms of interface temperature and thermal uniformity, the thermal characteristics of heat exchangers with lengths, different internal structures, 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 handled 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 forthput 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 signature over the three operating cases [10].

II. 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.

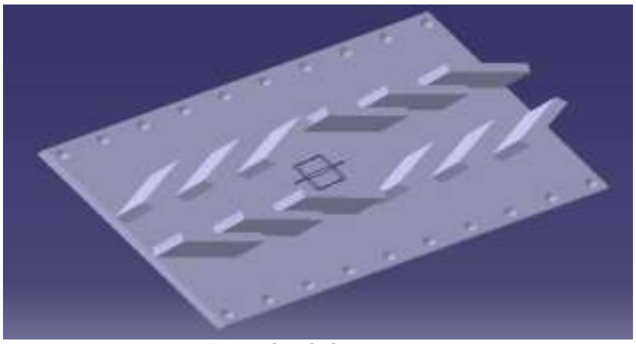

Fig.1 Inclined plate structure

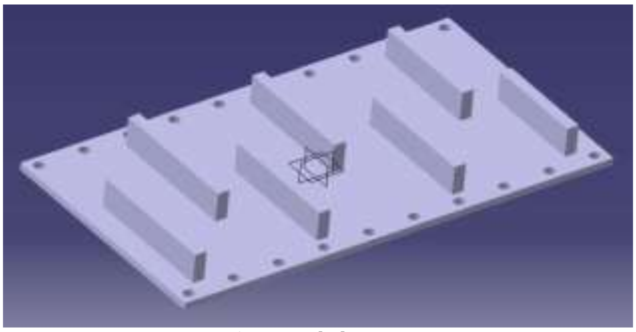

Fig.2 Serial plate structure

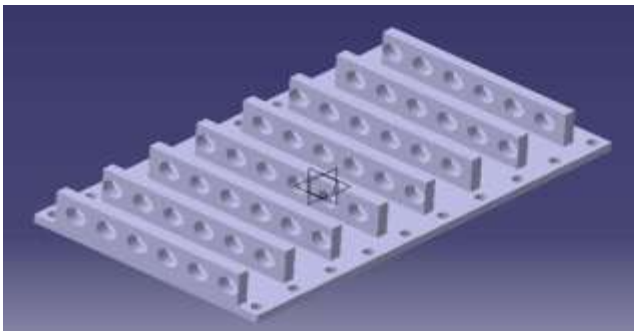

Fig.3 Separate plate with holes

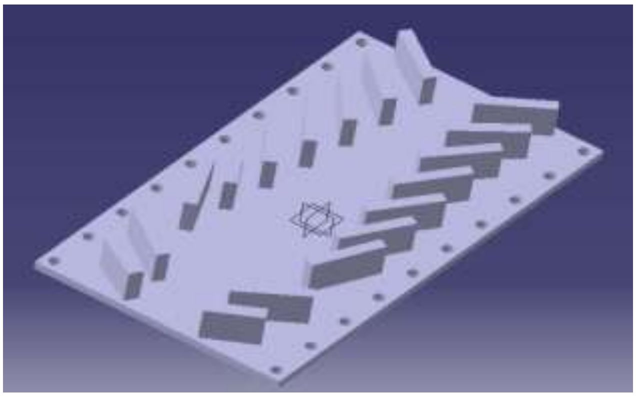

Fig.4 Fishbone-shape structure

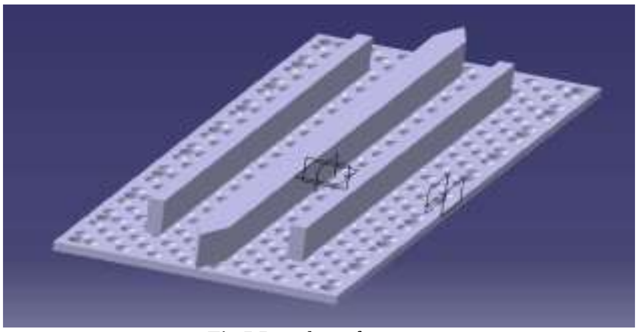

Fig.5 Dimple surface structure

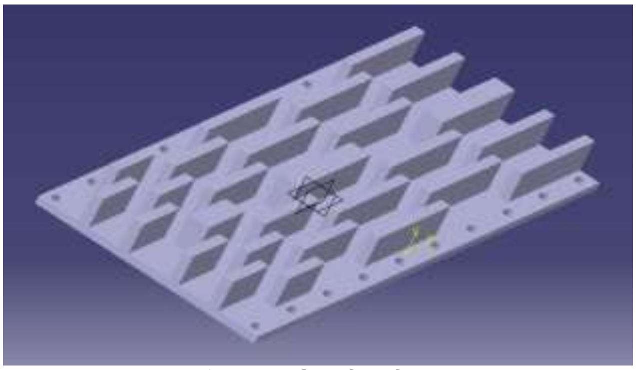

Fig.6 Accordion-shaped structure

III. DESCRIPTION OF USED INTERNAL STRUCTURE

The Fishbone-shaped structure and empty shape structure has been used in the heat exchanger to enhance heat transfer rate.

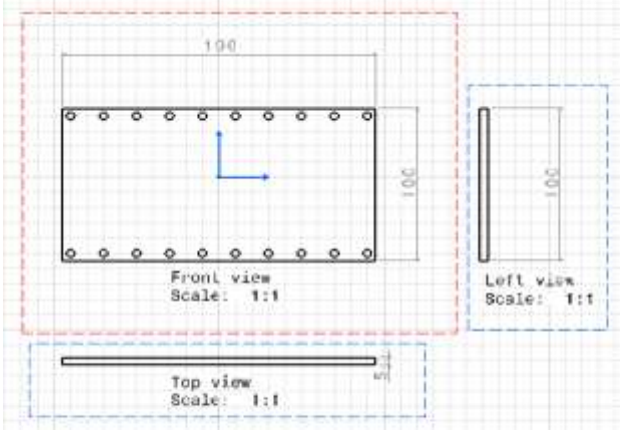

Fig.7 Description of empty shape structure

Number of Fins = 18
Length of fins = 30mm

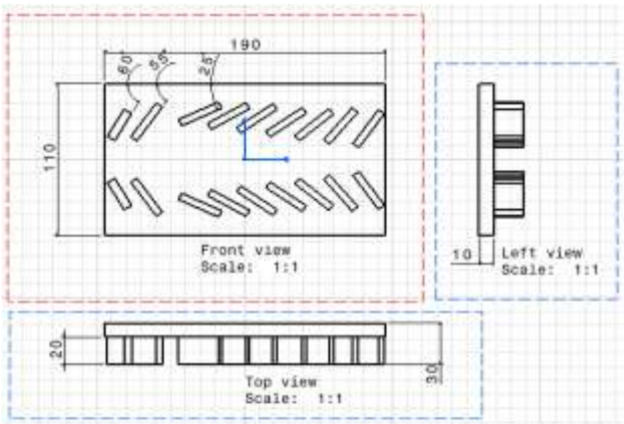

Fig.8 Description of fishbone-shape structure

IV. 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.

4.1 Boundary Conditions of Simulation Model

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.

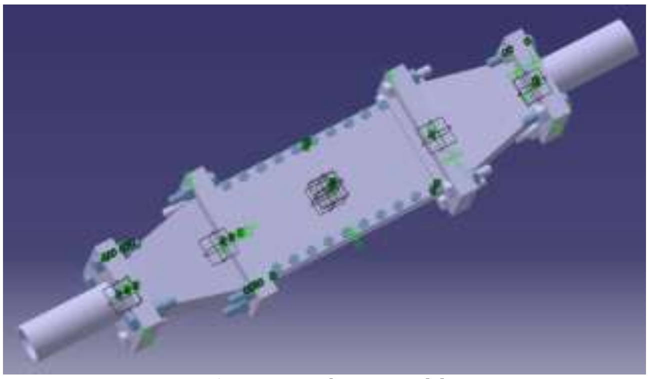

Fig.9 Heat exchanger model

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

4.2 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 fishbone shape) is relatively ideal, as compare to first structure (the empty shape).

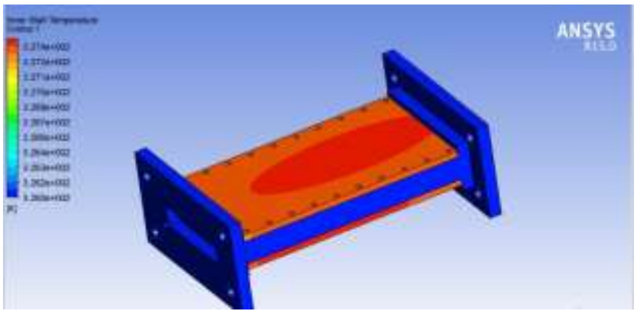

Fig.10 Simulation of the heat exchanger with no internal structure

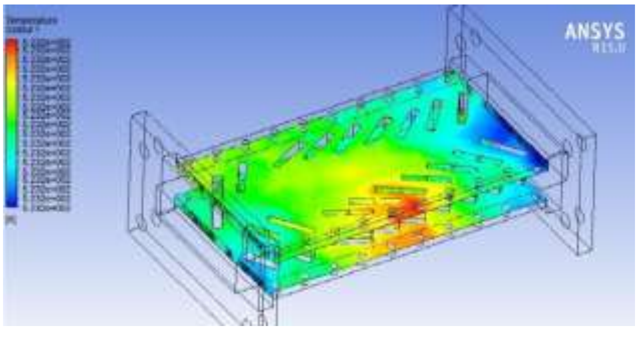

Fig.11 Simulation of the heat exchanger with fishbone shape structure

Indicated from the simulation results, the interface temperature of the heat exchanger without baffles is not distributed uniformly over the surface of the heat exchanger. The heat exchanger without baffles is not beneficial for waste gas transferring and quickens heat losing. 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.

V. RESULT AND DISCUSSION

Simulation result shows that, the interface temperature of the empty shape internal structure which used in heat exchanger is a maximum about 60℃ while the interface temperature of fishbone-shape internal structure is 250℃. So, by comparing the interface temperature of empty shape internal structure is less than fishbone-shape internal structure.

The temperature part of the heat is very low for empty shape internal structure. It is obvious that the heat exchanger cannot meet the requirement. So, considering even temperature distribution, the heat exchanger with baffles is more suitable for TEG.

VI. CONCLUSIONS

In this paper the thermal characteristics of heat exchanger with various heat transfer enhancement features are studied. Simulation results of the heat exchanger with internal structure shows an uniform temperature distribution over the surface of heat exchanger than empty 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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