A REVIEW ON CFD ANALYSIS OF EXHAUST HEAT EXCHANGER FOR OPTIMISING THERMOELECTRIC POWER GENERATION

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ABSTRACT

The present review was aimed to optimize the design of rectangual exhaust heat exchanger by removing internal fins and changing the cross-sectional area of heat exchanger to overcome problem of pressure drop. A large number of experimental and numerical works had been performed for enhancement of power generated by exhaust heat exchanger. A brief discussion is done on the effect of pressure drop, high back pressure,cross sectional area and analysis of geometric and flow parameters included in this paper. Different parameters like surface temperature, heat transfer rate and pressure drop, affect directly on the performance of heat transfer rate of exhaust heat exchanger..Discussions on some important points,which affect the performance of exhaust heat exchanger (i.e flow characteristics, cross sectional area of exhaust manifold) from various authors and their problem and related issues are presented in this paper. The cross sectional area and the related heat transfer characteristics in different other conditions are still needed to be verified.

Keyword : - *Exhaust gases, waste heat recovery, thermo-electric power, exhaust heat exchanger, thermo-electric module..*

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1. INTRODUCTION

In today's scenario there are lots of problem regarding energy crisis and thermal management. The engine exhaust management is the major topic of discussion for automobile industries in recent years and in Internal combustion engines, lots of heat is wasted in the form of exhaust gases and out of the total heat energy supplied to the engine combustion chamber in the form of fuel approximately 30-40% is been converted into useful work and the remaining one is expelled in the form of exhaust gases and this exhaust gases contains a lot of heat that can be recovered by using a waste heat recovery system. The temperature of the exhaust gases after the catalytic converter is between 300-600ºcentigrade. Thermo-electric technology plays a vital role in generating electrical power from heat, temperature differences and temperature gradients. Thermo-electric power generators are small with no moving parts and they are relatively efficient at these temperatures so they are ideals in such applications.

In automobiles, big and heavy alternators are connected to the engines in order to meet the increasing electrical demands of different accessories. An alternator which operates at an efficiency of 50 to 62% consumes about 1 to 5% of the rated engine work output. About 40% of the thermal energy of the fuel injected to an IC engine is rejected in the form of exhaust gases as waste heat. If approximately 6% of waste heat can be utilized from the engines exhaust, it can fulfill the electrical requirements of our automobiles and it would have been possible to reduce the fuel consumptions about 10%. As compared to heat rejected through coolant and lubricating oil a lot of heat is expelled through exhaust gases at very high temperatures. Thus a thermo-electric generator (TEG) can be used for converting energy from exhaust heat. TEG is similar to a heat engine which is used convert the heat energy into electrical energy and it basically works on the principle of Seebeck effect. Moreover TEGs are environmental friendly, highly reliable, operate smoothly and quietly, requires less maintenance.

2 LITERATURE SURVEY

G. Murali , G. Vikram [1] - CFD models having solid field, fluid field and solid-fluid field coalesce are generated for different heat exchangers profile to stimulate turbulence and temperature contours operating at same condition. Comparing four different heat exchangers, the serial plate has high rate of heat transfer compared with other heat exchangers. Serial plate heat exchanger pushes the exhaust gases to flow backwards by passing through baffles increasing the rate of heat transfer at the surface of heat exchanger and increasing problem of pressure drop.

P M Meena et al [2] - An theoretical model of TEG will can be made based on thermodynamic theory, semiconductor thermoelectric theory, and law of conservation of energy, the equations of power output and current of thermoelectric generator (TEG). According to the analysis the power output per unit area is independent of the thermo legs and of their cross sectional area. The power output is max. at a certain thermocouple length and depends on other parameters. Hence to improve the performance of TEGs by modifying the parameters and design methodology.

Rohan mathai chandy et al [3] – In this work a circular heat exchanger with fins attached with the TEGs for recovering waste heat from an automobile exhaust pipe is analysed by performing CFD analysis. As the temperature increases voltage produced also increased as voltage is proportional to the temperature difference. It is analysed that the heat exchanger attached between muffler and catalytic converter gives more uniform flow distribution, lower back pressure, and higher surface temperature.

P. Mohamed Shameer et al [4]- In this research work TEG is fabricated for a two wheeler silencer. The performance of the engine will not be affected because only the surface heat of the silencer is drawn out. The main aim of this research is to transfer the surface exhaust heat to avoid the accidents (Burn-outs) caused by the overheated silencers, and to transfer the recovered heat to useful electric energy. The output could be increased by connecting TEGs in series, so that the voltage gets added up leading to increased power. The energy produced from this system is utilized in powering any auxiliary devices in a vehicle directly or it could be stored in a battery and then used later.

D. T. Kashid et al [5] - The research work is on design and analyze the effectiveness of heat exchanger for thermo-electric power generation using exhaust heat energy from IC engine. The heat exchangers are assembled in sandwich arrangement with TEGs between them. Thermal grease is spread on the surfaces where TEG modules are attached to increase the heat transfer. It was found that Double stacked type heat exchanger gives better temperature gradient across the TEG. Counter flow type arrangement enhances the effective heat transfer.

Shengqiang Bai et al [6]- Six types of exhaust heat exchangers are designed and their models are analyzed on CFD to compare rate of heat transfer and pressure drop in driving conditions for a car with a 1.2 L gasoline engine. The result showed that the serial plate HEx increased heat transfer by 7 baffles and transferred the maximum heat of 1737 W. It also has a maximum pressure drop of 9.7 kPa in a suburban driving cycle. The numerical results for the pipe structure and an empty cavity were verified by experiments. At maximum power driving condition, only the inclined plate and empty cavity structure undergoes a pressure drop less than 80 kPa, and the largest pressure drop exceeds 190 kPa.

Dipak Patil et al [7] – The study focus on different working condition i.e. rate of mass flow, fluid temperatures and correct place of thermoelectric module. The electric power produced from TEG is observed to be a strong function of mass flow rate and inlet exhaust temperature. The heat exchanger should be highly efficient which is necessary to enhance the amount of heat energy extracted from exhaust gas. It is observed that exhaust gas parameters and heat exchanger structure have a significant effect on the power output and the pressure drop. It is also identified that the potentials of the technologies when incorporated with other devices to maximize the performance of the vehicles.

Hazli Rafis et al [8]– A DC to DC voltage Booster for boosting voltage from Thermoelectric Cooler (TEC) with high temperature is demonstrated. Since voltage output by TEC is very low between 0.2 to 0.8 Volts, it cannot be utilized in vehicle. In this circuit design integrated circuit is introduced as DC-DC boost converter. The booster circuit can boost input voltage down to 0.7 V and produce a high adjustable output voltage ranging from 2.7 to 5.5 Volts. The booster circuit performance was checked at various operating conditions and voltage output is estimated.

Olle Hogblom et al [9] - A transient 3D CFD model for simulation of exhaust gas flow, rate of heat transfer and power output is developed. The model works under critical design parameters for TEG-EGR to be verified and design criteria for the TEG to be mentioned. Besides the theory of Seebeck effects, the thermal simulations of model gives detailed analysis of the temperature gradients in the gas phase and inside the TEGs. CFD model is a valuable tool to identify bottlenecks, improve design and select optimal TE materials and operating conditions. CFD analysis shows that the greatest heat transfer resistance is in the gaseous phase and it is not possible to change this to get a larger temperature gradient over the thermo-electric elements without effecting on the maximum allowable pressure drop in the system.

C. Ramesh Kumar et al [10]– The study was conducted to measure performance of TEGs under various different types operating conditions. The thermo-electric modules on heat exchanger was tested in the engine test setup. Different designs of heat exchangers were modelled and CFD analysis is performed study the mass flow rate & rate of heat transfer characteristics. From the thermal simulation results it is observed that rectangular shaped heat exchanger satisfy our conditions. The study shoes that energy can be utilized from the exhaust gases and in future TEG can change the size of the alternator in automobiles.

Douglas Crane, Greg Jackson, and David Holloway [11] -The study is done on different working condition i.e. urban, suburban and high density traffic and correct place of TEG module. The electric power produced from TEG is observed to be a direct function of cross sectional area and inlet exhaust temperature. The heat exchanger should be highly efficient which is necessary to enhance the amount of heat energy extracted from exhaust gas. It is observed that exhaust gas parameters and heat exchanger structure have a significant effect on the power output and the pressure drop.

Ikoma, K., et al [12]]- In this research work TEG is fabricated for a four wheeler exhaust manifold. The heat exchangers are assembled in sandwich arrangement with TEGs between them. It was found that Double stacked type heat exchanger gives better temperature gradient across the TEG. Counter flow type arrangement enhances the effective heat transfer. It is also seen that the major of the technologies when incorporated with other devices to maximize the performance of the vehicles.

Anthony Joseph Tomarchio [13]-In this work a rectangualr heat exchanger with fins attached with the TEGs for recovering waste heat from an automobile exhaust pipe is analysed by performing CFD analysis. As the temperature increases voltage produced also increased as voltage is proportional to the temperature difference. . The output could be increased by connecting TEGs in series, so that the voltage gets added up leading to increased power. The energy produced from this system is utilized in powering any auxiliary devices in a vehicle directly or it could be stored in a battery and then used later.

J. Vazquez, M. A. Sanz-Bobi, [14]-Two types of exhaust heat exchangers are designed and their models are analyzed on CFD to compare rate of heat transfer and pressure drop in driving conditions for a car with a 1.3 L gasoline engine. It also has a maximum pressure drop of 9.8 kPa in a urban driving cycle. The numerical results for the pipe structure and an empty cavity were verified by experiments. At maximum power driving condition, only the inclined plate and empty cavity structure undergoes a pressure drop less than 83 kPa, and the largest pressure drop exceeds 197 kPa.

Ghamaty, S. Quantum Well [15] - A transient CFD model for simulation of exhaust gas flow, rate of heat transfer and power output is developed. The model works under critical design parameters for TEG to be verified and design criteria for the TEG to be mentioned. Besides the theory of Seebeck effects. According to the analysis the power output per unit area is independent of the thermo legs and of their cross sectional area. The power output is max. at a certain thermocouple length and depends on other parameters. Hence to improve the performance of TEGs by modifying the parameters and design methodology.

3. CONCLUSIONS

All studies verified that the design optimization of exhaust heat exchanger has significant effect on power generated capacity by TEG module. It is useful to note that the governing equations were solved by giving iterations with simple algorithm. The pressure, temperature contours and temperature distribution of the model are obtained after applying and solving the boundary value conditions on CFD.

On the other hand, some studies have done to resolve this situation by designing exhaust manifold. A considerable amount of related data on the design of exhausts pipes and average heat transfer and the pressure drop were established and qualitative judgements on rectangular exhaust exchangers are rendered. Despite of these earlier developments, this review indicated that further concentration on the existing problems in designing of exhaust heat exchanger geometry and thermal simulation are still necessary.

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