COMPREHENSIVE REVIEW OF EFFICIENCY ENHANCEMENT OF AUTOMOBILES USING TEGs

Sahil Sharma[1], Dhruv Tanwar[2], Abhishek Sharma[3]

[1]B.Tech Power System Engineering, Electrical Department,
[2,3] B.Tech Automotive Design Engineering, Mechanical Department
University of Petroleum and Energy Studies, Dehradun, (India)

ABSTRACT

The utilization of alternative energy conversion systems like using thermoelectric generators (TEG) increases the overall efficiency of the automobile and promises a higher electrical power output.TEG extracts the waste thermal energy from the exhaust and converts it into electrical power. It works on the principle of Seebeck effect. This review focuses on matlab/simulink based analysis of systems, techniques and models devised especially in last decade concerning the use of thermoelectric generation in field of automobiles. TEGs operate by developing potential by the virtue of temperature difference.

Keywords: Exhaust Gas, IC Engine, Matlab/Simulink, TEG.

I INTRODUCTION

As burning of fuels poses exorbitant environmental effects, it has become the priority of engineers around the world to improve the efficiency of engines. One such way is to recover waste heat from the exhaust gases in an automobile. This could be done by using TEG which is a device capable of convert thermal energy of the exhaust into electrical energy. It is based on the Seebeck thermoelectric effect which was first discovered in 1822 by Seebeck. Consider two dissimilar materials joined together in the form of a loop so that there are two junctions. If a temperature difference is maintained between these two junctions, an electric current will flow round the loop.TEG has no moving parts and is not bulky and hence is very suitable for automotive applications. With the improvements in the material technology, TEGs power output and efficiency of conversion has improved to a significant level so that the applications of TEGs in an automobile have become viable. This electricity generated by the TEG can substitute/eliminate fossil fuel based electricity generated in the automobile by the alternator. As shown in Fig 1.in a typical IC engine driven automobile, only about 25% of the energy supplied by the fuel is used by vehicle. About 40% of the energy is reflected in the form of heat in exhaust gases and about 30% is reflected in the form of the heat carried away by the engine coolant liquid. But fuel economy of IC engine can be increased by up to 20% simply by capturing the waste heat of exhaust gas and converting about 10% of it to electricity with thermoelectric modules.

Research on waste heat energy recovery systems of the exhaust gas in automobiles, thermoelectric modules has been actively conducted in recent years. TE modules can directly convert the heat energy to electrical energy. However, the output power characteristics of the TEG are highly nonlinear and heavily depend on the cooling system, external load, and heat source a proper power conditioning circuit and maximum power point tracking control are required.

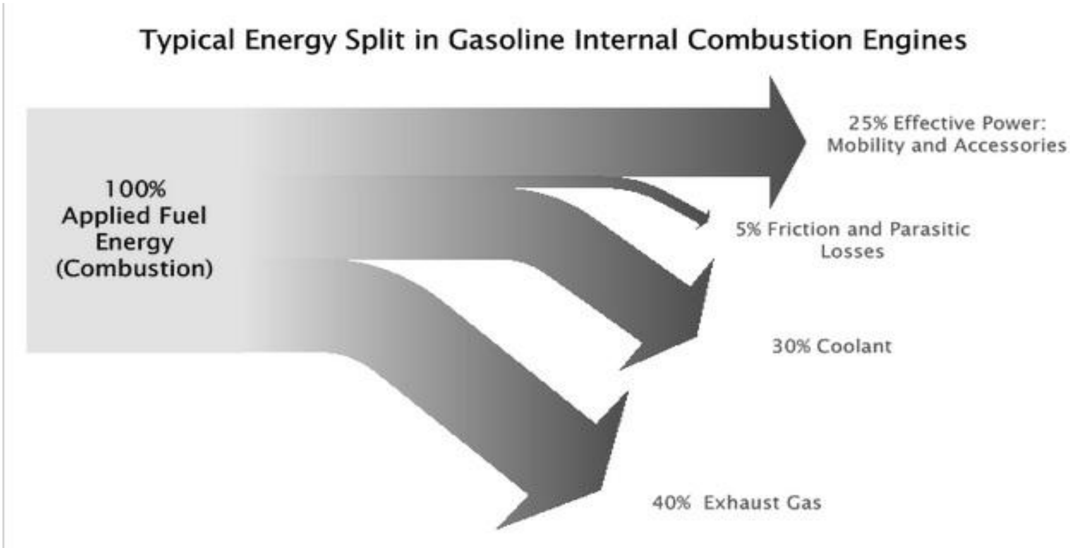

Fig. 1 Schematic Energy Flow Model of Internal Combustion Engine

As shown in Fig 2. TEG module usually consists of n-type and p-type semiconductors which are connected in series electrically. Large number of these materials or semiconductors are assembled together to form a thermoelectric module. The junctions present between hot and cold plates are connected by highly conducting metals like copper etc. Heat supplies at one end make that end a hot junction and the other end which is maintained at lower temperature by a heat sink is called cold junction.

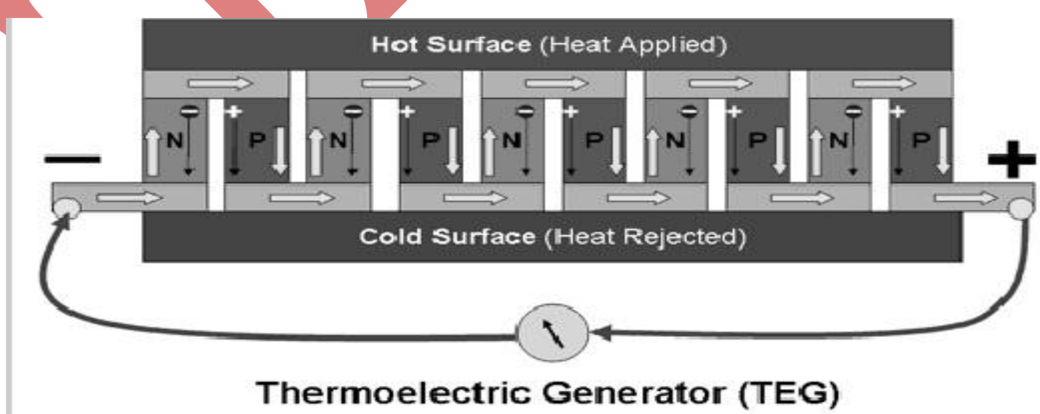

Fig .2 Schematic Diagram of Thermoelectric Generator

Due to temperature difference an output voltage is generated as a result of which current flows through an external load resistance. Most of commercially used TEGs produce a power output ranging from microwatts to few kilowatts. Power outputs of the TEGs depend particularly on temperature difference between hot and cold junctions and specifications of modules.

II BASIC FORMULAS RELATED TO TEGs

The performance of TEG could be expressed as

$$Z = \alpha^2/kR \qquad \text{... (1)}$$

Where Z is the thermoelectric material figure-of-merit and α is the Seebeck coefficient

R is the electric resistivity and k is the total thermal conductivity. This figure-of-merit may be made dimensionless by multiplying by (average absolute temperature of hot and cold plates of the thermoelectric module, K), i.e.

$$Z = \frac{\alpha^2 T}{kR} \qquad \text{... (2)}$$

And

$$T = \frac{T_h + T_c}{2} \qquad \text{... (3)}$$

Where,

T_h- Hot side Temperature (K)

T_c - Cold side temperature (K)

The term $\frac{\alpha^2}{R}$ is referred to as the electrical power factor. The efficiency of a TEG is defined as the ratio of power delivered to the heat input at the hot junction of the thermoelectric device. The maximum conversion efficiency of an irreversible thermoelectric power generator can be estimated using.

$$\eta = \frac{T_h - T_c}{T_h} \frac{\sqrt{1+Z\bar{T}}-1}{\sqrt{1+Z\bar{T}}+T_c/T_h} \qquad \text{... (4)}$$

$$Q = T_h - T_c / R \qquad \text{... (5)}$$

Where,

Q - Heat transfer (W)

R -Total thermal resistance of all the elements connected in series or parallel (K/W)

The electrical power so obtained from the TEG could be divided into its voltage and current. For this Seebeck coefficient (S) of the thermoelectric material is used.

$$V = S \times (T_h - T_c) \quad \ldots (6)$$

Where,

V - Voltage (V)

S- Seebeck coefficient (V/K)

ABOUT MATLAB

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data analysis, and scientific computation. Using the MATLAB product, one can solve technical computing problems faster than with traditional programming languages, such as C, C++. MATLAB can be used in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis, and computational biology. MATLAB provides a number of features for documenting and sharing our work. One can integrate its MATLAB code with other languages and applications, and distribute its MATLAB algorithms and applications.

SIMULINK MODEL

In Fig.3 general simulink model of circuitry or system containing TEG to produce electricity is being designed using MATLAB/SIMULINK toolbox, and its output could be obtained on the scope. The would be obtains in the form of a wave indicating the amount of voltage being produced.

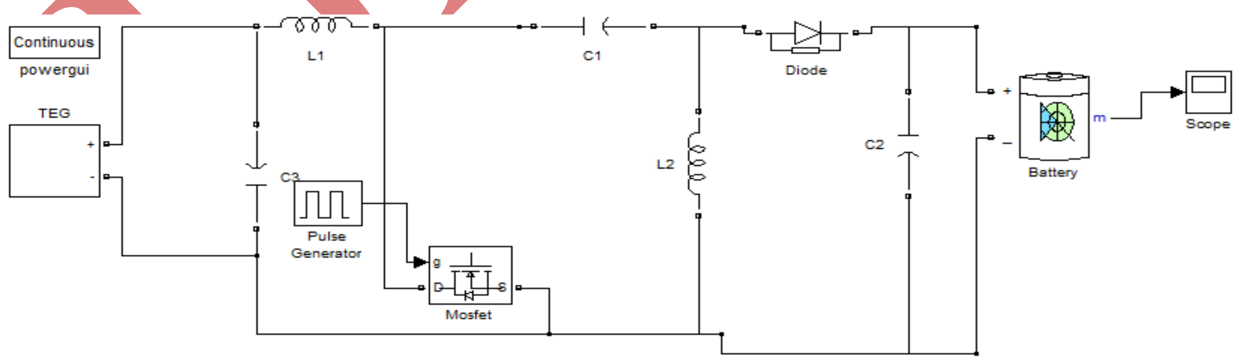

Fig. 3 Basic Simulink Model of the Thermoelectric Generation System

III FUTURE SCOPE

In this review the use of TEGs in automobiles was taken up which shows a promising future in conversion of waste heat into electricity and leads to increased efficiency. Future development in this field could be done by producing better thermoelectric material which have low temperature resistance, have higher efficiency and higher operational temperature. The application of TEGs could also be extended by use in chimneys in thermal and biomass power plants by using their high temperature exhaust gas to enhance their efficiency.

REFERENCES

[1] Xiaodong Zhang, K. T. Chau, and C. C. Chan, A Multi-hybrid Energy System for Hybrid Electric Vehicles, *World Electric Vehicle Journal*, Vol. 4 , ISSN 2032-6653.

[2] Kings Krishna NagarajaSingh.R, Manivannan.A, Matlab Based Simulation of Thermoelectric-Photovoltaic Hybrid System, *International Journal of Engineering Research and Applications (IJERA)*, ISSN: 2248-9622 Vol. 3, Issue 2, pp.975-979.

[3] Chethan R Reddy, Shrikantha S Rao, Vijay Desai, Karthikeyan Ramachandran, Modeling of an Automotive Thermoelectric Generator, *International Journal of Science and Research (IJSR)*, India Online ISSN: 2319-7064 Volume 2 Issue 5.

[4] K.Kharthikeyan, V. Sivakami, Analysis of Thermoelectric Battery Charger, *International Journal of Advanced Research in Electrical and Electronics Engineering*, Volume: 1 Issue: 3 08-Feb-2014, ISSN: 2321-4775.

[5] Sumeet Kumar, Stephen D. Heister, Xianfan Xu, James R. Salvador, Gregory P. Meisner, Thermoelectric Generators for Automotive Waste Heat Recovery Systems Part I: Numerical Modeling and Baseline Model Analysis, *Journal of Electronic Materials*, DOI: 10.1007/s11664-013-2471-9.