WASTE-HEAT ENERGY OF IC ENGINE FOR THERMOELECTRIC POWER GENERATION

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ABSTRACT
Energy conservation is the need of today's globalised world. Initiatives to save the resources were making it possible to improve the performance of the present systems. The combustion engines complies the losses in the form of the heat. This generated heat is probably the waste energy. Authors have presented the approach of thermoelectric generation from the heat generated from the IC engines. In coming future we are expecting almost all the vehicles with this great feature, i.e. an initiative towards saving the energy. Authors implemented the same concept of electricity generation in this paper. Use of the thermoelectric generator is the basis for the study carried out.

KEYWORDS: Thermoelectric generator, IC engine, Heat exchanger, Electric power, etc.

INTRODUCTION
Global warming is the severe problems faced worldwide in 21^{st} century. The natural resources are diminishing very fast, and the renewable sources are the only solution in coming future. Although the renewable energy generation is very effective and growing fast but still there is need to make the present utilization of the resources effectively.

The present conversion systems of the energy have huge scope to save the waste of resources there by implementing the effective conversion systems. Waste energy recovery is one of the effective stages in improving the use of energy. The conversion of this wasted heat to the electrical energy can surprisingly improve the utilization of energy to be wasted.

The proposed system, may also lead to saving the nature by reducing the global warming and CO2 emission. A combustion engine probably utilizes the 25% energy effectively and comprises of the losses of around 40 %.

Despite of the many initiative losses in the IC engine are much more than expected. The role of the design engineer is to optimize the performance. The use of the heat produced can help in generation of the energy. Conversion of heat to electricity is one of the basic methods of generation. The generated electricity is useful for various operations of the vehicle and results in the betterment of the overall performance of the system. The attention of this project is to design a TEG system which can incorporate into the automobile vehicle to generate electricity.

The study presented in this paper deals with the performance analysis of the thermoelectric generators for the speed changes of the engine.

METHODOLOGY
The power generation from the presented concept leads to the need of the proper generator for the conversion of the heat to electricity. It mainly made with the help of high efficiency power control electronic devices. The basic phenomenon is dependent on the concept of potential difference present between two points at different temperatures. The effect is called Seebeck effect after the discovery by Thomas Seebeck in 1821.

The basic concept is presented in the figure 1 below.

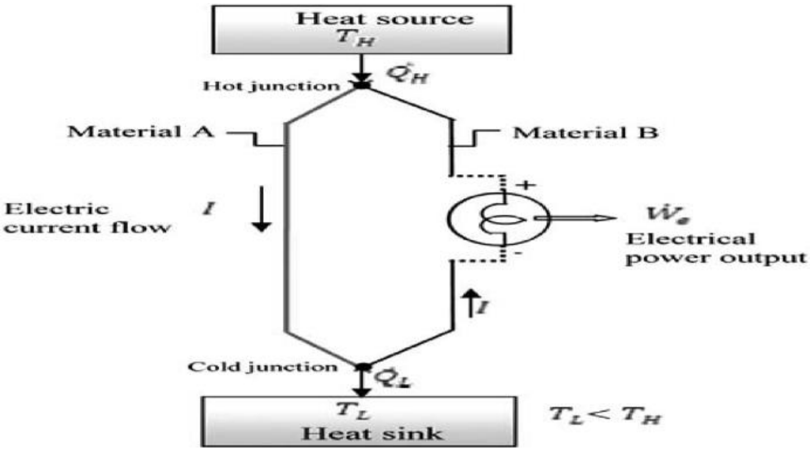


Fig. 1: Thermoelectric power generator operating based on Seebeck effect. [2]

The conversion of this concept, to the working generator needs some components to be added to the arrangement as shown in figure 2 below.

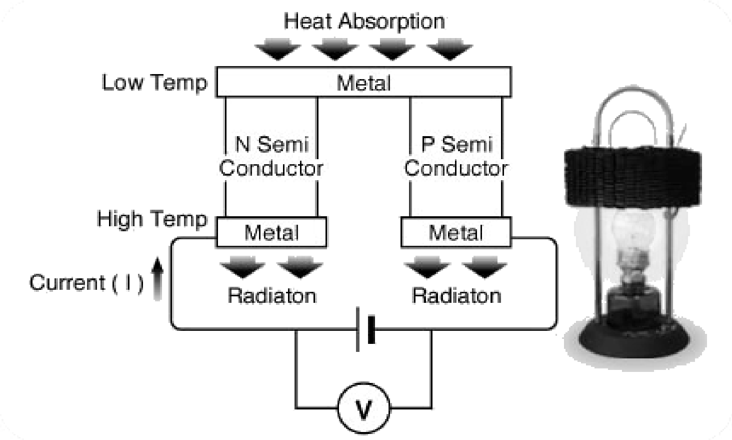


Fig. 2: thermoelectric power generator [2]

The effect is reverse to the heating effect of electric current. If electricity can generate the heat then the heat must generate the electricity in return.

IMPLEMENTED MODULE:

Cold & hot side exchangers of the heat are the main parts for the transfer of heat from one place to other. This transfer of the heat leads to generation of electricity. The change in the temperature is created purposely between the cold and hot sections.

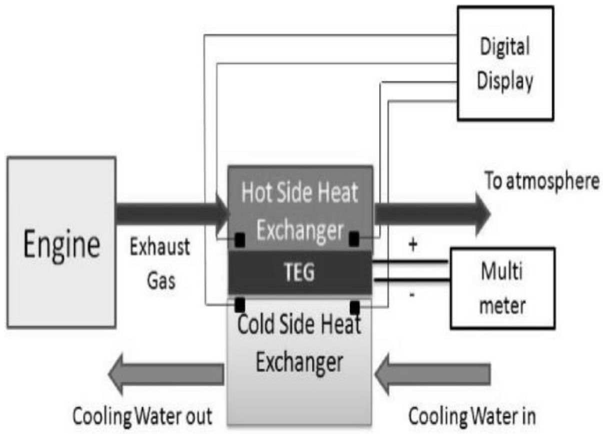


Fig. 3: TEG System Layout

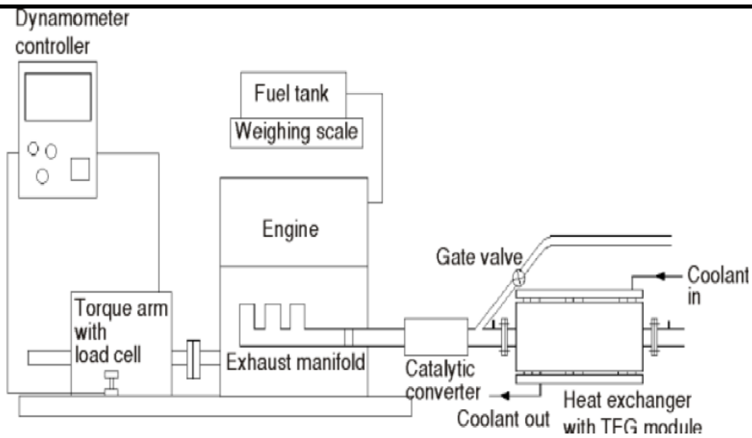


Fig.4 Experimental set-up [4]

The generator is present between the two heat exchangers at different temperatures.

Fig.5: Three cylinder, four stroke, Petrol Engine test Rig with TEG System

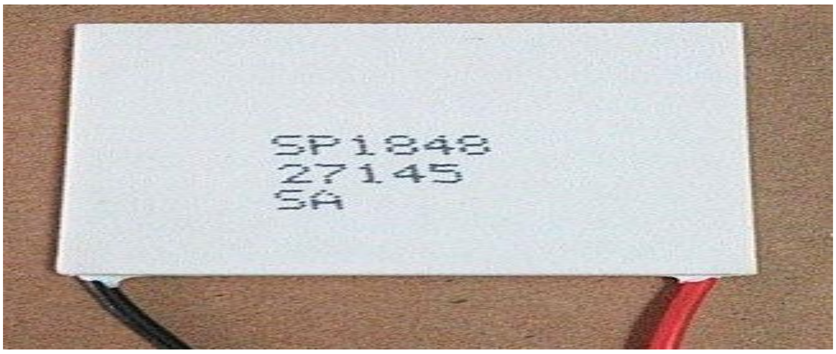


Fig.6: Thermoelectric module

CFD ANALYSIS:

The analysis of the system to be implemented in software environment is very effective to understand the performance of the system in detail virtually. The analysis of the exchanger is done in the software to understand the heating properties.

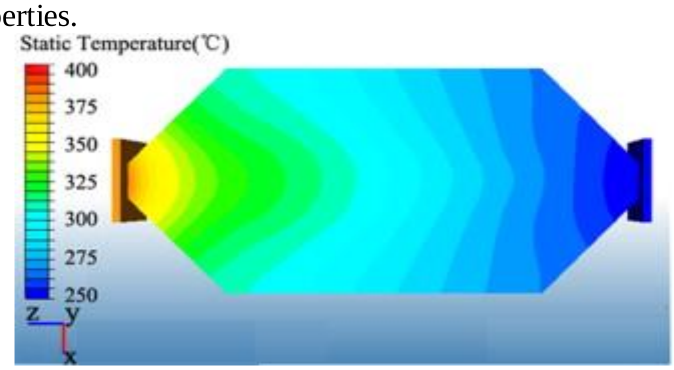


Fig.7: Static Temperature analysis of heat exchanger

CALCULATIONS

T_1= Hot side inlet temperature
T_2= Hot side outlet temperature
T_3= Cold side inlet temperature
T_4= Cold side outlet temperature
T_{in}= Exhaust gas temperature at TEG system inlet
T_{ex}= Exhaust gas temperature at TEG system exit
Sample Calculation:
Engine Speed (N) = 2122 rpm
Inlet Temperature of exhaust gas = 278^0C
Manometric deflection = 38 mm
Fuel flow in secs/ 100ml = 70 secs
Coefficient of discharge C_d = 0.6
Orifice diameter = 35mm
Density of air = 1.16 kg/m^3

1. Fuel intake (m_f):

$$m_f = \frac{\text{fuel consumed in m}^3 \times \text{density of fuel}}{\text{time required(t)}} \quad m_f = \frac{100 \times 10^{-6} \times 740}{70}$$

$=1.065\times 10^{-3}$ kg/s

2. Mass flow rate of air (m_a):

$$m_a = C_d \times A \times \sqrt{2g \times H_W \times \left(\frac{\rho_W}{\rho_a}\right)} = 0.6 \times \left(\frac{\pi}{4}\right) \times (0.035)^2 \times \sqrt{2 \times 9.81 \times 0.038 \times \left(\frac{1000}{1.16}\right)}$$

$$m_a = 15.329 \times 10^{-3} \text{kg/s}$$

3. Exhaust mass flow rate (m_{ex}):

$$m_{ex} = m_f + m_a$$

$=1.065\times 10^{-3}+15.329 \times 10^{-3}$

$=16.394 \times 10^{-3}$kg/s

4. Temperature drop:

$$\Delta T = (T_{in} - T_{ex})$$

Where

$$T_{in} = 278℃ \; T_{ex} = 273℃$$

$$\Delta T = (278 - 273) = 5℃$$

5. Input power of exhaust gas:

$$P_{in} = m_{ex} \times c_p \times \Delta T$$

Where,
Specific heat of exhaust gas= 1.02KJ/kg-k

$$P_{in} = 16.394 \times 10^{-3} \times 1.02 \times 5$$

=91.31 W

6. TEG output power:

$$P_{out} = V \times I$$

Where, Voltage generated, V=5.22 Volts
Current generated I=0.55 Amp,so

$$P_{out} = 5.22 \times 0.5$$

=2.71 W

7. TEG Overall efficiency:

$$\eta = \frac{P_{out}}{P_{in}} \quad = \frac{2.71}{91.31}$$

= 2.97 %

So, at the engine speed of 2122 rpm, input power of engine exhaust gas is 91.31 W & the TEG output power is 2.71 W, hence the overall efficiency obtained is 2.97%.

Table 1: Experimental Observation Table

10	3736	124	123	44	46	396	386	9.56	1.37	13.10
9	3708	120	118	43	45	388	378	9.31	1.36	12.66
8	3603	117	115	42	44	379	369	9.26	1.33	12.3
7	3566	114	112	42	44	372	363	8.91	1.32	11.71
6	3398	111	109	42	44	361	352	8.49	1.25	10.6
5	3186	108	107	41	43	350	342	7.67	1.14	8.73
4	3096	107	105	41	43	340	332	7.47	1.11	8.28
3	2845	105	103	41	43	336	329	6.28	0.80	5.01
2	2475	102	100	41	43	310	304	5.60	0.57	3.17
1	2122	99	97	40	42	278	273	5.22	0.52	2.71
Sr. No.	**Engine Speed (rpm)**	**T_1(^{0}C)**	**T_1(^{0}C)**	**T_1(^{0}C)**	**T_1(^{0}C)**	**T_1(^{0}C)**	**T_1(^{0}C)**	**Voltage v(V)**	**Current I (A)**	**O/P Power(W)**

RESULT AND DISCUSSION

The results obtained from experimentation, result table 1 has prepared which give information about-
1.Engine speed
2.Mass flow rate of exhaust gas
3.Temperature drop
4.Input power of exhaust gas
5.Output power of TEG
6.TEG overall efficiency

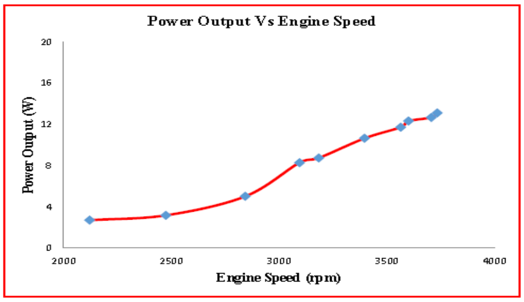
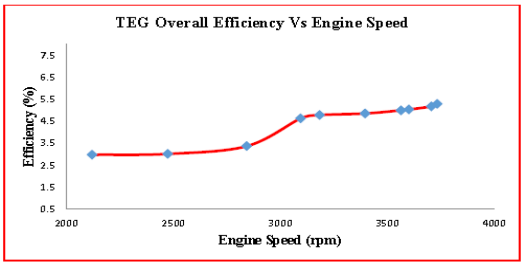


Fig.1 Power output Vs Engine



SpeedFig.2 Efficiency Vs Engine Speed

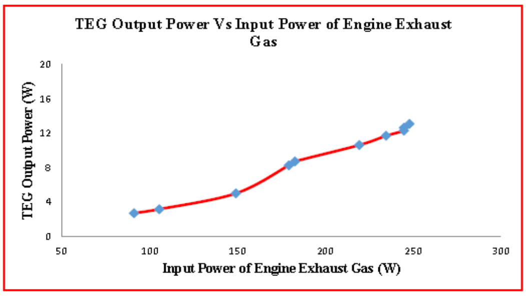


Fig.3 TEG Output Power Vs Input Power

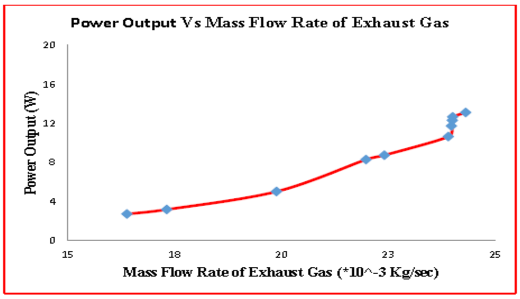


Fig.4 Power Output Vs Mass Flow Rate of Exhaust Gas

CONCLUSION

The system implemented is suitable for generation of the electricity. The speed of the vehicles is proportional to the electricity generated. Implemented system will play very crucial role in the electricity generation from the wasted heat energy. The efficiency of the system even though is very low; there is scope for improvement in the performance. The detailed analysis of the system is done to understand the outcomes of the implemented modul.

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