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WASTE HEAT RECOVERY SYSTEM UTILIZING T.E.G.

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Abstract
Waste heat recovery system are used to convert the waste heat to electricity. The reason to used the waste heat recovery system is to reduce the fuel consumption and load on the engine and also it reduces emission of harmful gases. The thermoelectric generator and heat pipes are used to take that advantage from waste heat gases and convert it into electricity. The internal combustion engine is a heat engine and no heat engine have a efficiency more than 50% as compare to other system the heat engine is very less efficient. So we are not increase the efficie ncy of the engine directly and the waste gas or exhaust from the engine is goes waste and for cooling, so we utilize that heat for generating the electricity by using thermoelectric generator and heat pipes. The thermoelectric generator and heat pipes are the most compactable, eco friendly, durable, and reliable source of energy. By using heat pipes we reduces the thermal resistance and pressure losses and also it control the temperature and it increase s the flexibility. Heat pipes do have limitations such as high rates of heat transfer and temperature limits. When used in conjunction, these technologies have the ability to create a completely solid state and passive waste heat recovery system. An waste heat recovery system utilizing thermoelectric generators and heat pipes.

Keywords: *IC Engine, Thermoelectric generators, Heat pipes, Seebeck effect, Waste heat utilization.*

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1. INTRDUCTION

We all are well known about the internal combustion engine and no engine have efficiency to convert only one third chemical energy of fuel into mechanical energy, and maximum heat energy goes waste to exhaust gases and in cooling. Before a new car is launch to the market, inspection and testing is taken to ensure it gives the latest emissions regulations results. The regulations different from country to country. The carbon dioxides emissions of a car are directly proportional to its fuel consumption. Since, to meet these tightening regulations, car companies must reduce the fuel consumption of their cars. Current internal combustion engine are having average approximately 28% efficient under typical driving conditions but can range from 20% to 45% depending on the engine type and operating conditions. The remaining 55%–80% will be wasted as heat in both the coolant and the exhaust gases. A waste heat recovery system has the ability to convert this waste heat into electricity and consequently reduce the fuel consumption of the car by reducing the load on the car engine. Heat pipes and TEGs could be used in conjunction for use in a waste heat recovery system. This current research is focusing on a technology, which is able to convert the thermal energy consist in the exhaust gas directly into electric energy. J. Ringler invented an exhaust gas thermoelectric power generator for an automobiles.

In this research, the exhaust waste gases in the exhaust pipe provide the heat source to the thermoelectric generator, whereas the cold side is suggested to be provided by cooling water.

2. WORKING PRINCIPLE

Seebeck Effect

The seebeck effect is says that when the two dissimilar conjunction metals are placed at temperature difference that time electric potential is generated. When two ends of a conductor are place at different temperatures the electrons at the hot junction at higher speed diffuse to the cold junction.

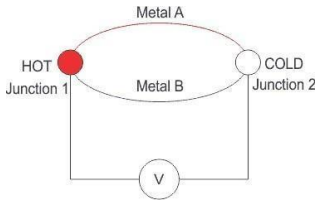

Fig-1: Seebeck Effect

Thermoelectric principle of operation says that thermoelectricity means the directly conversion of heat into electric energy, or electric energy into heat. According to Joule's law, a Jean C.A. Peltier invented an effect opposite to the Seebeck effect. If a current flow through a thermocouple, the temperature of hot junction increases and the temperature of cold junction decreases, so that heat is transferred from hot junction to cold junction. The rate of heat transfer is proportional to the current and the direction of transfer is reversed when the current is reversed.

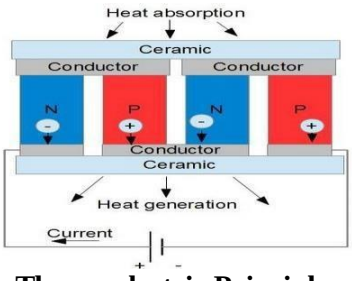

Fig-2: Thermoelectric Principle of Operation

3. WORKING

The main focus of energy conversion is on three conversion locations mainly exhaust gas pipe, exhaust gas recirculation cooler, and retarder. The most significant factors for the waste heat quality are power density and temperature range. The EGP is the target of the most automobile waste heat recovery related research. The exhaust system contains a large portion of the total waste heat in vehicle. The gas flow in exhaust gas pipe is relatively stable. Fig.3 shows that TEG utilizing the exhaust gas heat for operation. With exhaust temperatures of 973 K or more, the temperature difference between exhaust gas on the hot side and coolant on the cold side is close to 373 K. This temperature difference is capable of generating 100-500W of electricity.

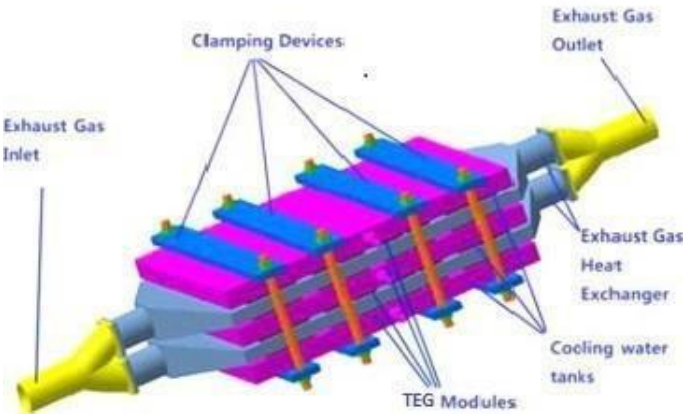

Fig-3: TEG utilizing the exhaust gas heat

In the water coolant based system, though the temperature is lower, it may be high enough to produce significant electricity for use in the vehicle when TEGs are attached. The main advantage of EGR gas is large temperature difference. Since EGR gas comes directly from the cylinders, its temperature is in the range of 820 K-1050 K, which is similar to that in exhaust manifold.

4. EXPERIMENTAL METHOD

A thermoelectric conversion system consists of heat absorbers (hot side), TEG modules, and heat sinks (cold side), where heat absorbers function as collected the heat and heat up the thermoelectric generator, and the heat sink functions to dissipate heat from the cold end of the thermoelectric generator module as instantly and efficiently as possible to increase the temperature difference between the hot and cold faces, to improve the performance of the thermoelectric generator module. The shell heat absorber is used inside the duct and the exhaust gases are guided along roundabout path from the inlet across them as can be seen in Figure. The absorbed heat is supplied to the hot face of the thermoelectric generator modules which are bolted to the surface of the heat absorbers. The exhaust gases are forced past the shell heat absorbers and the resulting turbulence wave and heat exchanges between the hot exhaust waste gases and the outer surface of the heat exchangers. The device also acts as a silencer means it reduces the engine noise. The parts are anodized means to provide the additional layer of protective of anti corrosive materials to protect them from corrosion and this also improves their aesthetic look. The shell are all the same length and make connect with the zigzag box in the center of the chamber. This arrangement guides the flow so that it is impossible for the exhaust gasses to get to the outlet without the development of turbulence wave and close contact with the large heat exchange surfaces on all four sides of the chamber. The bases of the shell heat exchange units are fastened to the body of the device with machine screws. The TEG modules are clamped between the top of the heat exchangers side and the cooling side, also with machine screws. An assembled heat exchange device with one heat exchanger block, TEG and cooling shell assembly take out for clarity. In use, the outer housing has four heat exchange blocks bolted to it and the ends of the heater exchange pins make contact with the central zigzag box which acts to guide the hot gasses on the proper path a cross all the heat exchange surfaces to the outlet.

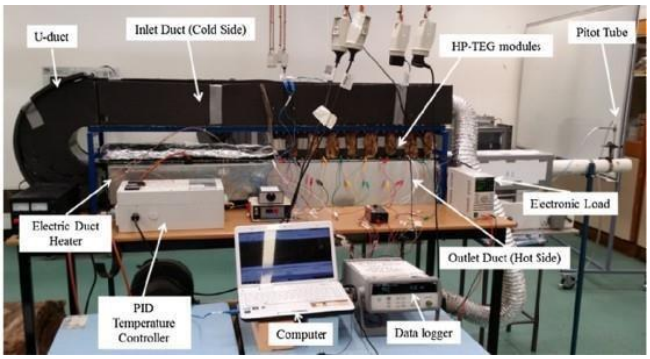

Fig-4: Experimental setup of Waste Heat Recovery Thermoelectric Conversion System

5. MATERIAL USED IN T.E.G.

Material used in thermo electric generator having capability to withstand high temperature, when the difference between hot junction and cold junction is minimum 60℃ that time the TEG or seebeck effect work well. Thermoelectric effect refers to phenomenon by which either temperature difference creates an electric potential this law is known as seebeck effect.

The material used in TEG are Bi2Te3 (Bismuth Telluride) and Bi2Se2 (Bismuth Selenide) it is a semiconductor and having capability to withstand 710℃ temperature and bismuth silicon germanium alloy are currently the best thermoelectric material around the 1000 ^{o}C temperature therefore it is used in waste heat recovery system.

Material used in heat exchanger are carbon steel, stainless steel, copper, bronze, brass, titanium which gives high strength and durability.

Table 5.1 N-type material groups by best temperature range

Group	Material	BTR (K)
Hot Side Material (700 K-1000 K)	CoSb 3 PbTe	650-1100 600-850

	SiGe	>1000
Cold Side Material (300 K-400 K)	Bi2Te3	<350

Table 5.2 P-type material groups by best temperature range

Group	Material	BTR (K)
Hot Side Material (700 K-1000 K)	Zn4Sb3	>600
	CeFe4Sb12	>850
	SiGe	900-1300
	TAGS	650-800
Cold Side Material (300 K-400 K)	Bi2Te3	<450

6. POWER GENERATION

Power generation is totally depends upon the temperature difference if temperature is about 1000℃ that time we obtained 650W to 1KW power. The FORD system heat exchanger uses many small parallel channels lines with thermoelectric material for the exhaust gas to pass liquid cooling is used in this case. The system is rated to produced a maximum of approximate 700W with 4.6kg of thermoelectric materials.

7. CASE STUDY

7.1BMW

The BMW system uses a shell and tube heat exchanger to produce electricity. High temperature thermoelectric generators are used and the system is rated to produce 755W from a number of 21W rated thermoelectric generators. The BMW system another heat exchanger uses many small parallel channels lined with TE material for the exhaust gases to flow.

This system is used to produce a maximum of approximately 400W with 4.6kg of thermoelectric material.

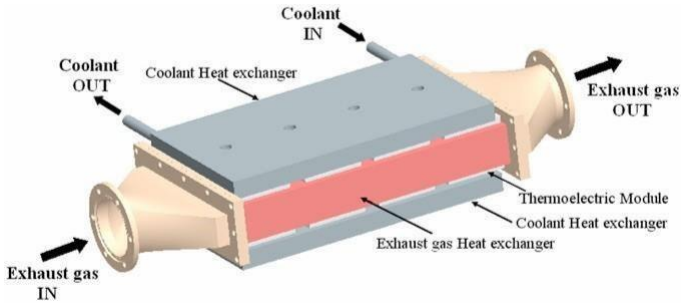

Fig-7.1: The CAD model of the assembled AETEG in BMW

7.2 Renault

The Renault system is to be rated on a diesel truck ICs engine. It has dimensions of 10cm×50cm×31cm. This system uses a counter flow heat exchanger arrangement using liquid cooling. A combination of high temperature thermoelectric generators sat the high temperature end and low temperature thermoelectric generators at the low temperature end were used. The model system is predicted to produce approximately 1000W. The Renault system used a simple design of a thin flat rectangular box with TEGs placed on the top and bottom surfaces. Liquid cooling was used in this design. The system consisted of 30mm×30mm TEGs and produced a maximum of approximately 550W. The claimed fuel consumption reduction is 4%.

Fig-7.2:Renault prototype vehicle using TEG waste heat recovery

8. BENEFITS

a. Thermoelectric generator is a rigid part and it does not have any moving parts.
b. Maintenance is very less because it having no moving parts.
c. It is compact in size and scalable, and it applicable for any size of device.
d. Thermoelectric generators are environment friendly because it does not having any emission.

9. CONCLUSION

Waste heat recovery system is used to generate the electricity from the waste gas heat by using the thermoelectric generator and heat pipes. It would also help to understand the improvement in performance and emissions of the engine if these technologies were taken by the automobile car manufacturers. By using this thermoelectric generator system one can generate electricity from the very high temperature difference and it is available at very low cost. In the heavy duty vehicles the exhaust coming out of the exhaustion system will form the very harmful gases which are major consist for the green house gases. But because of this the temperature will come down of exhaust gases so, the formation of the harmful gases will be minimize. If this concept of thermoelectric generator is used in all the automobiles we indirectly increases the efficiency of engine and also reduces the emission.

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