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Waste Heat Recovery From Exhaust Gases of Ic Engine By Using Teg

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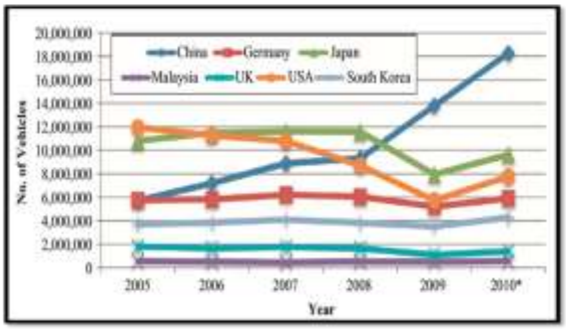
Abstract *: The focus of this study is to review the latest developments and technologies on waste heat recovery of exhaust gas from internal combustion engines (ICE). Also we know that A major part of heat supplied to an IC engine is not realized at efficiency work output as a waste heat .If this waste energy possible to trap and converted into another form of energy it will definitely save fuel consumption which is initiated by the TEG technique With the help of TEG fuel consumption can be reduced up to 10% by converting only 6% of waste energy.TEG is works on the principal of SEBECK EFFECT, when the TEG plate is attached on the silencer the one side of the plate heat up rapidly and another side of the plate is not heated because the ceramic molecules are placed between the two plates hence though are bad conductor ,and due to this potential difference is created and energy is developed in the form of the electricity and which is feed to the engine indirectly with the help of the energy converter and reduce the fuel consumption and increases the efficiency of the system and reduce pollution.*

Keywords: *waste heat recovery technology, internal combustion engine ,waste heat recovery ,TEG,see beck effect*

I. Introduction

In recent years the scientific and public awareness on environmental and energy issues has brought in major interests to the research of advanced technologies particularly in highly efficient internal combustion engines. The number of vehicles (passenger and commercial vehicles) produced from 2005 to 2010 shows an overall increasing trend from year to year despite major global economic downturn in the 2008–2010 periods (Fig. 1.1). Note that China's energy consumption in transportation sector is the lowest (13.5%) although the country produced the highest number of vehicles in 2009 to 2010 as compared to the other countries (Table-1). Viewing from the socio-economic perspective, as the level of energy consumption is directly proportional to the economic development and total number of population in a country, the growing rate of population in the world today indicates that the energy demand is likely to increase. It is also expected that the average increase in population growth between 2010 and 2020 is projected to be 10.74%. For instance, the current population of Malaysia is expected to rise from 28 million in 2010 to 33 million by the year 2020 . In consequence, Malaysia Gross Domestic Product (GDP) saw a stable increase from RM 87,280 million in 1980 to RM 675,825 million in 2009. From 1980 to 2009, the per capita income also recorded an increase from RM 6341 to RM 24, 604 (US $ 1¼ RM 3.50). Malaysia is thus presented a stable percentage values for transportation sector in 2002 period. As discussed before, the growing number of population puts transportation sector in a very crucial role due to its dependability towards the continuous and rapid development of a nation urban areas and the standard of living for its people. For instance, in document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create this, incorporating the applicable criteria that follow.



“**Fig 1.1:-** Energy Consumption In Different Countries”

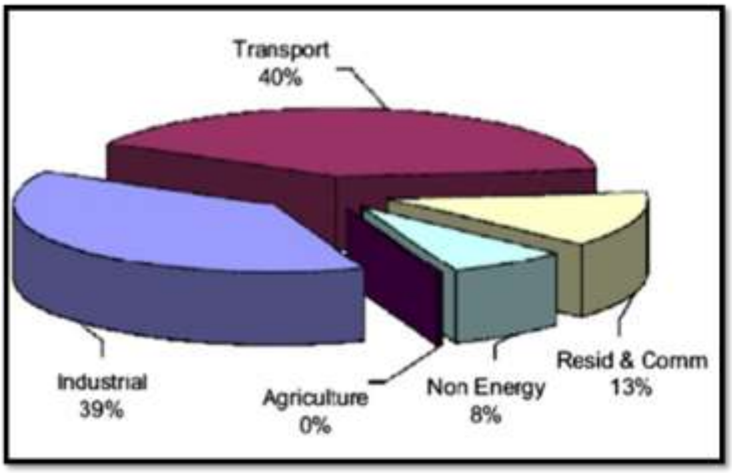


Fig 1.2:- Final Energy Usage By The Main Sector Of Malaysia 2012

Table

Regions	Total Consumption	Energy Consumption In Industry	Energy Consumption In Transportation	Energy Consumption In Agriculture	Non energy use
CHAINA	597	327(54.8)	80.5(13.5)	165(27.6)	24.4(4.1)
USA	1597	394(25.3)	623(40.0)	475(30.5)	65.4(4.2)
UA-(15)	1057	320(30.3)	321(30.4)	386(36.5)	30.2(2.8)
JAPAN	359	135(37.6)	94.4(26.3)	119(33.2)	10.5(2.9)
OECD	3692	1106(30.0)	1242(33.6)	1120(33.0)	125(2.4)
TOTAL	6212	2144(34.4)	1831(29.5)	2035(32.8)	201(3.1)

Table 1- Terminal Energy Consumption Structure By Region And Sector.

II. Literature Survey

According to Mr., Om Prakash, Mr. Mukesh Pandey. By using Thermoelectric generator, energy can be recovered from a cheaper source but the relative fuel saving may not be in proportion. So there is need of maximizing power generation efficiency of TEG. This can be done by providing large temperature difference between hot and cold side. Moreover cost, space, weight, additional cooling circuit provision, module interface, electronic control and unsteady exhaust flow are practically different issues in implementing TEG. thermoelectric module along with better heat exchanger.

According to Dr. Saidur It has been identified that large amount of energy saving through the use of waste heat recovery technologies. Waste heat recovery entails capturing and reusing the waste heat from internal combustion engine

According to Mr. Pratik Sapre About 63.25% harmful emission is get reduced also the fuel consumption is decreased. About 2.5% of fuel is saved by using thermoelectric generator Efficiency of intercooler or heat exchanger is increases due to shell and tube type arrangement. So generation of electricity about 250 Watts in D.C. form is possible. Pollution and performance of engine is stringently improved by waste heat recovery. Also Pollution and performance of engine is stringently improved.

According to Mr. Shubham Suryawanshi, Miss. Manasi Sonawane, It is possible to utilize the waste energy by using a thermoelectric generator and produce optimum amount of electrical energy to charge a battery. The main advantage of this project is that the consumption of fuel as well as the emissions will be reduced. Also consumption of fuel as well as the emissions will be reduced. The fuel used will be indirectly used to charge the battery which will operate the vehicle as an electric bike. The reduction in emissions is an important aspect with respect to environmental damage. As a whole, this project is a blend of energy conservation and security.

III. General Concept

3.1 Laws of Fuel Energy Distribution

In 2002, the transportation sector of Malaysia used about 40% of the total energy consumed. A number of irreversible processes in the engine limit its capability to achieve a highly balanced efficiency. The rapid expansion of gases inside the cylinder produces high temperature differences, turbulent fluid, motions and large heat transfers from the fluid to the piston crown and cylinder walls. These rapid successions of events happening in the cylinder create expanding exhaust gases with pressures that exceed the atmospheric level, and they must be released while the gases are still expanding to prepare the cylinder for the following processes. By doing so, the heated gases produced from the combustion process can be easily channelled through the exhaust valve and manifold. The large amount of energy from the stream of exhausted gases could potentially be used for waste heat energy recovery to increase the work output of the engine. Consequently, higher efficiency, lower fuel consumption by improving fuel economy, producing fewer emissions from the exhaust, and reducing noise pollutions have been imposed as standards in some countries. Hatazawa et al., Stabler, Taylor, Yu and Chau and Yang stated that the waste heat produced from thermal combustion process generated by gasoline engine could get as high as 30–40% which is lost to the environment through an exhaust pipe. In addition, 12–25% of the available energy in a fuel will be used to drive the wheels shown in fig4.1 and other accessories which technical descriptions of those literatures are heavily discussed. In internal combustion engines a huge amount of energy is lost in the form of heat through the exhaust gas. Conklin and Szybist investigated that the percentage of fuel energy converted to useful work only 10.4% and also found the thermal energy lost through exhaust gas about 27.7%. The second law analysis of fuel has been shown that fuel energy is converted to the brake power about 9.7% and the exhaust about 8.4% as shown in Fig.4.2 In another research the value of exhaust gases mentioned to be 18.6% of total combustion energy. It is also found that by installing heat exchanger to recover exhaust energy of the engine could be saved up to 34% of fuel saving. A major part of heat supplied to an IC engine is not realized at efficiency. Work output as waste, If this waste energy possible to trapped and converted into energy it will definitely save fuel hence its possible due to TEG technique

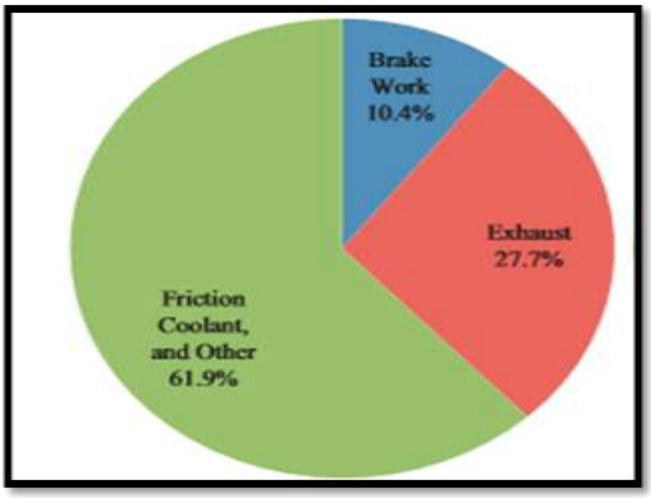


Fig 3.1.1: 1_{St} law of fuel energy distribution

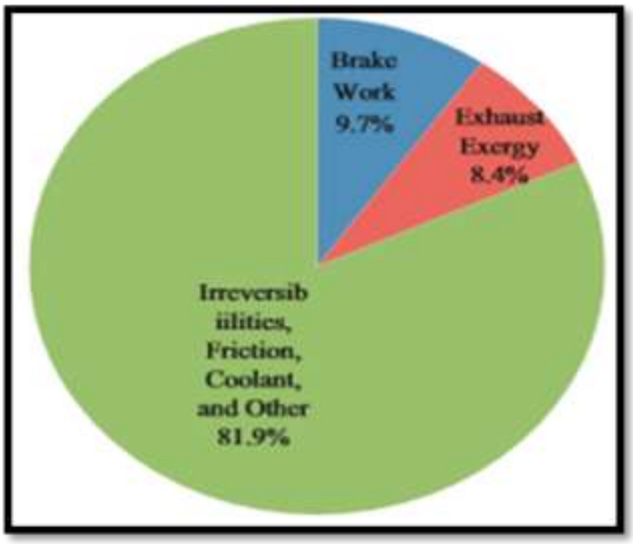


Fig 3.1.2: 2^{nd} law of fuel energy distribution

3.2 Thermoelectric energy conversion technology

Being one of the promising new devices for an automotive waste heat recovery, thermoelectric generators (TEG). One of the most important and outstanding devices in the future. Within the recent years, the revival of interests into clean energy production has brought TEG technology into the attention of many scientists and engineers. Mori et al studied the potentials of thermoelectric technology in regards to fuel economy of vehicles by implementing thermoelectric (TE) materials available in the market and certain industrial techniques on a 2.0 l gasoline powered vehicle. Husain et al. Studied the effects of thermoelectric waste heat recovery for hybrid vehicles. Stobart and Milner explored the possibility of thermoelectric regeneration in vehicles in which they found out that the 1.3 kW output of the TE device could potentially replace the alternator of a small passenger vehicle. Stobart etal reviewed the potentials in fuel saving of thermoelectric devices for vehicles. They concluded that up to 4.7 % of fuel economy efficiency could be achieved. From these articles, the understanding of TEG technology has been comprehensively discussed as a promising new technology to recover waste heat from internal combustion engines. Studies on thermoelectric devices are still an ongoing matter. TE devices may potentially produce twice the efficiency as compared to other technologies in the current market. TEG is used to convert thermal energy from different temperature gradients existing between hot and cold ends of a semiconductor into electric energy. This phenomenon was discovered by Thomas Johann Seebeck in 1821 and called the ‘‘Seebeck effect’’. The device offers the conversion of thermal energy into electric current in a simple and reliable way. Advantages of TEG include free maintenance, silent operation, high reliability and involving no moving and complex mechanical parts as compared to Rankine cycle system which will be discussed in the next section of this study. In regards with the applicability of TEG in modern engines, the ability of ICE’s to convert fuel into useful power can be increased through the utilization of the mentioned device. By converting the waste heat into electricity, engine performance, efficiency, reliability, and design flexibility could be improved significantly. The fuel efficiency of gasoline powered, diesel and hybrid electric vehicles (HEVs) that utilize the power generation of IC engine is as low as 25% and conversely as much as 40% of fuel energy can be lost in the form of waste heat through an exhaust pipe . An increase of 20% of fuel efficiency can be easily achieved by converting about 10% of the waste heat into electricity. Further more, secondary loads from the engine drive trains can be eliminated with the help of TEG, and as a result torque and horsepower losses from the engine can be reduced. This would help to reduce engine weight and direct the most of the increased power to the drive shaft, which would in turn help to improve the performance and fuel economy. Additionally, the possibility of minimizing the battery needs and exhaustion of vehicle battery life while permitting operation of specific accessories during engine off can be achieved by utilizing TEG.

IV. Construction

As shown in fig 4.1 TEG consist of PN junction module, ceramic molecules and plate also metal interconnect with the external electrical connects taken out as shown in figure The one metal plate is connected at the one end and other plate is connected at the other side and the ceramic molecules are placed between though two plates which creates PN junction and the potential difference is obtained at those ends and the two metal plates are interconnected with the PN junction molecules to obtain potential difference the external electrical connections are provided which is connected the molecules .Hence the one end of the metal plate is connected to the silencer which carries exhaust gases and heat is absorbed and these absorbed heat is rejected to the ceramic molecule where the one metal plate is acts as the conductor and other metal plate is bad conductor because the ceramic molecules are placed between though two plates.

Also in the PN junction P forms positive potential and N forms negative potential and the direction of heat flow is from good conductor to bad conductor which creates potential difference and generation of seebeck effect .the practical model of TEG as shown in fig 4.2.

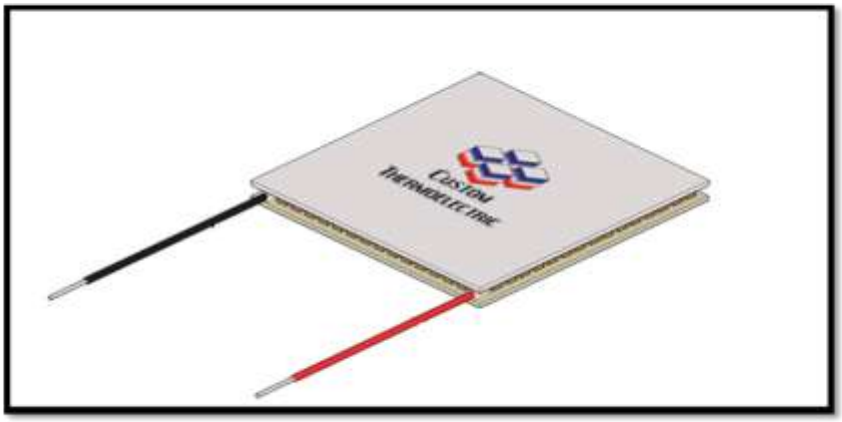


Fig 4.1: TEG plate

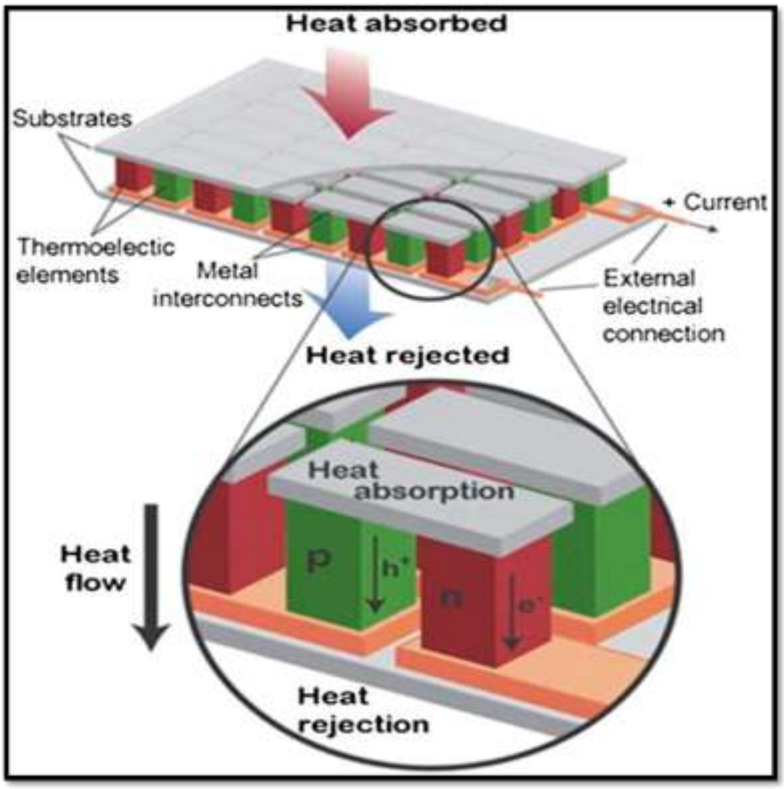


Fig 4.2: Construction of TEG plate

V. Working

The working principal of TEG technique is based on "seebeck effect". which is discovered by Thomas John seebeck in 1821 and called the seebeck effect. It states that when one end of metal is heated and another end is cold then there is a potential difference is occurs because the temperature difference is directly proportional to the current hence the current is passes from hot junction to the cold junction and electric potential difference is occurs between two end and finally obtain the electric energy. Similarly TEG works , when the TEG plate is attached on the silencer the one side of the plate heat up rapidly and another side of the plate is not heated because the ceramic molecules are placed between the two plates hence though are bad conductor ,and due to this potential difference is created and energy is developed in the form of the electricity and which is feed to the engine indirectly with the help of the energy converter and reduce the fuel consumption and increases the efficiency of the system and reduce pollution, The fig shown below.

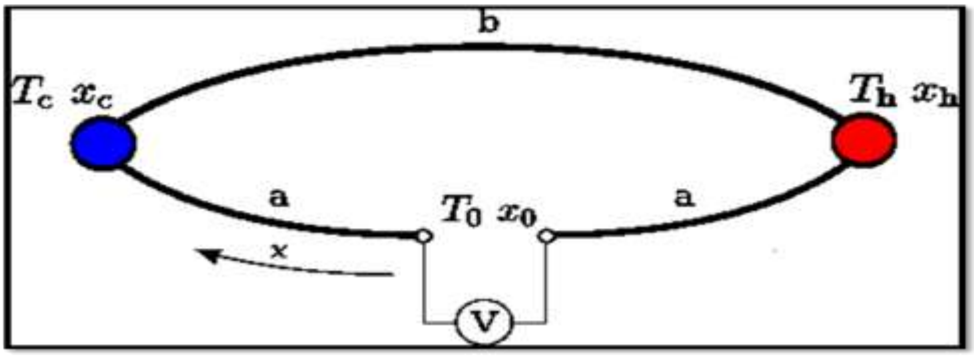


Fig 5.1: Working Principal Of TEG

5.1 Installation
a) Just after exhaust manifold.
b) Just before catalytic convertor.
c) After catalytic convertor

5.2 TEG in the automotive industry

For an automobile engine, there are two main exhaust heat gas sources which are readily available. The radiator and exhaust gas systems are the main heat output of an IC engine. The radiator system is used to pump the coolant through the chambers in the heat engine block to avoid overheating and seizure. Conversely, the exhaust gas system of an IC engine is used to discharge the expanded exhaust gas through the exhaust manifold. Zhang and Chua reported that presently TEG is mostly installed in the exhaust gas system (exhaust manifold) due to its simplicity and low influence on the operation of the engine. Furthermore, TEG system including the heat exchanger is commonly installed in the exhaust manifold suitable for its high temperature region. Basically, a practical automotive waste heat energy recovery system consists of an exhaust gas system, a heat exchanger, a TEG system, a power conditioning system, and a battery pack; with the operation of the TEG waste heat recovery system described as follows:
i) During the normal operation of an internal combustion engine, the produced waste heat released through the exhaust manifold is captured by the heat exchanger mounted on the catalytic converter of the exhaust gas system.
ii) Electricity is then generated from the thermal energy captured by the heat exchanger after it is transferred to the TEG system.
iii) Power conditioning is performed by the power converter to achieve maximum power transfer.

5.3 Challenges of TEG

The primary challenge of using TEG is its low thermal efficiency (typically Ztho4%) . Thermoelectric materials efficiency depends on the thermoelectric figure of merit, Z; a material constant proportional to the efficiency of a thermoelectric couple made with the material. Karri et al. stated that future thermoelectric materials show the Promise of reaching significantly higher values of the thermoelectric figure of merit, Z, and thus higher efficiencies and power densities can be obtained. Materials such as BiTe (bismuth telluride), CeFeSb (skutterudite), ZnBe (zinc–beryllium), SiGe (silicon–germanium), SnTe (tin telluride) and new nano-crystalline or nano-wire thermoelectric materials are currently in development stage to improve the conversion efficiency of TEGs. BiTe-based bulk thermoelectric material is mostly used in waste heat recovery power generation due to its availability in the market and high applicability in low and high exhaust gas temperature range. The performance of a thermoelectric material can be expressed as ZT¼S2T/kr, where S is the thermo power, T the absolute temperature, k the total thermal conductivity, and r the electrical resistance. Another challenge which is considerable is bigger size of the radiator and extended piping to the exhaust manifold. This problem can be mitigated by using a nanofluid in a radiator system. By using nanofluid, the size and weight of an automotive car radiator could be reduced without affecting its heat transfer performance.

5.4 Recent development of TEG in automotive industry

TEG could be coupled with various other devices to maximize its potential. Yu and Chua has proposed and implemented an automotive thermoelectric waste heat recovery system by adopting a Cuk converter and a maximum power point tracker (MPPT) controller into its proposed system as tools for power conditioning and transfer. The other exciting development of TEG is the combination of thermoelectric and photovoltaic (PV) systems which can be called as a hybrid system. Zhang and Chau proposed the TE-PV system coupled with MPPT controller to achieve maximum power output. They reported that the power improvement is recorded from 7.5% to 9.4% when the hot-side temperature of the TEG is heated from 100 1C to 250 1C and the irradiance of PV Generator (PVG) is fixed at 1000 W/m2. Typical waste heat energy

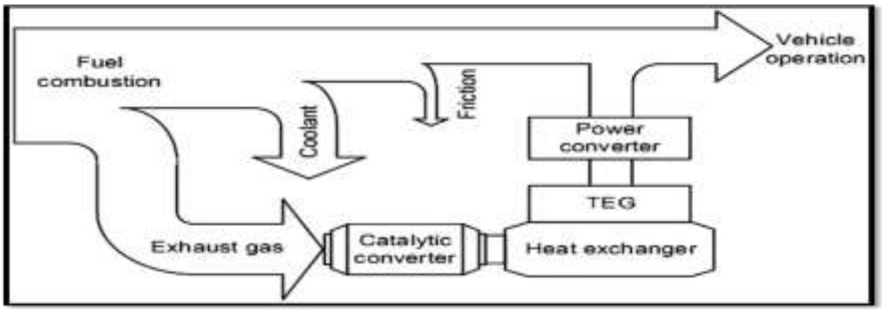


fig 5.4.1 : waste heat energy recovery system

VI. Advantages

1. Efficient use of exhaust gas energy:
2. Increase the fuel economy.
3. Reduce the load on engine.
4. Better control of pollution.

VII. Limitation

1. Setup is complicated
2. Cost is more due to complicated construction
3. Installation cost is more

VIII. Apllication

1. Electricity generation.
2. Preheating the air for carburetor
3. Hybrid vehicle
4. Gasoline engine vehicle
5. Passenger car
6. Pulp and paper mill
7. Truck engine

IX. Conclusion

It has been identified that there are large potentials of energy savings through the use of waste heat recovery technologies. Waste heat recovery entails capturing and reusing the waste heat from internal combustion engine and using it for heating or generating mechanical or electrical energy.

Also incorporating another system like exhaust gases recirculation technique, turbocharger and catalytic convertor with TEG leads to less production of pollutants like NOx and SO2 during creating the same amount of power

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