IC ENGINE WASTE HEAT RECOVERY SYSTEMS

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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). These include thermoelectric generators (TEG), organic Rankine cycle (ORC), six-stroke cycle IC engine and new developments on turbocharger technology. Furthermore, the study looked into the potential energy savings and performances of those technologies. The current worldwide trend of increasing energy demand in transportation sector are one of the many segments that is responsible for the growing share of fossil fuel usage and indirectly contribute to the release of harmful greenhouse gas (GHG) emissions. It is hoped that with the latest findings on exhaust heat recovery to increase the efficiency of ICEs, world energy demand on the depleting fossil fuel reserves would be reduced and hence the impact of global warming due to the GHG emission would fade away

Key Words: Waste Heat Recovery, Organic Rankine Cycle, Thermoelectric Generator.

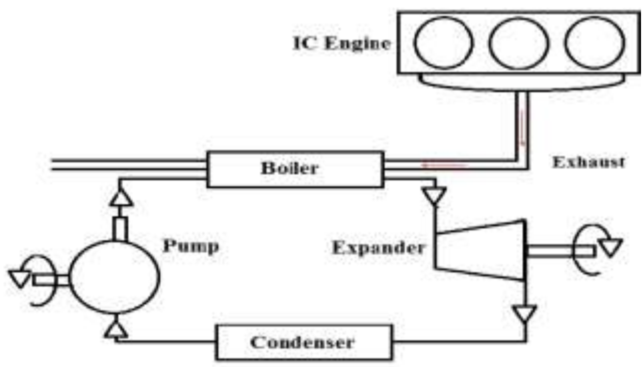
INTRODUCTION

Recent trend about the best ways of using the deployable sources of energy in to useful work in order to reduce the rate of consumption of fossil fuel as well as pollution. Out of all the available sources, the internal combustion engines are the major consumer of fossil fuel around the globe. Out of the total heat supplied to the engine in the form of fuel, approximately, 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting in to entropy rise and serious environmental pollution, so it is required to utilized waste heat into useful work. The recovery and utilization of waste heat not only conserves fuel, usually fossil fuel but also reduces the amount of waste heat and greenhouse gases damped to environment. It is imperative that serious and concrete effort should be launched for conserving this energy through exhaust heat recovery techniques. Such a waste heat recovery would ultimately reduce the overall energy requirement and also the impact on global warming

WASTE HEAT RECOVERY IN AUTOMOBILES

i. ORGANIC RANKINE CYCLE METHOD

Basic working principle of the waste recovery system is based on Organic Rankine cycle. Basically the system works on 4different thermodynamic cycles which describe heat absorption process, expansion process, heat rejection process and the pump work. The system consists of an evaporator or a heat generator, a turbine basically scroll or screw type, condenser and a pump. The waste heat obtained from the exhaust gas is supplied into the shell and tube heat exchanger ie, the evaporator at a temperature around 2000C – 2500C at 5 bar pressure. In the evaporator the working fluid is heated to super heat condition at temperature around 100C inside° the tube of the shell and tube heat exchanger. Now through the vapor line super heated refrigerant vapor flows into a turbine having single stage. By the expansion of super-heated vapor in turbine, turbine starts rotating thus required output power is produced. Now the expanded vapor is in the form of super-heated state or saturated vapor state or in liquid vapor form at exit condition i.e., about 50̊C at 1 bar. This vapor is now fed into a water cooled condenser, where the vapor is condensed into the liquid form. Now this liquid refrigerant is fed through liquid line and is pumped to the working pressure i.e. at 5bar by means of a positive displacement pump basically a diaphragm pump. The cycle is repeated for 'n' number of cycles. Now the micro turbine is coupled to an alternator to produce electrical energy and stored in a battery..



Rankine Cycle Diagram

Scope of the Work

This work focuses on the Rankine cycle as the most promising existing technology for engine waste heat recovery in terms of recuperation efficiency. While it is a comparatively mature technology and is widely used in power generation, its use in vehicles presents new challenges in system design. These stem from environmental and packaging issues, as well as difficulties relating to the quality and quantity of the available heat and its transient availability. It is not yet clear which working fluid and expansion device are optimal for use in a Rankine cycle-based system for vehicular applications. However, previous studies have indicated that these components are among the most important factors for the system's performance. The Rankine cycle is a promising technique to recover waste heat. This additional amount of heat recovered implies impacts on aerodynamic of the truck and/or on the existing cooling system. A simple Rankine cycle based on exhaust gas has been preferred as it is today a heat source that exists on all existing engines on the market (EGR or non EGR engines). By recovering on engine exhaust gases, the Rankine cycle will affect the engine fuel consumption because of higher pressure losses on the exhaust line. The challenge for waste heat

ADVANTAGES

- High turbine /thermodynamic cycle efficiency
- Turbine low mechanical stress
- No need de mineralize water
- No risk of blade erosion
- Complete automatic
- Simple maintenance procedure

DISADVANTAGES

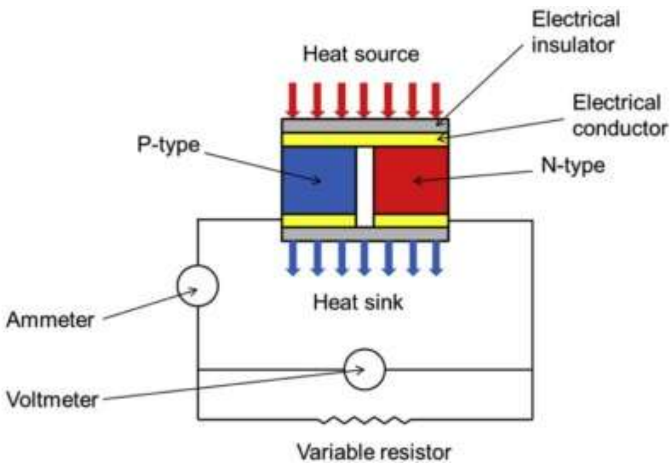
- very low pressure, high specific volume, big installations needed (turbine, condenser, etc)
- high pressure drop to become a high enthalpy drop: expensive multi-stage turbines needed
- expansion has to start in the superheated area to avoid too much moisture content after expansion
- efficiency loss and limited suitability to waste heat recovery

APPLICATIONS

The Organic Rankine Cycle (ORC) is a well matured waste heat recovery technology that can be applied in vehicle power trains, mainly due to the low additional exhaust backpressure on the engine and the potential opportunity to utilize various engine waste heat sources.

ii. THERMOELECTRIC GENERATOR METHOD

Thermoelectric generators (TEG) are solid-state semiconductor devices that convert a temperature difference and heat flow into a useful DC power source. Thermoelectric generator semiconductor devices utilize the Seebeck effect to generate voltage. This generated voltage drives electrical current and produces useful power at a load.



Thermoelectric Generator Module

A thermoelectric generator is not the same as a thermoelectric cooler. (also known as TEC, Peltier module, cooling chips, solid-state cooling)

A thermoelectric cooler works in reverse of a thermoelectric generator. When a voltage is applied to thermoelectric cooler, an electrical current is produced. This current induces the Peltier effect. With this effect, heat is moved from the cold side to the hot side. A thermoelectric cooler is also a solid-state semiconductor device. The components are the same as a thermoelectric generator but the design of the components in most cases differ.

While thermoelectric generators are used to produce power, thermoelectric coolers (Peltier coolers) are used for removing or adding heat. Thermoelectric cooling has many applications in cooling, heating, refrigeration, temperature control and thermal management.

ADVANTAGES

- Reliability
- Quiet
- No Greenhouse Gases
- Wide Range of Fuel Sources
- Scalability

DISADVANTAGES

- Thermoelectric generators are less efficient than some of the other energy conversion technologies.
- Thermoelectric generators can have a higher initial cost per watt of electrical power output than some energy conversion technologies for some applications.

- There is a fair amount of thermoelectric generator module manufacturing knowledge

CONCLUSIONS

The internal combustion (IC) engine is probably the most important heat engine nowadays but still has a major drawback: most current engine designs reject more than half of the supplied fuel energy in the form of heat losses. There is a pressing need to improve the efficiency of IC engines because of the danger of climate change and the earth's diminishing fossil fuel reserves, making the use of waste heat recovery systems for IC engines increasingly attractive. Systems based on the Rankine cycle are considered to be among the most promising technologies for this purpose because of their heat recovery efficiency. It has been observed that there is a large amount heat is waste from the engine. Approximately heat lost by exhaust as is same to useful work produced by engine. It is identified that there is large potential of energy saving through the use of waste heat recovery technologies. The recovery and utilization of waste heat not only conserves fuel but also reduces the greenhouse gases and waste heat by increasing efficiency of engine. This study shows the Benefits of waste heat recovery, Heat carried away by the exhaust gas, various possible methods for heat recovery. This also shows that the new concept of Heat wheel may be used for exhaust gas heat recovery for intake air preheating of Diesel engine.

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