DESIGNING NEW COOLING SYSTEM FOR AUTOMOBILES TO GET MORE FUEL EFFICIENCY AND LESS ENVIRONMENT DEFECTS.

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ABSTRACT

Almost all of the internal combustion engines waste a significant amount of their fuel energy from cooling system or exhaust gas. On the other hand in the warm season or regions, it needs to remove some extra heat from air conditioner radiator (condenser). This subject effects directly on global warming. Changing some part of this waste energy to shaft work (or electricity) not only has benefit in the way to find a source for hybrid automobiles but also, it has effect on global warming, fuel economy, saving natural resources and if the fuel produce CO_2, less greenhouse effect and less air pollution defect could be remarkable. In this work, a new cooling system is offered that is the same as a core of boiling water (nuclear) reactors (BWR), it means a subcooled working fluid could enter to engine shell then during the heat removes from engine and exhaust gas, it will be a boiling generator (boiling heat exchange) for a smart thermodynamic cycle. In this way not only could change some parts of unused energy to work, but also it has more capability with environment. Here, it is offered this idea by using the typical engines data. The Results confirm that it can recover at least about 20% of waste heat. This new cooling system is suitable for hybrid electric vehicle (HEV) which combines a conventional propulsion system with an on-board rechargeable energy storage system. However, it can use this idea for almost the entire internal ignition engines in automobiles or somewhere that needs to remove some heat from a device, same as condensers of modified power plants or engine of ships.

Keywords: Thermal efficiency, cooling system, Fuel efficiency, hybrid vehicle, global warming.

INTRODUCTION

World liquids petroleum and other liquid fuels consumption in the IEO2007 reference case [1] increases to 118 million barrels per day (239 quadrillion Btu) in 2030, as the world continues to experience strong economic growth. As it is shown in the Fig. 1, two-thirds of the increment in world liquids consumption in the reference case is projected for use in the transportation sector, where there are few competitive alternatives to petroleum.

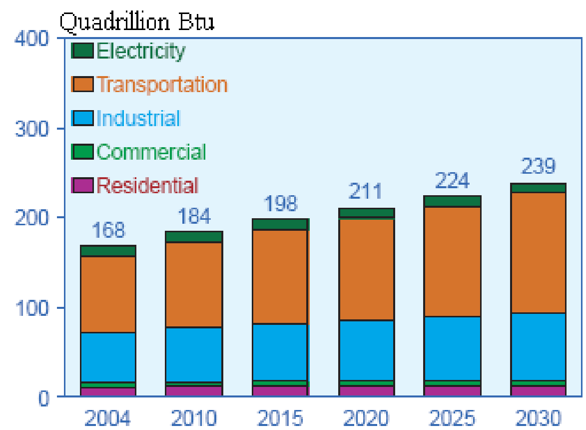

Fig1 World liquid fuels consumption by Sector, 2004-2030 [1]

In order to know about different type of fuel which is used for transportation, china is a good sample that is shown in Fig. 2 [1]. It is clear that the transportation fraction of liquid fuels is more than 50% of all. These two figures indicate that growth in economic activity and population growth are the key factors that determine transportation sector energy demand. On the other hand, because of overall thermal efficiency of transportation vehicles is less than 50% [2, 3], thus less than 50% of this energy could be employed to work in the transportation manner. It means that more than half of this energy will be transfer to environment directly. This subject has five important defects, consist of; increasing global warming, green house effect (because of additional exhaust gas), air pollution, wasting natural resources and final cost of the transportation. Hence researches on waste to energy in transportation (increasing thermal efficiency of vehicles) should be remarkable.

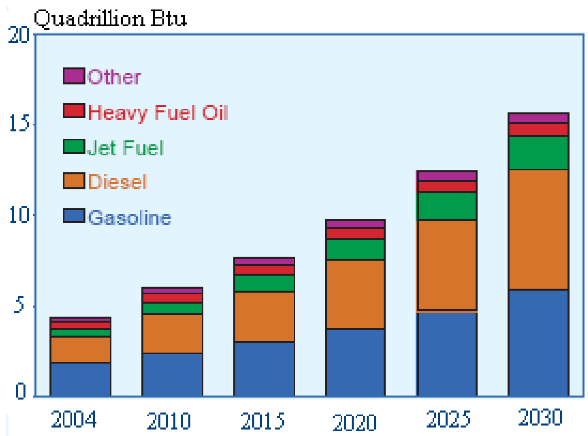

Fig2 China's Transportation energy use by fuel type, 2004-2030 [1]

Usually, energy wastes from two places in an engine; radiator (engine cooling system) and exhaust gas. The temperature of the coolant and exhaust gas depends on type of fuel and also which cycle the engine operates (Diesel, Otto, Dual, Miller…). However these temperatures for exhaust gas (at the instant time that exhaust valve is open) vary from about 650 ºC for Diesel one to 1150 ºC for Otto one [2]. Also typically, the coolant at engine water jacket has temperature about 60 ºC to 120 ºC for different automobiles.

Heat recovery from automotive engines has been predominantly for turbo-charging [2], cabin heating [4] or for recovery of heat to run absorption chillers [5-7]. Lin and Hou [8] investigate about the effects of heat loss characterized by a percentage of the fuel's energy, friction and variable specific heats of working fluid on the performance of an air standard Otto cycle with a restriction of maximum cycle temperature. Qin et al. [9] offered a new arrangement of exhaust gas-driven automobile metal hydride refrigeration systems.

In this study, it is offered three different ways to use some part of the waste heat of an engine, base on a smart thermodynamic cycle which works between high temperature fluid and environment temperature. The first one is Engine Waste Energy Converter (EWEC), which can use it for employing waste energy of engine jacket and exhaust gas with one working fluid. The EWEC system is good for new hybrid electric vehicles (HEV).The second one is Exhaust Gas Energy Converter (EGEC), for only the hot exhaust gas of an engine. Finally, the third one is Hot Liquid Energy Converter (HLEC) that could utilize instead of typical radiator of the old designed engines (most of the available engines) to recover fraction of the waste heat of cooling system.

ENGINE WASTE ENERGY CONVERTER (EWEC)

For converting some part of waste energy to work in a liquid-cooled engine, it could use a smart Engine Waste Energy Converter (EWEC) system. According to Fig. 3 this system has two different sections of cooling jacket. The first one is around cylinder (cylinder jacket) and the second one surrounds the exhaust gas (exhaust gas jacket). An exact compressed liquid as a working fluid enter to cylinder jacket with temperature and pressure of P_1, T_1 (in an actual case, one could obtain the working fluid and then the P_1, T_1). Whenever the working fluid gets temperature of engine operating condition, the thermostat let working fluid goes from cylinder jacket to exhaust gas jacket. It means, cylinder jacket is a pre-heater for exhaust gas jacket. The exhaust gas jacket is almost the same as a core of boiling water reactor (or smart heat exchanger), in which, the subcooled working fluid could enter to a housing and gets the heat of exhaust gas till boiling occurs.

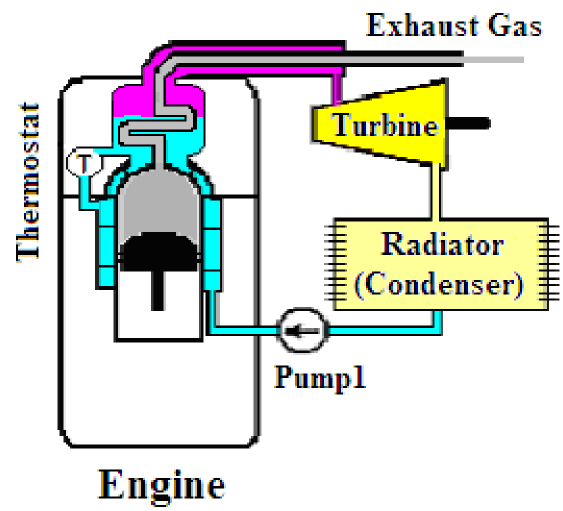

Fig3 Engine Waste Energy Converter (EWEC)

The exhaust gas transfers some heat during the path when is going out. Thus, during the cooling happens inside the exhaust pipe, boiling occur outside of the pipe for the working fluid, i.e. inside the housing. It can put a recirculation pump to circulate the working fluid inside the housing with an accurate control system. Therefore by changing the recirculation pumps performance, it can control the amount of exchanged heat. The upper parts of the pipe are not inside the working fluid, and then it helps to make dry (or a little superheat) the vapor of the working fluid along the path. It is the same as chimney in the BWR but heated one. Hence, boiling produce vapor and the vapor could go to a small turbine to generate shaft work (for air conditioner) or electricity (for any applications same as hybrid propose). Thus, this cooling system is suitable for hybrid electric vehicle (HEV) which combines a conventional propulsion system with an on-board rechargeable energy storage system.

EXHAUST GAS ENERGY CONVERTER (EGEC)

Usually a significant amount of energy wastes in the exhaust gases of automobiles, ships, gas-turbine power plants. It can get some part of this waste energy by using a proper working fluid in an exact thermodynamics cycle which could operate between the exhaust gas temperature and environment temperature. The Exhaust Gas Energy Converter (EGEC) is a smart thermodynamics cycle with proper working fluid for recovering some fraction of waste heat from a high temperature exhaust gas [10]. It includes boiling heat exchanger, turbine, condenser and a pump with a smart control system. Fig 4 shows an EGEC schematically, in which the hot exhaust gas could pass from down to up in a coil (or tube bundle), the out side of the coil is almost fill of a subcooled working fluid. The hot gas exchanges some heat to the working fluid, then after a while boiling occurs.

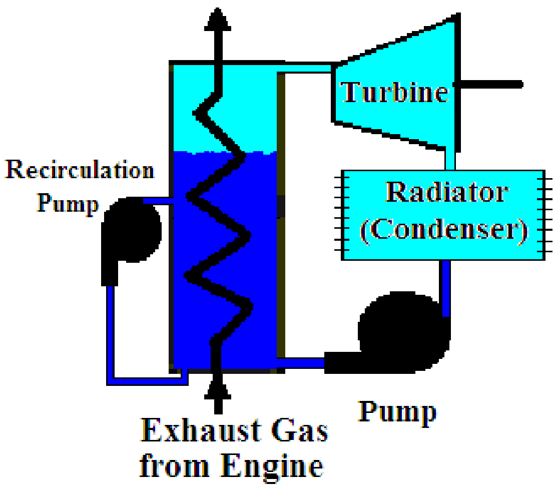

Fig. 4 The Exhaust Gas Energy Converter(EGEC)

Thus, the vapor could enter to a proper turbine to produce work. Depends on the amount of excess heat of the exhaust gas, it can use a recirculation pump to circulate the working fluid inside the heat exchanger with a smart control system. Therefore, it can enhance the amount of exchanged heat.

HOT LIQUID ENERGY CONVERTER (HLEC)

In order to converting some part of engine waste heat in almost all of ignition engines without much modification, it can use this idea. As it is shown in the Fig. 5, a Hot Liquid Energy Converter (HLEC) is almost the same as a Boiling condenser (BC) [11], in which, from upward to down, hot liquid (water) form engine coolant exit can enter inside vertical tube bundles (or tube coil). Outside of the tube bundles (inside the housing) is almost filled of a subcooled working fluid. The hot liquid loses some heat within coming down. Thus, during the liquid losses some heat inside the tube, boiling occurs outside of the tube. There can be a smart recirculation pump which circulates the working fluid among the tube bundles. Therefore with changing the recirculation pumps performance, it can change the velocity of boiling working fluid among the tube bundles. The upper parts of the tube bundles are not inside the working fluid, and then it helps to dry (or a little superheat) the vapor of the working fluid. Now, the vapor of the working fluid can enter a proper turbine in a cycle. Next, the vapor goes to a condenser that could be a new radiator for the engine. In this way, by utilizing, new radiator system, it is possible to get some work from unused energy and also it has more compatibility with environment.

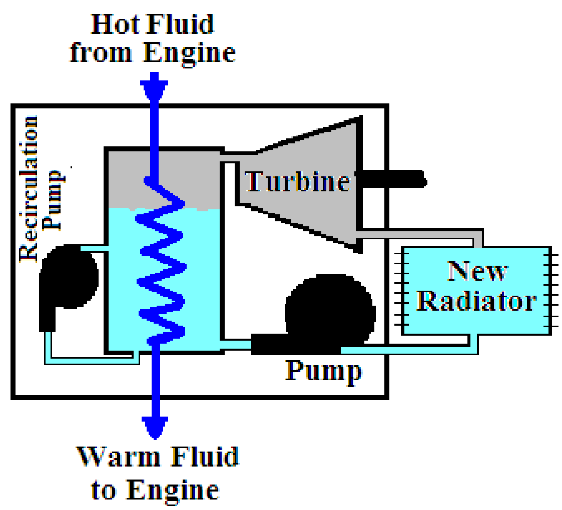

Fig. 5 The Hot Liquid Energy Converter (HLEC)

RESULTS AND DISCUSSION

All of the three cases of engine waste energy converter (EWEC), exhaust gas energy converter (EGEC) and hot liquid energy converter (HLEC) consist of an exact thermodynamics cycle includes a smart controller to adjust the cycle with environment in different weather. Thermal analyzing of an exact cycle needs to use data of an actual engine. In this study is used typical information of engines through lack of actual data. Typically, the coolant at engine water jacket has temperature between 60 ºC to 120 ºC and exhaust gas flow could be about 450 ºC [2]. According to these data in the table 1 and 2 are offered some sample thermal efficiencies of the thermodynamic cycle for some different conditions. The working fluid for table 1 is steam and for table 2 is R141-b. The average ambient temperature ($T_{amb\text{-}ave}$) in a year is assumed to be 20 ºC. For deriving this data, it is used EES software [12], by considering the pump and turbine efficiency of 90 %. This result shows that not only at least about 20% of unused energy of engine could be employed, but also it has consistency with environment. Table 1 and 2 are sample calculations of converting some part of engine waste energy to work. For example if an engine has 40% thermal efficiency (60% of fuel heat wastes from engine coolant and exhaust gas), by using EWEC recovery system with 30% waste heat recovery, the final thermal efficiency of the engine will be 58% Hence in an actual situation, with exact data, it could design more accurate cycle with proper working fluid for more efficiency. However, it can use these systems for anywhere that needs to remove some energy of high temperature gas or liquid.

Table1 Sample Calculation for thermal efficiency using Steam

Working Fluid of the Cycle = Steam	$\eta_{Thermal}$ *(%)*
Tmax = 330 °C , Tamb-ave =20°C Ttur= 300 °C, Tcond = 46 °C, P tur= 5 Mpa, P cond = 0.01 Map	*31.45*
Tmax = 280 °C , Tamb-ave =20°C Ttur= 250 °C, = 46 °C, P tur= 1.5 Mpa, P cond = 0.01 Map	*26.72*
Tmax = 180 °C , Tamb-ave =20°C Ttur= 150 °C, Tcond = 39 °C, P tur= 0.4 Mpa, P cond = 0.007 Mpa	*20.86*
Tmax = 130 °C , Tamb-ave =20°C Ttur= 100 °C, Tcond = 39 °C, P tur= 0.1 Mpa, P cond = 0.01 Mpa	*14.57*

Table 2 Sample Calculation for thermal efficiency using R-141b

Working Fluid of the Cycle = R-141b	$\eta_{Thermal}$ *(%)*
Tmax = 175 °C, Tamb-ave =20°C, Ttur = 165 °C, Tcond = 31.7°C P tur = 2.1 Mpa, P cond = 0.1 Mpa	*20.15*
Tmax = 160 °C, Tamb-ave =20°C, Ttur = 150 °C, Tcond = 31.7°C P tur = 1.7 Mpa, P cond = 0.1 Mpa	*19.21*
Tmax = 135 °C, Tamb-ave =20°C, Ttur = 125 °C, Tcond = 28.74°C P tur = 1 Mpa, P cond = 0.09 Mpa	*16.94*
Tmax = 120 °C , Tamb-ave =20°C Ttur = 110 °C, Tcond = 31.7°C, P tur = 0.8 Mpa, P cond = 0.1 Mpa	*15.05*

It is possible to manage the recovery group size of this work in the empty places which are around the engine.

Because of the boiling temperature of the working fluid of the recovery system is much less than the maximum temperature of exhaust gas, thus the unsteady conditions of the engine couldn’t effect on the ability of the recovery system.

CONCLUSION

Three different simple systems have offered in order to convert some part of the waste heat of an ignition engine to work. They are base on a smart thermodynamic cycle to adjust the cycle and environment. The first one is the Engine Waste Energy Converter (EWEC) which is good for new hybrid electric vehicles (HEV). It can convert both of the excess heat of engine coolant system and exhaust gas. The second one is Exhaust Gas Energy Converter (EGEC), for converting (only) exhaust gas energy to work. The last one is Hot Liquid Energy Converter (HLEC) that could employ a fraction of waste heat of engine coolant system for typical ignition engines. The results confirm that by using exact cycle and proper working fluid, it can employ at least about 20% of engine waste energy to work. This subject has five important advantages, consist of; decreasing global warming, green house effect, air pollution, wasting natural resources and final cost of the transportation.

NOMENCLATURE

EGEC	Exhaust Gas Energy Converter
EWEC	Engine Waste Energy Converter
HLEC	Hot Liquid Energy Converter
P tur	Pressure of working fluid at turbine entrance
P cond	Pressure of working fluid at condenser
Tamb-ave	Average temperature of environment in a year
Tcond	Temperature of working fluid at condenser
Tmax	Maximum temp. of exhaust gas (or coolant)
Ttur	Temperature of working fluid at turbine entrance

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