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RESEARCH ARTICLE

REVIEW ON UTILIZATION OF WASTE HEAT & RENEWABLE FUELS IN INTERNAL COMBUSTION ENGINE

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ABSTRACT

In this article, review on hydrogen internal combustion engines is discussed. The objective of this paper is to provide a means of waste heat and renewable hydrogen based fuel utilization. Energy, once used, is not regenerative. This means that, during any energy activation, we are filling up the space and Planet with parasite in the forms of energy (Anergy) or Global warming. The development of a high efficiency, low emissions electrical generator will lead to establishing a path for renewable hydrogen based fuel utilization. The increasingly worldwide problem regarding rapid economy development and a relative shortage of energy, the internal combustion engine exhaust waste heat and environmental pollution has been more emphasized heavily recently. 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 (fossil fuel) but also reduces the amount of waste heat and greenhouse gases damped to environment. This paper deals with the availability and possibility of waste heat from internal combustion engine, also describe loss of exhaust gas energy of an internal combustion engine.

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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 (Endo *et al*., 2007). Such a waste heat recovery would ultimately reduce the overall energy requirement and also the impact on global warming. The Internal Combustion Engine has been a primary power source for automobiles and automotives over the past century. Presently, high fuel costs and concerns about foreign oil dependence have resulted in increasingly complex engine designs to decrease fuel consumption. Many researchers recognize that Waste Heat Recovery from engine exhaust has the potential to decrease fuel consumption without increasing emissions, and recent technological advancements have made these systems viable and cost effective (Johnson *et al*., 2002). This paper gives a comprehensive review of the waste heat from internal combustion engine, waste heat recovery system and methods of waste heat recovery system. Major concerns to use of hydrogen as a renewable energy carrier today are:

- To provide a transition strategy from hydrocarbon fuels to a carbonless society and
- To enable renewable energy sources.

The first requires deep understanding while, the second one is self-evident. The most common and cost effective way to produce hydrogen today is the reformation of hydrocarbon fuels, specifically natural gas.

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Literature Review

Robert Williams discusses the cost and viability of natural gas reformation with CO_2 sequestration as a cost-effective way to reduce our annual CO_2 emission levels. He argues that if a hydrogen economy was in place then the additional cost of natural gas reformation and subsequent CO2 sequestration is minimal (Williams 1996), (Vijay Chauhan *et al*., 2012). Decarburization of fossil fuels with subsequent CO2 sequestration to reduce or eliminate our CO2 atmospheric emissions provides a transition strategy to a renewable, sustainable, carbonless society. However, this requires hydrogen as an energy carrier. Electrical generators capable of high conversion efficiencies and extremely low exhaust emissions will no doubt power advanced hybrid vehicles and stationary power systems. Fuel cells are generally considered to be ideal devices for these applications where hydrogen or methane is used as fuel. However, the extensive development of the IC engine, and the existence of repair and maintenance industries associated with piston engines provide strong incentives to remain with this technology until fuel cells are proven reliable and cost competitive. In addition, while the fuel cell enjoys high public relations appeal, it seems possible that it may not offer significant efficiency advantages relative to an optimized combustion system. In light of these factors, the capabilities of internal combustion engines have been reviewed.

In regards to thermodynamic efficiency, the Otto cycle theoretically represents the best option for an IC engine cycle. This is due to the fact that the fuel energy is converted to heat at constant volume when the working fluid is at maximum compression. This combustion condition leads to the highest possible peak temperatures, and thus the highest possible thermal efficiencies. Edson (1964) analytically investigated the efficiency potential of the ideal Otto cycle using compression ratios (CR) up to 300:1, where the effects of chemical dissociation, working fluid thermodynamic properties, and chemical species concentration were included. He found that even as the compression ratio is increased to 300:1, the thermal efficiency still increases for all of the fuels investigated. At this extreme operating for instance, the cycle efficiency for isooctane fuel at stoichiometric ratio is over 80%. Caris and Nelson (1959) investigated the use of high compression ratios for improving the thermal efficiency of a production V8 spark ignition engine. They found that operation at compression ratios above about 17:1 did not continue to improve the thermal efficiency in their configuration. They concluded that this was due to the problem of non-constant volume combustion, as time is required to propagate the spark-ignited flame (Caris and Nelson *et al*., 1959). The goal of emissions compliance further restricts the design possibilities for an optimized IC engine. For example, in order to eliminate the production of nitrogen oxides (NOx), the fuel/air mixture must be homogeneous and very lean at the time of combustion (Das 1990, Van Blarigan 1995). (It is subsequently possible to use oxidation catalyst technologies to sufficiently control other regulated emissions such as HC and CO) Homogeneous operation precludes diesel- type combustion, and spark-ignition operation on premixed charges tends to limit the operating compression ratio due to uncontrolled auto ignition, or knock. As well, very lean fuel/air mixtures are difficult or impossible to spark ignite (Christensen *et al*., 1998). James C. Conklin and James P. Szybist (James Conklin *et al*., 2010) have designed a six-stroke internal combustion engine cycle with water injection for in-cylinder exhaust heat recovery which has the potential to significantly improve the engine efficiency and fuel economy. R. Saidur *et al* (James Conklin *et al*., 2012) Rankine bottoming cycle technique to maximize energy efficiency, reduce fuel consumption and green house gas emissions. Recovering engine waste heat can be achieved via numerous methods. The heat can either be reused within the same process or transferred to another thermal, electrical, or mechanical process. Hou xuewjun *et al*. (2012) has studied the analysis of exhaust gas waste heat recovery and pollution processing for diesel engine. They analyzed total effect of waste heat on pollution or environment. Waste heat can be utilized for some useful works and it is reduces pollution. The diesel engine exhaust gas waste heat recovery rate increase with increasing diesel engine exhaust gas emission rate. On the other hand, lean charges have more favorable specific heat ratios relative to stoichiometric mixtures, and this leads to improved cycle thermal efficiencies. Equivalence ratio is no longer required to be precisely controlled, as is required in conventional stoichiometric operation when utilizing tree way catalysts. Equivalence ratio is defined here as the ratio of the actual fuel/air ratio to the stoichiometric ratio.

Advanced Combustion Approach

Homogeneous charge compression ignition combustion could be used to solve the problems of burn duration and allow ideal Otto cycle operation to be more closely approached. In this combustion process a homogeneous charge of fuel and air is compression heated to the point of auto ignition. Numerous ignition points throughout the mixture can ensure very rapid combustion (Onishi *et al.,* 1979). Very low equivalence ratios ($\varphi \sim 0.3$) can be used since no flame propagation is required. Further, the useful compression ratio can be increased as higher temperatures are required to auto ignite weak mixtures. HCCI operation is unconventional, but is not new. As early as 1957 Alperstein *et al*. (1958) experimented with premixed charges of hexane and air, and n-heptane and air in a Diesel engine. They found that under certain operating conditions their single cylinder engine would run quite well in a premixed mode with no fuel injection whatsoever. In general, HCCI combustion has been shown to be faster than spark ignition or compression ignition combustion. And much leaner operation is possible than in SI engines, while lower NOx emissions result. Most of the HCCI studies to date however, have concentrated on achieving smooth releases of energy under conventional compression condition (CR ~ 9:1). Crankshaft driven pistons have been utilized in all of these previous investigations. Because of these operating parameters, successful HCCI operation has required extensive EGR and/or intake air preheating. Conventional pressure profiles have resulted (Thring 1989, Najt and Foster, 1983).

In order to maximize the efficiency potential of HCCI operation much higher compression ratios must be used, and a very rapid combustion event must be achieved. Recent work with higher compression ratios (~21:1) has demonstrated the high efficiency potential of the HCCI process (Saidur *et al.*, 2012), (Christensen *et al.,* 1998, Christensen *et al.,* 1997).

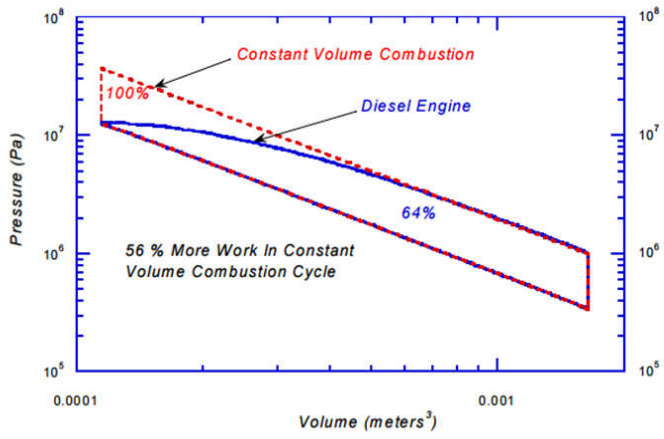

Fig. 1. Modern 4-Stroke Heavy Duty Diesel Engine

In Figure 1, the amount of work attained from a modern 4-stroke heavy duty diesel engine is shown at a 16.25 : 1 compression ratio. The results show that under ideal Otto cycle conditions (constant volume combustion), 56% more work is still available. This extreme case of non-ideal Otto cycle behavior serves to emphasize how much can be gained by approaching const

Heat recovery system for engine heat recovery

Large quantity of hot flue gases is generated from internal combustion engine etc. If same of this waste heat could be recovered, a considerable amount of primary fuel could be saved. It is depends upon mass flow rate of exhaust gas and temperature of exhaust gas. The internal combustion engine energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and losses be minimized by adopting certain measures. There are different methods of the exhaust gas heat recovery namely for space heating, refrigeration and power generation. The mass flow rate of exhaust gas is the function of the engine size and speed, hence larger the engine size and higher the speed the exhaust gas heat is larger. So heat recovery system will be beneficial to the large engines comparatively to smaller engines. The heat recovery from exhaust gas and conversion in to mechanical power is possible with the help of Rankine, Stirling and Brayton thermodynamic cycles, vapour absorption cycle. These cycles are proved for low temperature heat conversion in to the useful power. Engine exhaust heat recovery is considered to be one of the most effective means and it has become a research hotspot recently.

Possibility of heat recovery and availability from i.c. engine

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. This heat depends in part on the temperature of the waste heat gases and mass flow rate of exhaust gas. Waste heat losses arise both from equipment inefficiencies and from thermodynamic limitations on equipment and processes (Mohsin *et al*., 2012). For example, consider internal combustion engine 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. It means approximately 60 to 70% energy losses as a waste heat through exhaust (30% as engine cooling system and 30 to 40% as environment through exhaust gas). Exhaust gases immediately leaving the engine can have temperatures as high as 842-1112°F [450-600°C]. Consequently, these gases have high heat content, carrying away as exhaust emission. Efforts can be made to design more energy efficient reverberatory engine with better heat transfer and lower exhaust temperatures; however, the laws of thermodynamics place a lower limit on the temperature of exhaust gases. Fig. 2 show total energy distributions from internal combustion engine.

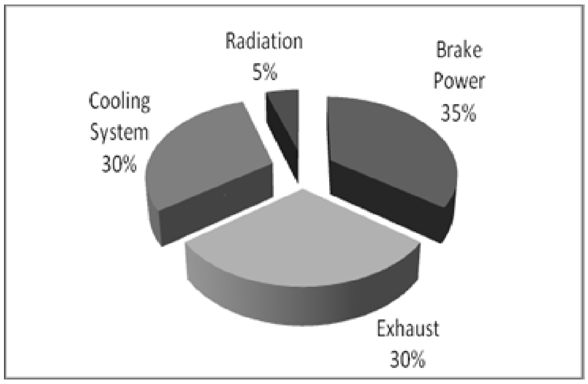

Fig. 2. Total Fuel Energy Content in I. C. Engines

Conclusion

It has been identified that there are large potentials of energy savings through the use of waste heat recovery technologies and usage of renewable fuels for energy combustion. Waste heat recovery defines capturing and reusing the waste heat from internal combustion engine for heating, generating mechanical or electrical work and refrigeration system. It would also help to recognize the improvement in performance and emissions of the engine. If these technologies were adopted by the automotive manufacturers then it will be result in efficient engine performance and Low emission. The waste heat recovery from exhaust gas and conversion in to mechanical power is possible with the help of Rankine, Stirling and Brayton thermodynamic cycles, vapour absorption. For waste heat recovery thermoelectric generator is use low heat, which has low efficiency. It is helpful for the same amount of increases in thermal efficiency and reduction in emission and usage of renewable energy fuels leads to sustainable development.

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