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Influences of Gasoline Fuels on Waste Heat Recovery Potentiality of a Spark Ignition Engine

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Abstract

Objectives: In this study, evaluation of the potential of energy recovery in spark ignition engine using RON 95 gasoline fuels. **Methods:** The engine has been operated at a single engine speeds of 3500 RPM with 50% of Wide Throttle Open (WTO). The potential of energy recovery was measured by means of engine effective power, Water Heat Losses (WHL) and Exhaust Heat Losses (EHL). **Findings:** Comparative analysis of the experimental results showed an improvement of 1.16%, 2.12% and 3.08% in EHL at 75°C, 50°C and 25°C, respectively, by taking 120°C as the reference temperature of EHL. The results of the contour plot showed that a trade-off between the WHL and EHL. **Conclusion:** Higher proportions of energy losses can be utilised by considering both WHL and EHL.

Keywords: Exhaust Heat Losses, Effective Power, Water Heat Losses (WHL)

1. Introduction

Gasoline fuel plays a major role in light duty industrial development and transportation sector. However, gasoline fuel is non-renewable energy and causes adverse effect to environmental pollution. As a result, stricter automotive legislations is mandated at different countries to combat these phenomenon[1]. The present high demand of gasoline fuel has also forced automotive researchers to fully utilise the potential energy sources from the combustion of gasoline fuels. The concept car of future generation of gasoline based vehicles, which fuel economy is nearly similar to hybrid cars, have recently been announced in the Japanese and European markets[2].

A gasoline engine used spark to ignite the combination of air and fuel in the combustion chamber. There are two types of gasoline engine that is normally used in the roads which is Direct Injection (DI) and Port Fuel Injection (PFI) spark ignition engines. Since the main use of both types of the engine is gasoline, and the burning of gasoline is the primary sources of atmospheric pollution, the first area for studying the potential of waste heat recovery will be from the analysis of heat transfer in Internal Combustion Engine (ICE) using the gasoline fuels. According to the research analysis of heat transfer in ICE, most of the engines produce 20% to 40% of engine effective power, which means that another 60% to 80% is taken away by the waste energy.

Finding ways to recover the lost from heat energy has become a main role in recent ICE development. The importance of energy usage from the heat losses in internal combustion engine has been investigated by various researchers. The use of energy recovery offers the potential for significant fuel reduction because this method capture and reuse the waste heat from ICEs for generating work. The key energy balance terms are the effective power, the WHL and the exhaust loss or EHL. The undetermined energy losses are categorised as the unaccounted heat loss[3]. Water injection towards in-cylinder exhaust heat recovery has been found to significantly improved fuel consumption and engine efficacy. Turbocompound was also described to reduce the engine fuel

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consumption and improve engine efficacy however it is still relying on engine condition[4]. Despite of the advantages mentioned in the literature, the cost to apply a waste heat recovery system may outweigh the advantage gained from the waste recovered heat. Additionally, maintenance of equipment as well as, extra instrumentations demand added maintenance cost.

The potential of waste heat recovery is an interesting topic to be discussed since once all of the energy distributed in and out of an engine was determined, it will be easier to address the patent landscape of the energy distributions. By knowing the estimated energy distributed as well, will direct those researches and engineers to find further approaches for better energy management. The aim of this research project has therefore been to try and establish the potential of energy recovery in internal combustion engine using gasoline fuel under 50% of WTO. All the works can provide further analysis for optimizing ICE energy utilization efficiency and evaluating the recovery potential of waste heat energy.

2. Materials and Methods

The engine was operated with gasoline fuel and denoted as G100 fuels in this study. Gasoline was bought from a local petrol station and kept in the engine laboratory. Table 1 lists the main properties of gasoline fuel.

Table 1. Properties of gasoline and 2-butanol[5]

Property	Gasoline	2-butanol
Molar C/H ratio	0.44 – 0.50	-
Density (kg/m3)	736	806.3
Latent heating value (kJ/kg^3)	44, 300	33, 000
Stoichiometric air/fuel ratio	14.6	11.1
RON/MON	95/85	101/92~97
Auto – ignition temperature (°C)	228 – 470	406.1
Boiling point (°C)	27 – 225	99.5
Heat of vaporization (kJ/kg)	349	551
Flammable limits (%volume)	1.4 – 7.6	1.7 – 9.8

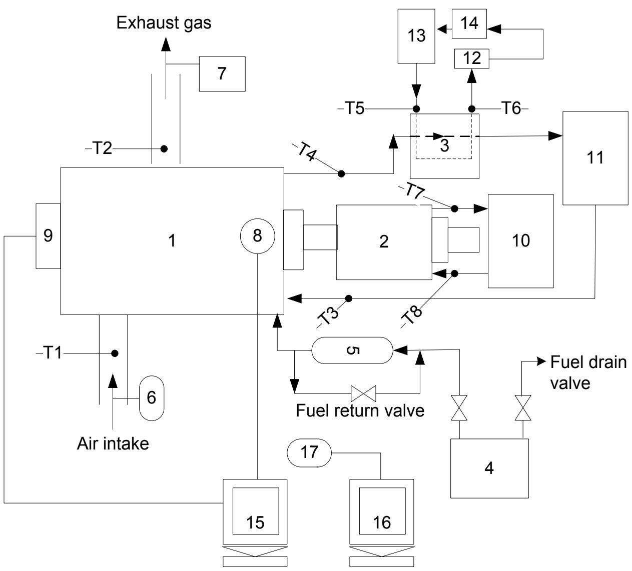
In this study, the research was done on a single overhead camshaft four-cylinder four-stroke port fuel injection naturally aspirated spark ignition gasoline engine. The engine specifications are given in Table 2. Figure 1 indicated the schematic diagram of the engine test bed. K-type thermocouples were assign to the engine and heat exchanger with data collected by a Picolog TC-08 data logger. The engine cooling from the external water tank was organized to maintain the temperature of the engine cooling water at 80°C. The external water tank was circulated and connected to the heat exchanger. Two thermocouples were attached separately to capture the reading of the external cold water temperature at the outlet and inlet of the heat exchanger. The engine was operated until the engine reached the steady state condition. Each experiment was repeated for three times, and the collected experimental values were averaged.

Table 2. Engine specifications

Engine Descriptions	
Bore x Stroke	81.0mm x 89.0mm
Piston Displacement	1834cc
Compression Ratio	9.5:1
Fuel injection type	Electronically controlled fuel injection
Max Power	86kW @ 5500rpm
Max Torque	161Nm @ 4500rpm

3. Results and Discussion

Figure 2 shows the energy flow diagram of the gasoline engine operated at engine speeds of 3500 RPM with 50% of WTO. In ICEs the heat from the fuel combustion was used to perform the work done. However, since the combustion was not 100% utilized as the useful energy, the energy was also taken away by the form of WHL, EHL and unaccounted losses. The two components of WHL and EHL has been identified as being potentially important for waste heat energy recovery technology. It is interesting to note that between WHL and EHL, EHL is the most attractive sources of energy for the heat recovery purposes. This is because of the high temperature contributed by the combustion process. The limiting factor is the temperature at which the EHL can be cooled. In this study, 120°C will be used as the reference temperature of cooled EHL. The baseline results at engine speeds of 3500 RPM is 22.13%, 22.68%, 28.52% and 26.68% for EHL, WHL, brake power and unaccounted losses, respectively. In order to further appreciate the EHL, the exhaust gas was assumed to be cooled down at three different conditions which is (b) 75°C, (c) 50°C and (d) 25°C. Based on the flow energy diagrams, it can be seen that a quarter of the fuel energy is converted to WHL, EHL and unaccounted losses. Comparing between WHL and EHL, apparently WHL is greater than EHL by 0.55%. However, the calculated difference between WHL and EHL increases by 1.16%, 2.12% and 3.08% once the energy is cooled down at 75°C, 50°C and 25°C, respectively. The relevant findings from this study is that there are possibilities to further used energy from EHL if we managed to recover the energy at lower temperature. In a previous study Abedin et al.[6] the analysis was not conclusive since the energy balance only focus at single exhaust temperature for EHL.



1.	Engine	11.	Engine cooling tank
2.	Dynometer	12.	Chiller
3.	Hear exchanger	13.	External water tank
4.	Fuel tank	14.	Water flow rate
5.	Fuel pump	15.	Combustion analyzer
6.	Air flow meter	16.	Computer
7.	Gas analyzer	17.	Data logger
8.	Pressure sensor		
9.	Crank angle encoder		
10.	Cooling tank		

Figure 1. Engine schematic diagram.

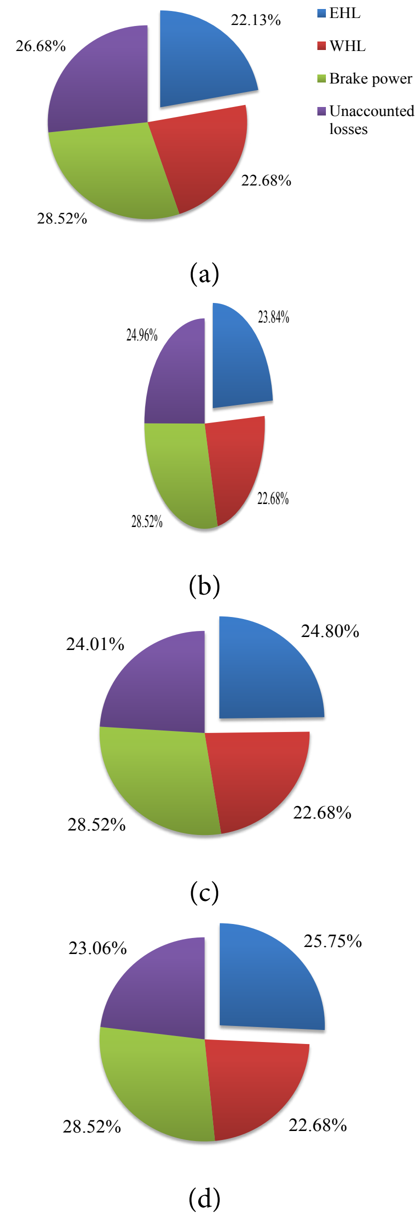


Figure 2. Energy flow diagram for G100 fuel at 3500 RPM with 50% of WTO: (a) exhaust gas cooled to 120°C; (b) exhaust gas cooled to 75°C; (c) exhaust gas cooled to 120°C and (d) exhaust gas cooled to 25°C.

However, a major problem with cooling the exhaust gas temperature is the formation of acid condenses and water precipitate at the exhaust part causing corrosion. Therefore, in practical applications, exhaust gas from gasoline combustion are cooled down to 120°C, because of the above-mentioned problem of the acid condenses. Therefore, data collected for this study has been selected at 120°C as the reference conditions.

Figure 3 shows the effects of the operating conditions on the energy distributions of the engine, for the G100 fuels at engine speeds of 1000 to 4000 RPM with 50% of WTO. The graphs represent the maps of effective power with respects to engine Brake Mean Effective Pressure (BMEP) and engine speed. It is apparent from this graphs that a better exploitation of the fuel is attained at higher engine speeds and loads. The main reason for this may have something to do with the lessening of energy losses contributed from the friction losses at higher engine speeds and loads. Throughout the graphs, the maximum engine effective power over the supplied energy are in the regions of engine speed 2000 to 3500 RPM and BMEP of 6.2 to 7.2 bar.

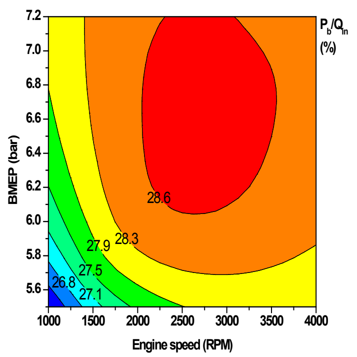


Figure 3. Percentage engine effective power over supplied energy with respects to engine BMEP and speed with 50% of WTO.

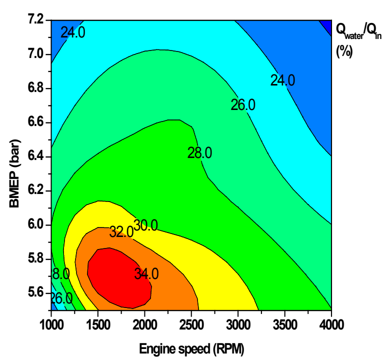


Figure 4. Percentage of WHL over supplied energy with respects to engine BMEP and speed with 50% of WTO.

Figure 4 indicates the percentage of WHL over supplied energy with the functions of engine BMEP and speed with 50% of WTO. The percentage of energy carried away by WHL is an important source of energy absorb by the coolant system. what is interesting in this data is that, WHL is more sensitive at lower engine BMEP at the regions of 5.5 to 6.0 bar and engine speed of 1400 to 2000 RPM by 34%. A possible explanation for these resutls may be the lack coverted energy to the effective work at low load, as a results most of he fuel energy is contributed into friction and heat transfer losses taken away by the WHL.

Figure 5 indicates the percentage of EHL over supplied energy with the functions of engine BMEP and speed with 50% of WTO. This graphs is quite revealing in several ways. First, at low loads and engine speeds from the range of 5.4 to 6.4 bar and 1000 to 2000 RPM, EHL was increased respects to the both parameters, by producing 3.8 to 19% of percentage of EHL. However, at point of engine BMEP in the range of 6.4 to 7.2 bar did not have a significant influenced towards the EHL. Interestingly, EHL is much more occupied at higher engine speeds at the regions of 2500 to 4000 RPM. A possible explanation for this might be that the time available for the combustion decreases and the time for heat transfer from the combustion products to the surrounding isreduced. Therefore, more fuel energy flows to the exhaust gas resulting in higher temperature at exhaust and hence, higher EHL percentages.

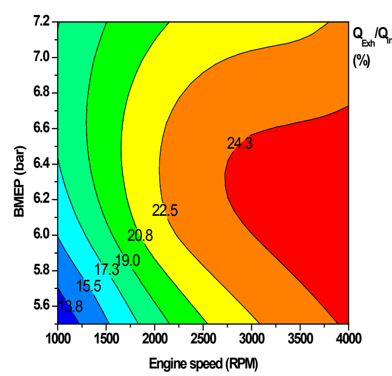


Figure 5. Percentage of EHL over supplied energy with respects to engine BMEP and speed with 50% of WTO.

4. Conclusion

This research analyse the extent of energy recovered in the gasoline engine. The energy analyses allow us to develop a systematic approach that can used to categorize the real losses of the total energy in spark ignition engine. Together, these methods will further benefits the potential of energy utilisation towards the engines by knowing the sites of the real losses of valuable energy. The main findings of the present work can be summarized as follows:

a. Comparing between WHL and EHL, apparently WHL is greater than EHL by 0.55%. However, the calculated difference between WHL and EHL increases by 1.16%, 2.12% and 3.08% once the energy is cooled down at 75°C, 50°C and 25°C, respectively.

b. The maximum engine effective power over the supplied energy are in the regions of engine speed 2000 to 3500 RPM and BMEP of 6.2 to 7.2 bar.

c. WHL is more sensitive at lower engine BMEP at the regions of 5.5 to 6.0 bar and engine speed of 1400 to 2000 RPM by 34%.

d. EHL is much more occupied at higher engine speeds at the regions of 2500 to 4000 RPM.

The International Conference on Fluids and Chemical Engineering (FluidsChE 2017) is the second in series with complete information on the official website[6] and organized by The Center of Excellence for Advanced Research in Fluid Flow (CARIFF)[7]. The publications on chemical engineering allied fields have been published as a special note in volume 3[8]. Host being University Malaysia Pahang[9] is the parent governing body for this conference.

5. Acknowledgement

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