Study on temperature profile of internal combustion engine exhaust gas for implementing waste heat recovery

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ABSTRACT – For a vehicle using internal combustion engine (ICE), the waste energy produced by exhaust can be harness by implementing waste heat recovery system. Temperature exhaust becomes a significant factor to be considered for recovering energy. The paper is study on the temperature profile from internal combustion engine of exhaust gas. A set of experiments are conducted in order to study the temperature profile by installing nine points of thermocouple that located along the exhaust gas pipe using the experimental vehicle. It is found that the temperature profile of exhaust gas is consisted in three segments that can lead to implement a waste heat recovery system such as Rankine Cycle system based on the boiling point of fluids.

1. INTRODUCTION

The energy from the automotive exhaust can be harness by implementing heat pipe heat exchanger in the automotive system. In order to maximize the amount of waste energy that can be turned to useful energy, the used of appropriate fluid in the heat exchanger is important. Water is used as the fluid, thus converting the system to steam turbine mechanism.

The waste heat energy covers about 70% of fuel energy. Therefore, it is of interest to recover this energy and utilize it to top up the efficiency of overall performance of internal combustion engine. This is as a waste utilization in term of waste-to-energy like other recycling methods such as carbon molecular sieve from waste of oil palm shell [1], and activated carbon from waste of pinang frond [2].

It has been identified in Peng et al. [3] that the temperature of the exhaust gas varies depending on the engine load and engine speed. As the engine speed increases, the temperature of the exhaust gas will also increase. The recent technologies on waste heat recovery of internal combustion engine (ICE) is consist of low grade heat from cooling system and high grade heat from exhaust system. For low grade waste heat, the organic Rankine Cycle is the favorite choice to recover waste energy [4], whereas high grade heat [5]. The temperature profile along the exhaust gas pipe is an important parameter to be known to determine what kinds of waste heat recovery system are appropriate to be implemented. Therefore, this study is being conducted. Note that, the study is done from real condition and on the real road track.

2. METHODOLOGY

The experiment was performed on a Toyota vehicle having 1.6 liter in-line four-cylinder gasoline engines. The detail of running this experimental vehicle can be found in Herawan et al. [6].

Since the exhaust stream pipe has certain length, hence it is wise to study heat distribution along the exhaust stream pipe for a broader picture of where the waste heat recovery system should be placed.

The experimental work of heat distribution along the exhaust stream pipe was conducted by installing nine points of thermocouple using three units of 4-channel Thermocouple logger (type K) along the exhaust pipe as shown in Figure 1. The actual implementation is shown in Figure 2.

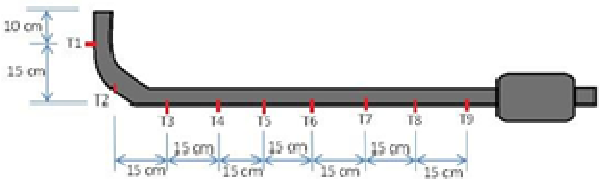

Figure 1 Schematic of thermocouples location along the exhaust pipe

Figure 2 Thermocouple point location on the experimental vehicle

3. RESULTS AND DISCUSSION

Figure 3 shows the temperature profile on the exhaust pipe of experimental vehicle. Figure 3 reveals that the nearer the position of the thermocouple to the exhaust manifold, the higher is the temperature gain. In

this case, T1 was the nearest position to the exhaust manifold followed by T2, T3 up to T9. During normal driving, the temperature was in the range of 100°C up to 500°C along the exhaust pipe, which was 120 cm long as shown in Figure 3 in the range of 0 to 370 s and 820 to 1620 s. Meanwhile, the full throttle test revealed that the exhaust temperature could go up to 680°C, which occurred in the range of 370 to 820 s (Figure 3).

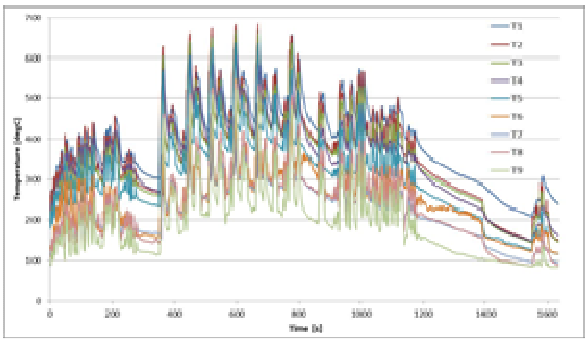

Figure 3 Temperature profile on the exhaust pipe of experimental vehicle

The dynamics profile of exhaust temperature, which is up and down of exhaust temperature was influenced by air flow rate, engine speed, and throttle angle which explained detail in Herawan et al. [7] in heat energy from waste heat. When throttle angle increased, this trend was followed by air flow rate, engine speed, and exhaust temperature. This behaviour also occurred when the trend of throttle angle was descending.

The temperature profile along the exhaust pipe based on thermocouple location can be seen in Figure 4. It is clearly shown that there are three segments which are the important finding to implement the correct waste heat recovery system. The first 40 cm from exhaust manifold exposed the highest temperature between 210°C up to 610°C. In this range as a first segment, the waste heat recovery system can be implemented an appropriate heat exchanger using high boiling point fluids such as water. Whereas on the second 45 cm from the first segment (as a second segment) subjected to the middle temperature between 100°C up to 320°C that suitable for organic fluids with lower boiling point. For the last 45 cm from the second segment (as a third segment) was seemly for lowest boiling point organic fluids since the temperature only between 100°C up to 160°C.

The waste heat recovery system which discussed previously, is lead to organic Rankine Cycle [4,5,7]. This system is consisted of steam generator or heat exchanger and steam turbine to generate work as a main component, and others are such condenser, receiver, etc.

4. CONCLUSIONS

The study of the temperature profile from internal combustion engine of exhaust gas in the experimental vehicle has been reported. It reveals that the nearer the position of the thermocouple to the exhaust manifold, the higher is the temperature gain. There are three segments along the exhaust gas pipe, which could be address for appropriate waste heat recovery system implementation on the correct location that based on the boiling point of fluids in Rankine Cycle system.

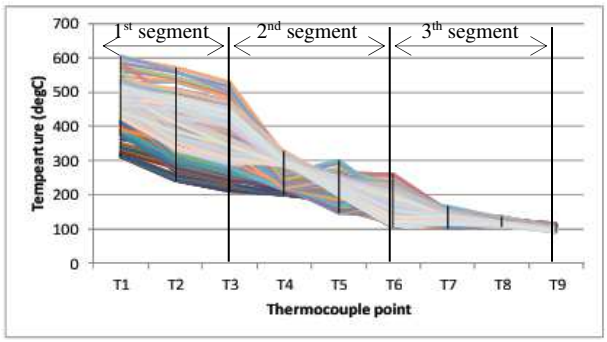

Figure 4 Temperature profile at thermocouple point with three segments

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