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An Experimental Study on Improved Fuel Economy and Lower Exhaust Emissions of New Automotive Engine adopting Split Cooling System

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This paper presents a split cooling system for a new inline 4-cylinder automotive engine. The split cooling system circulates coolant to the cylinder head and cylinder block separately. The coolant flow in the cylinder block is controlled by a 2^{nd} Thermostat installed at the outlet of cylinder block. The 2^{nd} thermostat closes when the coolant temperature is low. And this makes the coolant flow in cylinder block nearly stagnant, thereby reducing the coolant-side heat transfer coefficient and raising cylinder bore temperature. The 2^{nd} thermostat starts to open when the coolant temperature reaches a specified temperature. The test results on engine dynamometer show improved fuel economy and lower exhaust emission which result from the decrease in friction works and cooling loss. Also, several vehicle tests with application of the new engine have been performed. Fuel economy improvement of 0.5 ~ 2.0% yields from different test modes and details are discussed in this paper.

Keywords : Split-Cooling. Thermostat. Cooling Loss. Heat Transfer Coefficient. Friction Work

1. INTRODUCTION

Engine cooling in recent years has been concerned with controlling the coolant temperature in order to optimize the engine and vehicle cooling system which in turn can lead to improved fuel economy and emission.

In order to establish such aims, research into the characteristics of engine metal surface temperature[1] and new ideas based on such research are being applied to newly developed engines for optimization of cooling system. Application of Map Controlled Thermostat[2] and Split cooling system are good examples of the new approach[3.4].

The opening temperature for Map Controlled Thermostat is controlled by ECU and differs from the current mechanical thermostats that just depend on the surrounding coolant temperature. Map controlled Thermostat has a Precision Register installed to the Wax element and its opening can be controlled by computer set values as well as by the surrounding coolant temperature.

Such concept uses the fact that for most of the time a vehicle is driven in a low speed. part load condition that has relatively less heat generated compared to a full load. full speed condition and they aim to control the coolant at higher temperature to maintain optimum engine running condition. In other words. Map Controlled Thermostat aims to control the metal surface temperature by means of controlling the coolant temperature for all engine conditions.

On the other hand. the concept of Split Cooling is to separate coolant flow in cylinder head and cylinder block and by regulating the coolant flow in the cylinder block at the coolant exit via a second thermostat. which effectively allows higher coolant temperature in the block as well as control of the coolant flow. the temperature of the metal surface can be controlled as desired[5].

This split cooling method aims to increase the metal surface temperature of the cylinder block. which may be over cooled during a part load. low speed condition. in order to reduce friction loss and heat loss through the coolant and help contribute toward improving the fuel economy and emission.

With these in mind. this study investigated the effect of a second thermostat in split cooling system that are employed in newly developed engines and its influence on the metal surface temperature and the coolant characteristics. as well as the fuel economy and emission reduction. were measured in a bench test. The effect of split cooling on the fuel economy and emission was also measured in a vehicle test under various test modes. A problem of possible over heating in engine block in a full load. full speed condition due to the presence of a second thermostat has also been investigated and the effect of a proposed solution was tested.

2. EXPERIMENTAL APPARATUS

All the tests reported in this work have been performed on a newly developed 2.0 ℓ spark ignited 4-cylinder gasoline engine.

2.1 The Experiment Setup

The tests were proceeded with a vehicle and on a dynamometer. Figure 1 shows the schematic diagram of experimental setups on the dynamometer.

The coolant temperature was controlled with the temperature measured at the engine outlet. Since it was controlled by the radiator showering system. it was maintained at a certain temperature most of case.

The fuel consumption rate was measured with AVL 4210-F1 Fuel Instrument Controller. and the exhaust gas was measured with HORIBA Motor Exhaust Gas Analyzer MEXA-8210.

The vehicle tests were proceeded on both a chassis dynamometer and paved road. and to compare the difference of coolant temperatures in case of whether the second thermostat was mounted or not. A HMC's 2.0L MPI engine was employed for these tests.

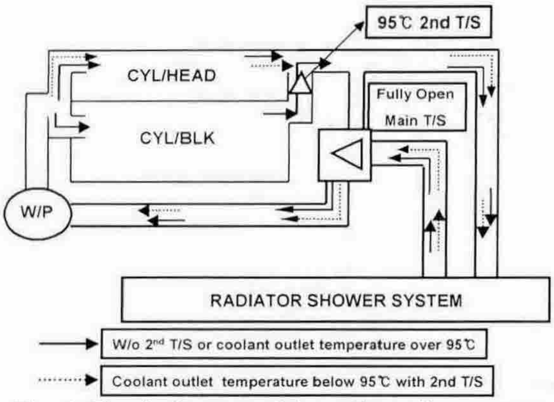

Fig. 1 Circuit diagram of the split cooling system

2.2 Experiment Methods

For these tests, several second thermostats with different opening temperatures were prepared to investigate the characteristics and effects of the separate cooling system. In this paper, the only two test results, which one is with the second thermostat of 95℃ opening temperature and without any second thermostat, were explained.

3. TEST RESULTS

The metal temperature of cylinder liner, fuel consumption rate, and emissions are examined at 2000 rpm, BMEP 2 bar with two conditions, i.e., with or without the 2nd thermostat. Figure 2 shows the temperatures of metal and coolant in the cylinder block with respect to the varying temperature of the coolant at engine outlet. The coolant temperature in block is kept higher than that at engine outlet with the 2nd thermostat closed, though no noticeable difference between them is observed without the 2nd thermostat. The phenomenon can be rooted from the fact that the coolant, once entering the cylinder block, becomes nearly stagnant and allows the heat transfer from cylinder bore during the sufficient period of time.

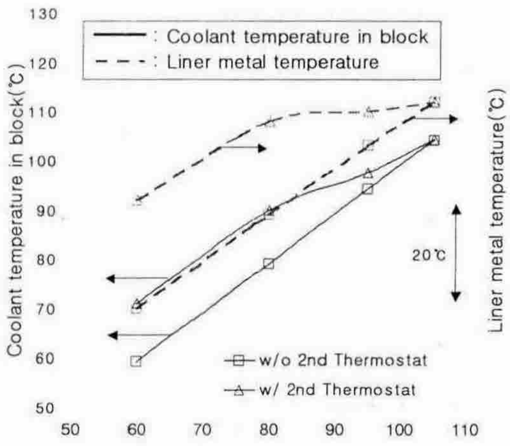

Fig. 2 Correlation between liner metal temperature and coolant temperature at engine outlet (2000RPM, 2bar BMEP)

The increment of the liner temperature amounts up to as much as two times the coolant temperature difference, from which it can be inferred that the split cooling is more effectively realized through the increased metal temperature by reducing coolant velocity and thus minimizing heat transfer coefficient of the coolant side rather than by increasing the coolant temperature itself. When the coolant temperature at engine exit reaches 105℃, the metal and coolant temperatures of two conditions becomes nearly the same, since the 2nd thermostat fully opens allowing similar flow patterns.

Maintaining the liner metal temperature at a higher level by employing the 2nd thermostat leads to the improvement of fuel economy and reduction of HC emission, which will be described in detail in forthcoming paper. The mechanism and results from several vehicle tests will be also discussed.

4. CONCLUSION

The split cooling concept was introduced in a newly developed engine and it was tested in a vehicle and on the dynamometer to investigate the effects and problems of it.

(1) The split cooling has effects on reducing the heat transfer rate to coolant and increase the coolant temperature in the cylinder block under low speed and low load conditions.
(2) The increased metal surface temperatures of the cylinder bore consequently decrease the fuel consumption rate and exhaust emission by lessening the friction and heat transfer rate to the coolant.
(3) These effects were investigated on the dynamometer tests by measuring the metal surface temperature, the coolant temperature, the fuel consumption rate, and the exhaust emission gas. Also, the reliability that it would not cause any problem in the metal surface temperature even in high speed and high load conditions was confirmed if the second thermostat were compulsively opened by the pressure difference.
(4) Through the vehicle tests, 0.5 ~ 2.0% of improvement in fuel consumption rate was obtained. In the real road test, split cooling shows more effects in conditions of low coolant temperature such as low environment temperature and the outstanding vehicle cooling performance by a strong dead wind.
(5) To complete the split cooling system, the leakage from the cylinder block must be minimized. However, this could cause to overheat the metal surface temperature of cylinder bore. Therefore, the leakage from the cylinder bore should be optimized regarding these two opposite points of views.

5. REFERENCES

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