

Effect of New Cooling System in a Diesel Engine on Engine Performance and Emission Characteristics

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ABSTRACT

Automotive manufacturers and engineers have paid attention to promoting engine performance with low emissions satisfying many emission regulations. With such goals in mind, we have investigated new cooling strategies such as high coolant temperature control, fast warm-up and post cooling using an automotive cooling system controlled by electronic actuators. The cooling system in a 2.7 liter HSDI engine was modified for the purpose of this study, and an engine experiment was carried out on a New European Drive Cycle (NEDC). The conventional water pump was decoupled from the engine and electronically controlled by a BLDC motor. Valves were installed at the coolant pathways between the engine and cooling components. Overall, this modification led to a reduction in both fuel consumption and exhaust gas emissions (e.g. THC, CO). The reduction was particularly considerable at the low speed and low load-drive conditions by controlling high temperature of the coolant. In addition, independent operation of the water pump along with the coolant flow control using valves reduced warm-up time during cold start which contributed to a decrease in harmful emissions and fuel consumption.

INTRODUCTION

A typical automotive engine cooling system has three major components, namely, a mechanical water pump, a cooling fan, and a wax-type thermostat.[1-6] These components are not independent of various engine driving conditions. The pump and fan are coupled with a

crank shaft by belts, thereby being subject to the engine operating speed.[7-10] Furthermore, the mechanical cooling pump is not able to supply sufficient flow for cabin heating at idle condition because of its low efficiency.[11] With respect to the thermostat, its opening and closing relies only on thermal expansion of wax. This gives rise to several shortcomings such as high pressure drop, slow response time and hysteresis. For these reasons, a flexible control of engine temperature is in great difficulty with current cooling technology. Fortunately, technologies on electronic pumps and actuators have been considerably developed; hence, such difficulty could be easily solved by replacing the mechanically driven system with electronically controllable one.[12-15]

Our strategy in this study was basically to employ electronic equipments that could control the coolant temperature and flow rate more flexibly. The strategy was expected to promote combustion performance in the aspect of fuel saving and emissions penalty. With such goal in mind, engine experiments were performed with a new cooling system containing an electric water pump (EWP) and electronic water valves. The experiment was also accomplished during warm-up period under the NEDC operating mode to explore how much the renovated cooling system could contribute to shortening the warm-up period.

EXPERIMENTAL APPARATUS

The experimental set-up used in this study is shown in Figure 1. It consisted of a cooler substituted for a radiator in real vehicles, an electric water pump, an electronic valve replaced with the wax-type thermostat, and an emission sampling system (Horiba MEXA-7100DEGR). The engine for this experiment was the 2.7L HSDI diesel engine. The specifications of the engine are summarized in Table 1.

Thermocouples were used to measure the coolant temperature, and the temperature data were sent to a control module to determine the valve opening ratio.

A conventional water pump was operated electrically by connecting it with a BLDC motor. To select the capacity of BLDC motor, the driving torque of the water pump was measured. This motor had a uniform driving torque for all pump speed range.

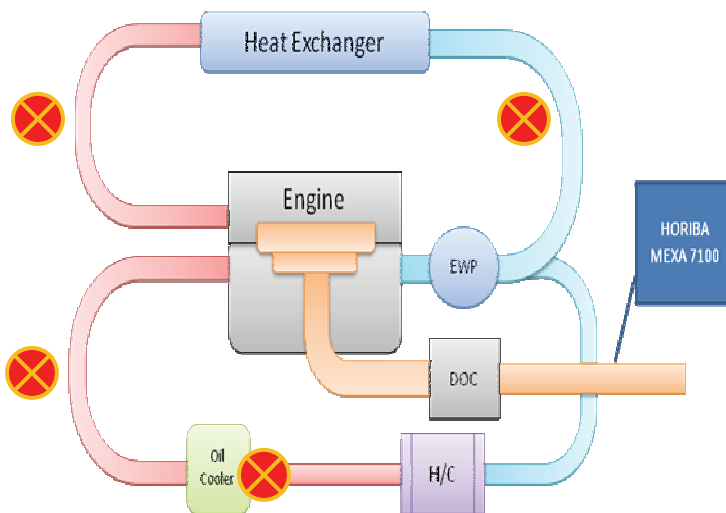


Figure 1 Schematics of experimental set up

Table 1 Engine Specification

Cylinder array	In line 5
Swept volume	2696cc
Bore x Stroke	86.2mm x 92,4mm
Number of valves	20
Compression ratio	18 : 1
Rated power	125kW at 4000rpm
Rated torque	347Nm at 1800rpm

TEST PROCEDURE

OPERATING CONDITON

For the dynamometer test, eight different engine conditions were selected based on the NEDC drive cycle. The list of Key Point and corresponding engine conditions are tabulated in Table 2:

Table 2 NEDC Key Point

Key Point		1	2	3	4	5	6	7	8
Speed	rpm	750	1100	1200	1600	2000	1900	2200	2600
Torque	Nm	2	120	34	64	21	172	152	238
BMEP	bar	0.1	5.6	1.6	3.0	1.0	8.0	7.1	11.1

These conditions were spread over the various engine load range as the real engine driving cycle. Engine BMEP was suspected to be dependent in the real engine driving conditions.[15]

In order to find the effect of coolant temperature, the experiment was carried out for each Key Points by increasing coolant temperature from 90 to 105°. A cooler was used to change the coolant temperature and maintain it constant for this set of experiment.

For this case, an electric water pump was used to control the coolant flow rate. Through reducing the water pump speed, the flow was down to 60% of conventional flow, which was the minimum coolant flow rate as the best condition for safety issues. Beyond the flow rate, the engine temperature would be overheated.

FLOW CONTROL SYSTEM

During warm-up period, the engine temperature needs to be increased as fast as it could because combustion performance is not optimum. This transient period