Research on Coolant Using Nano Additives and Heavy Water

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ABSTRACT

Research was done on coolants with the objective of increasing automobile radiator cooling efficiency and contributing to aerodynamics by enhancing the thermophysical properties of engine coolants.

The research confirmed the effectiveness of adding nano additives to enhance heat conductance, as well as using heavy water in solvent to increase specific heat of the coolant. Because evaluations of cooling performance in actual engines have not shown a clear difference from conventional coolants using water, a precise heat transfer measurement technology was established to clarify the factors affecting heat transfer, and from this, directions were established for the development of engine coolants.

1. Introduction

Formula One engine coolants have conventionally used water. Coolants circulate between the engine and radiator to radiate heat. Increasing the radiator's cooling efficiency makes it possible to reduce the surface area of the radiator duct aperture and lower aerodynamic resistance. Additionally, by making the radiator itself smaller, it is possible to design in ways that reduce weight and enhance aerodynamic characteristics, factors that could shorten lap times.

The target of the research was to enhance cooling efficiency by the equivalent of one rank of duct aperture surface area (equivalent to reducing coolant temperature by 4°C) by enhancing the coolant's thermophysical properties. This paper introduces research that, based on a patent[(1)] concerning heat transport fluids from research on mass-produced automobiles, sought to raise the coolant's heat transfer coefficient by producing experimental coolant whose thermophysical properties have been enhanced by adding nano additives at a high concentration and using heavy water.

2. Materials Development

The heat transport capacity of coolants is generally calculated from the specific heat per unit volume and from the heat transfer coefficient, as shown in Eq. (1). From Eq. (3), which is found by substituting Eq. (2) into Eq. (1), it is supposed that raising thermal conductivity, raising specific heat and lowering viscosity will cause heat transport capacity to increase.

Heat transport capacity =

$$\underbrace{[Cp \times \rho]}_{\text{Specific heat per unit volume}} \times \underbrace{[Pr^{1/3} \times \lambda \times (U/\nu)^{1/2}]}_{\text{Heat transfer coefficient}} \quad (1)$$

$$Pr = \frac{\nu \times Cp \times \rho}{\lambda} \quad (2)$$

Substituting (2) into (1),

Heat transport capacity =

$$[Cp \times \rho] \times [\nu^{-1/6} \times (Cp \times \rho)^{1/3} \times U^{1/2} \times \lambda^{2/3}] \quad (3)$$

Pr: Prandtl number; Cp: specific heat; ρ: density;
ν: dynamic viscosity
U: flow velocity; λ: thermal conductivity

The properties of the coolant experimentally produced are shown in Table 1. Based on a heat transport fluid patent, the aim was to increase the coolant's thermal conductivity by adding cup-stacked carbon nanotubes (below, CS-CNT). Coolant DW178 was test-produced in which dispersant was used in water to disseminate CS-CNT at a rate of 10 wt%, and the coolant was tested in a wind simulator[(2)], but the radiator became clogged and prevented evaluation. The cause is believed to be that the heat tolerance of the dispersant was insufficient in the coolant temperature zone of 100°C and up in which coolants are used in Formula One racing.

The aim in this research was to increase thermal conductivity by not using a dispersant whose heat tolerance was in question, and to increase specific heat

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Table 1 Thermal properties of coolant

Material	Additive	Dispersant	Thermal conductivity W/(mK)	Specific heat J/(cm³K)	Kinetic viscosity mm²/sec	Density g/cm³
H_2O (Base)	–	–	0.61	4.2	0.7	1.00
DW178	CNT 10%	ROSO$_3$-Na	0.74	4.0	1.4	1.06
$H_2O+Al_2O_3$	Al_2O_3 30%	–	0.73	4.0	1.5	1.27
D_2O	–	–	0.60	4.6	0.9	1.11
$D_2O+Al_2O_3$	Al_2O_3 30%	–	0.79 (+30%)	4.5 (+7.7%)	2.5 (+270%)	1.41

by using heavy water. Al_2O_3 nano additive (below, Al_2O_3), formulated by a sputter rapid cooling technique, was used as an additive since it offers better dispersion in water as compared to CS-CNT. To increase specific heat, heavy water (below, D_2O) was used that has 10% higher volume specific heat than ordinary water (below, H_2O). Adding Al_2O_3 to D_2O at a rate of 30 wt% increased thermal conductivity by 30% and specific heat by 7.7%. Viscosity, however, also increased by 270%.

Three formulations were tested in the wind simulator: Al_2O_3-added H_2O, Al_2O_3-added D_2O, and D_2O. The cylinder head temperature fell by 2 - 5°C, but at the same time engine output dropped by 4 - 8 kW, there was no correlation between test results, and reproducibility was low. Therefore, a technique was devised that evaluates the coolant, including the impact of the flow of each coolant, by separating heat conduction within solids and the heat conduction on the fluid/solid boundary.

3. Stand-alone evaluation results

A liquid-circulating heat exchange testing system was built as shown in Fig. 1. Figure 2 shows results of measuring heat transfer coefficient dependence on flow velocity. The development specifications suggest that cooling performance will be enhanced as compared to water in the flow velocity zone of 0.5 m/sec and below, but above 0.5 m/sec, cooling performance will decline. It is predicted that since the flow velocity in the cylinder head's water channels is 2 - 6 m/sec, and that inside the radiator tubes is 1 - 2 m/sec, cooling efficiency will decline if this is used in Formula One coolants.

Based on the above, at low flow velocities, the impact of the liquid's thermal conductivity will be great, but at high flow velocities, the impact of viscosity will

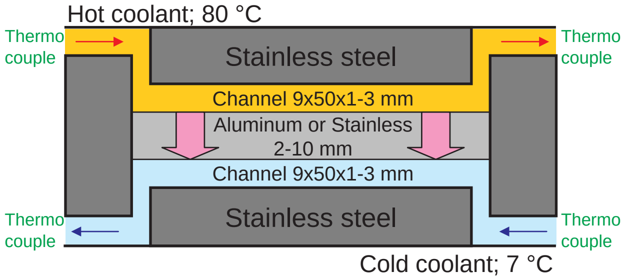

Fig. 1 Overview of heat transfer coefficient measurement apparatus

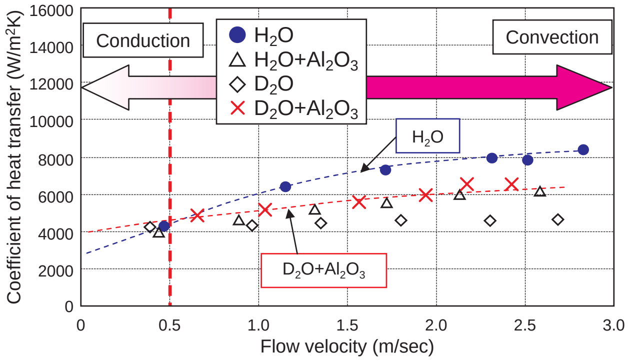

Fig. 2 Relationship between heat transfer and flow rate

be great. In other words, at low flow velocities, heat transfer within and among substances is dominant, but at high flow velocities, heat transfer from movement of the substances themselves is dominant. This made it clear that an automotive engine coolant must be formulated to strike a good balance between increasing thermal conductivity and reducing viscosity.

4. Conclusion

The newly developed nano fluid increases thermal conductivity, but at the same time causes an increase in viscosity because of the effect of interactions between additive particles, indicating that cooling efficiency would decline at the flow velocities at which Formula One engine coolants are used. Therefore, engine coolants need to be formulated to strike a good balance between increasing thermal conductivity and controlling increases in viscosity.

References

(1) JP, P2008-201834, A (2008)
(2) Nakamura, S., Motohashi, Y., Hayakawa, S.: Development of Wind Simulator Equipment for Analysis of Intake Phenomena in Formula One Engines, Honda R&D Technical Review, F1 Special (The Third Era Activities), p. 95-100

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