

Development of Lightweight and Low-friction Resin Materials for Oil Pump Rotor

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ABSTRACT

The total weight of the scavenge and feed oil pump rotors fitted in Formula One V10 engines was previously more than 1 kg, leading to demands for weight savings and friction reductions. A polyethyl ethyl ketone material and a polyimide material have been used to manufacture the scavenge pump outer rotor in a two-stage injection molding process, and a polyethyl ethyl ketone extrusion material has been used to manufacture the feed pump outer rotor. This has resulted in a weight saving of 465 g and a friction reduction of 1.8 kW.

1. Introduction

Because dry sump lubrication is employed in Formula One engines, two oil pumps are used: A feed pump to increase pressure, and a scavenge (“scav”) pump to scavenge oil. Both pumps are trochoid pumps. One set of rotors for the feed pump and seven sets of rotors for the scav pump are fitted in each V10 engine at the commencement of development, the total weight of which was previously more than 1 kg. The oil pump rotors have conventionally been manufactured from steel and aluminum (Al) sintered metal. The project discussed in this paper developed resin rotor materials in order to achieve weight savings and reduce friction.

2. Product Development

2.1. Material Evaluation

The materials used to manufacture pump rotors are required to display mechanical strength, dimensional stability, wear resistance, and sliding performance at oil temperatures of around 120 °C. Candidates for the resin material were selected from among high-strength and high temperature resistance super engineering thermoplastic resins and thermosetting resins. These were a polyethyl ethyl ketone (PEEK) injection material reinforced with 30% carbon fiber (CF), a PEEK extrusion material reinforced with 30% CF, a thermoplastic polyimide (PI) injection material reinforced with 30% CF, and a phenol resin injection material reinforced with 40% glass fiber (GF). High-temperature tensile tests and high-temperature tensile fatigue tests were conducted on test pieces formed into ASTM#1 dumbbells. The results of the fatigue tests are shown in

Fig. 1. The materials selected were the PEEK injection material reinforced with 30% CF and the PI injection material reinforced with 30% CF, which displayed high strength in the temperature range in which the rotors would be used.

2.2. Development of Manufacturing Methods

Injection molding not only enables the achievement of high strength, but also obviates the need for the cutting process, thus reducing costs. However, because the outer rotor is thick, it was a challenge to achieve dimensional accuracy using normal injection molding, given the large surface sink. A two-stage process was therefore applied in which the inner part of the outer rotor is molded first, after which the outer part of the outer rotor is molded by enveloped casting. The two-stage injection molding method enables different

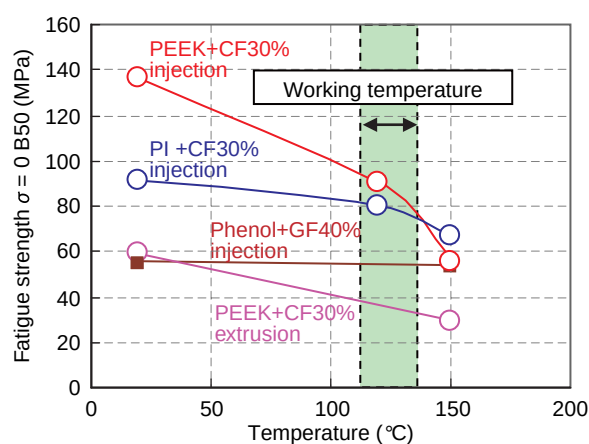


Fig. 1 Fatigue strength of resin materials

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materials to be used for the inner and outer parts. The PEEK material with its good wear resistance was employed for the inner part and the PI material with its good dimensional stability was employed for the outer part, enabling the issues of the surface sink and wear resistance to be resolved simultaneously. In addition, the method has enabled the accuracy of the teeth on the outer rotor to be controlled to within $\pm 20\text{ }\mu\text{m}$, and the teeth machining process can therefore be omitted (Fig. 2). The inner rotor is manufactured using a WE54 magnesium alloy extrusion material in order to achieve weight savings. A weight saving of 420 g (53%) was achieved against Al sintered materials in the case of the scav rotor.

The coefficient of thermal expansion of the resin materials varies with their method of manufacture, and they display strong anisotropy. For the injection materials, the coefficient of thermal expansion was measured in two directions to set the dimensions. For the extrusion materials displaying a high level of variation between lots, the coefficient of thermal expansion of different lots was measured in two directions in order to set the rotor thickness and the diameter dimensions.

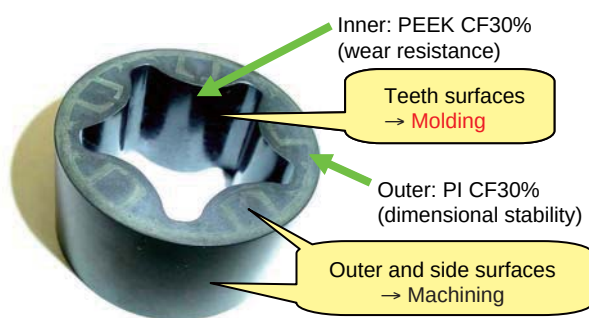


Fig. 2 Developed outer rotor manufactured using two-stage injection molding

3. Performance and Effects

An oil pump rig test was performed at an oil temperature of 100 °C using an injection molded resin scav rotor. As Fig. 3 shows, the results of the test indicated a 10% decline in torque. An engine test showed a decline in friction of 1.8 kW. No mechanical damage or significant performance declines were observed following engine durability tests.

There were concerns that the use of resin for the feed rotor would increase rotor wear due to increased pressure. The wear resistance of a variety of materials was tested in oil pump rig tests. The lowest amount of wear was displayed by a rotor with an outer rotor manufactured using the PEEK extrusion material, and an inner rotor manufactured using an Al sintered material. In addition, no significant performance declines were observed following engine durability tests using a rotor manufactured from these materials. A weight saving of 45 g (52%) was achieved in the feed pump.

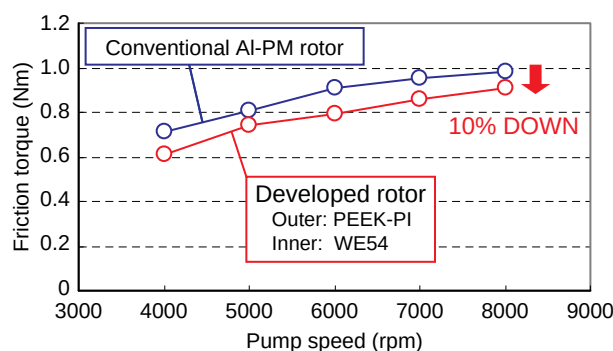


Fig. 3 Results of friction torque measurements

4. Conclusion

Resin oil pump rotors were developed, with the following outcomes.

(1) Scav pump rotor

The outer rotor is manufactured from PEEK and PI in a two-stage injection process, and the inner rotor is manufactured from WE54 magnesium alloy, resulting in a weight saving of 420 g and a friction reduction of 1.8 kW. The new rotor has been employed in races since the first race of 2004.

(2) Feed pump rotor

The outer rotor is manufactured from a PEEK extrusion material and the inner rotor is manufactured from the conventional Al sintered metal, resulting in a weight saving of 45 g. The new rotor has been employed in races since the 16th race of 2004.

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