Development of a Totally Enclosed Permanent Magnet Synchronous Motor

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1. Development objectives

Traction motors for electric trains are generally equipped with a ventilation cooling system to save weight and boost motor power outputs. Unfortunately, the ventilation brings outside dust and dirt into the motor, necessitating periodic disassembly and cleaning of the motor. The ventilation system is also a source of noise. If, however, the traction motor is totally enclosed, it will not need such disassembly or cleaning, and will emit less noise. Enclosing the motor, however, would lead to the need for a new type of cooling structure and greater efficiency, to prevent the temperature of component parts from rising above acceptable limits while ensuring sufficient motive power.

We therefore examined the possibilities of a highly efficient permanent magnet synchronous motor (PMSM), and first developed a totally enclosed prototype with a continuous rated output of 140 kW. We then examined the possible use of such a motor for a next-generation train for suburb-to-city transit, and developed a traction motor with a far higher continuous rated output of 235 kW. (Fig. 1)

2. Prototype motor design

Development of the more powerful motor targeted a maximum train speed of 140 km/h, a high acceleration rate of 2.6 km/h/s, and a train set configuration ratio of 1 motorized car to 2 trailers. For these reasons, we targeted an increase in the continuous rated output to 235 kW. In addition, because the new motor would be used on narrow-gauge (1067mm) track, we designed a totally enclosed PMSM that would meet space restrictions, while still ensuring the targeted output.

If a PMSM is to be used to power an electric train, the induced voltage from the magnet must not exceed acceptable limits. We therefore designed the rotor of the motor so that it would increase the magnetic saliency to generate the reluctance torque (see Fig. 2). This enables the reduction of the induced voltage while preventing an increase in electric current.

Fig. 1 235kW Totally-enclosed PMSM

We also employed a sensorless control system to eliminate the need for a rotor position sensor. This ensured enough space for the greater output, greater reliability and lower cost.

3. Test results

We first performed temperature rise tests and verified that the prototype motor could achieve the targeted output within acceptable temperature limits. From the test results, we calculated an efficiency rate of about 97%, considerably higher than the approximately 92% of a conventional traction motor.

We also measured noise emitted from the prototype motor when in stationary operation, and determined that noise levels were lower than those of a conventional induction motor (see Fig. 3). The ventilation fan and other components of a conventional self-ventilated traction motor emit noise that increases with rotation speed. On the other hand, measurement results indicated that, by totally enclosing the prototype motor, it is possible to reduce noise levels far below those of a conventional motor operating in the high-speed range.

4. Conclusions

We found that mounting a permanent magnet synchronous motor within a totally enclosed structure makes it possible to reduce maintenance, cut noise emissions and save energy, while still maintaining the motive power of a conventional traction motor. The results also indicated a continuous rated output of 235 kW, even in the restricted space available for narrow-gauge track operations. The new traction motor technology is now being used in U@tech test vehicles of JR West for tests on actual rolling stock equipped with the totally enclosed PMSM, with a view to using this new type of motor in commercial operations.

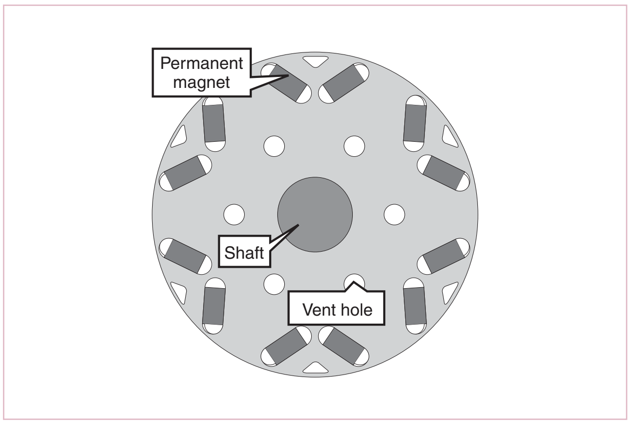

Fig. 2 Sectional view of the rotor

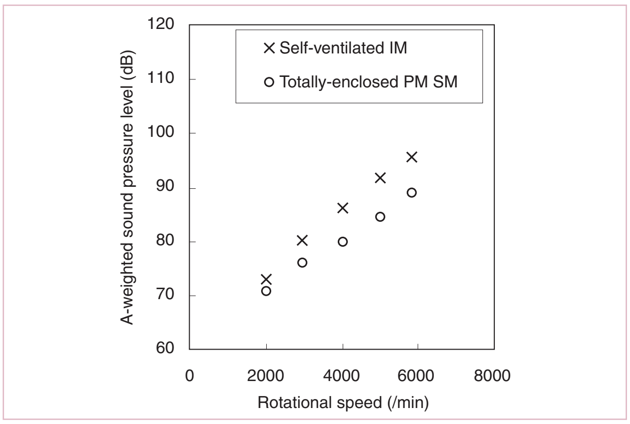

Fig. 3 Noise measurement results