JFE TECHNICAL REPORT
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Evaluation Techniques for Electromagnetic Properties by JFE Techno-Research

1. Introduction

In recent years, CASE (Connected, Autonomous, Shared & Service, Electric) related to carbon neutrality and the automotive business has gained momentum as a countermeasure against global warming. In response to this trend, companies in the automotive sector have set targets for increasing their ratio of electric vehicles (EV, HEV, PHEV, FCV) toward fiscal year 2030, and as a result, increasingly strong requirements for high performance and high efficiency are now applied to motors, which are the most important component part used in electric vehicles.

JFE Techno-Research Corporation (JFE-TEC) possesses high analysis and evaluation techniques for the non-oriented electrical steel sheets used in motors. As fields of application, JFE-TEC has developed techniques for understanding the effects of changes in magnetic properties due to various types of processing when motors are actually manufactured, as well as techniques for visualizing local magnetic properties[1). The company is also working to develop evaluation techniques for the fundamental physical properties of the permanent magnets that make up motors, evaluation techniques for their magnetic properties when actually used in motors, and numerical analysis techniques for evaluating motor characteristics[1)]. Utilizing these techniques, we have established a reverse engineering method that makes it possible to reproduce motor power characteristics by purchasing motors for use in electric vehicles, and applying a combination of motor testing, disassembly, analysis, CAE and other techniques. In addition, we have also established evaluation techniques for electromagnetic properties under the high magnetic flux density and high frequency conditions required in the high power region of EV motors.

2. Evaluation Techniques

2.1 Reverse Engineering

JFE-TEC possesses advanced material investigation techniques in the areas of motor performance investigation, disassembly, and structural investigation, and provides a full range of services from investigation of the physical properties of materials, including their composition and magnetic properties, investigation of the material grade, and numerical analysis (CAE) of motors based on the results as a "one-stop solution service." For example, this service includes the purchase of actual motors, measurement of various motor characteristics by benchmark tests, followed by disassembly and investigation of the motors. In this process, the investigation can be carried out responding to the client's requirements, such as EDX analysis or magnetic measurement of the magnets removed from motors, measurement of the magnet geometry (shape and dimensions), *etc*. This means the measurement results and CAE results can be compared directly, and various motor characteristics can be evaluated with a high level of accuracy. In addition, in the magnetic field analysis, motor efficiency maps can be created, as shown in **Fig. 1**, by virtually applying a sinusoidal current as the drive condition. This makes it possible to predict the properties of motors under a wide range of drive conditions, and contributes to reduction of prototyping costs in motor design.

2.2 Evaluation of Motor Drive Properties

In investigations of motor performance, it can be said that the bench test is the most important motor-related test, as this test can evaluate torque, rotational speed, *etc*., which are the main characteris-

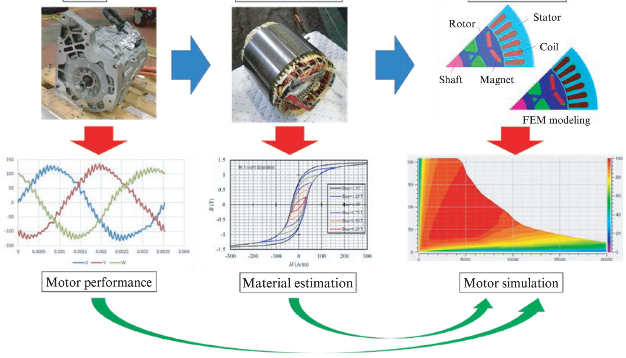

Fig. 1 Image of motor survey

† Originally published in *JFE GIHO* No. 52 (Aug. 2023), p. 78−79

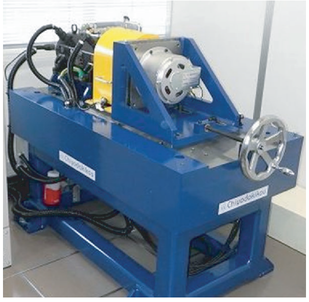

Photo 1　Motor bench system

Table 1　Motor bench specification

Items	Specification
Rated power	11.0 kW
Max. speed	18 000 rpm
Max. torque	15.0 Nm
Max. DC voltage for test motor	400 V

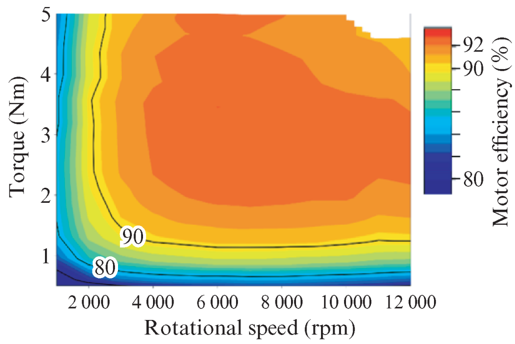

Fig. 2　Motor efficiency

tics of motor drive performance. Due to the wide variety of needs in bench tests of EV motors, JFE-TEC is working to strengthen its services not only in terms of in-house equipment, but also through collaboration with external partners, in order to respond to the both qualitative and quantitative needs of clients.

For example, in evaluations of high-speed motors, JFE-TEC uses a high-specification motor bench (**Photo 1**) owned by JFE Steel, which makes it possible to evaluate high-speed motors with rotating speeds exceeding 10 000 rpm. **Table 1** shows the specification of the motor bench, and **Fig. 2** shows an example of a motor efficiency measurement.

2.3 Evaluation of Electromagnetic Properties of Materials

Since increasingly high social expectations are placed on electric vehicles (EVs), all auto makers are competing to develop more outstanding EVs. The most important component of an EV is the traction motor, which provides the power necessary for vehicle travel.

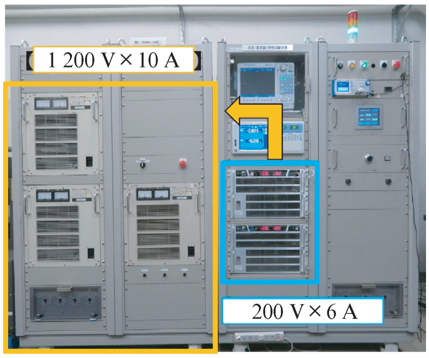

Photo 2　Magnetic measurement system

While the essential requirements for traction motors include the ability to output high torque and low energy loss, small space occupancy and light weight are also desirable. To meet these requirements, motors are designed so as to operate at a high rotating speed, and increase the magnetic flux density, which is the quantity of electricity flowing in the magnetic core, in order to reduce the size of the motor. In other words, due to this orientation toward compact size and light weight, the core materials of EV motors are magnetized under the conditions of high magnetic flux density and high frequency.

To accurately evaluate the magnetic properties of core materials and the motor cores of recent EVs, JFE-TEC established an electromagnetic measurement technique which is capable of measuring iron loss under high magnetic flux densities and high frequencies of levels unprecedented in the past. In alternating current (AC) magnetic measurements, it is necessary to use a high voltage proportional to the frequency, magnetic flux density and cross-sectional area of the core being measured. In both magnetic measurements of actual motor cores and magnetic measurements of test specimens under AC magnetization, measurements that reproduce the conditions of traction motors are not possible with the 200 V power sources that were generally used in conventional magnetic measurements. To overcome this problem, JFE-TEC increased the voltage of the excitation power source shown in **Photo 2** to 1 200 V, and established a method that achieves sinusoidal control of the magnetic flux density waveform, which is important for more accurate evaluation of iron loss up to the high magnetic flux density region. The development of this method has expanded the magnetic measurement range, as shown in **Fig. 3**, and made it possible to evaluate the iron loss of EV traction motors over a wide range of drive conditions that could not be measured until now.

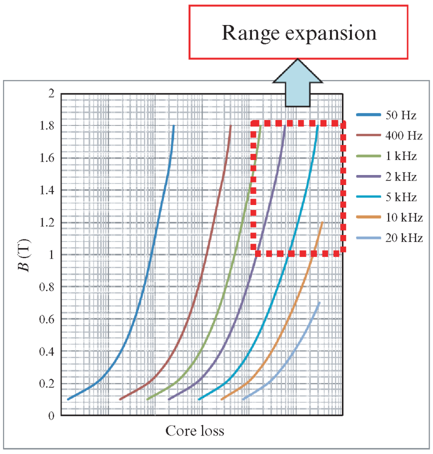

Fig. 3 Expansion of measurement range

3. Conclusion

In addition to the technologies introduced in this paper, JFE Techno-Research Corporation (JFE-TEC) also possesses various other motor-related analysis techniques, and will actively utilize these resources to respond to the requirements of each client.

References

1) Nakada, T.; Nakanishi, T. Evaluation and Analysis Techniques of Magnetic Materials for EV Motors. JFE GIHO. 2021, vol. 47, p. 44–49.

For Further Information, Please Contact:

Sales Division, JFE Techno-Research
Phone: (81) 3–5877–5613
Homepage: https://www.jfe-tec.co.jp/en/