JFE TECHNICAL REPORT
No. 27 (Mar. 2022)

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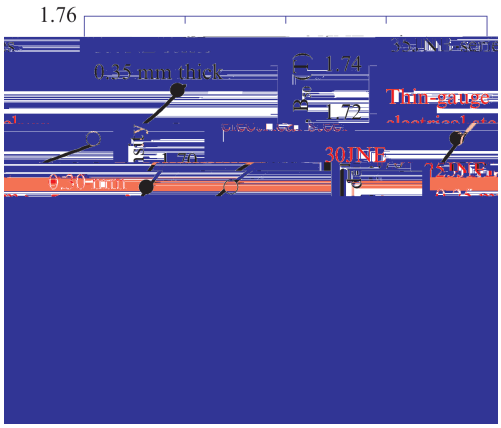
1. Introduction

Electrical steels are used as core materials for electric vehicle (EV) traction motors, and are the key material which affects motor performance.

JFE Steel offers a lineup of electrical steels for EV traction motors thaor20tmxSera ltha, electrical steels for EV5



3.3 Electrical Steel Sheets for High Torque Motors: "JNP™"

Large torque is required in EV traction motors when starting, hill climbing and accelerating, and for this reason, further increases in magnetic flux density are desired in electrical steel sheets used as core materials. Against this backdrop, JFE Steel developed the JNP Series, which offers higher magnetic flux density than the conventional material[5]. **Figure 3** shows the balance between magnetic flux density and iron loss of the developed materials. In comparison with the JNE Series, the magnetic flux density of the JNP Series is approximately 0.01 to 0.02 T higher at the same iron loss. Aiming at high magnetic flux density by texture control, in the JNP Series, the amounts of added Si, Al, Mn and other alloy elements are optimized, grain boundary segregation elements are used, and optimization technologies are applied in the intermediate processes.

Because this material has high magnetic flux density, it is considered suitable for motors requiring high torque. Direct-drive in-wheel motors are a type of EV motor in which high torque is required[6]. High torque is demanded in direct-drive motors in order to rotate the wheel directly without reduction gears. In comparison with motors that use gears for high speed rotation, one distinctive characteristic of direct-drive motors is a low ratio of iron loss to total motor loss due to their low rotational speed. Based on this, the iron loss requirement for electrical steel sheets for direct-drive motors is not particularly high, but on the other hand, high magnetic flux density is strongly required.

Figure 4 shows the motor efficiency and torque of an IPM type direct-drive motor with a rated output of 1.6 kW at a rotational speed of 1 250 rpm (equivalent to a vehicle speed of 60 km/h). In comparison with the 35JN250 used as the conventional material, both torque and efficiency are improved by using the developed 35JNP5. Thus, 35JNP5 is a suitable core material for high torque motors such as direct-drive motors.

3.4 High Strength Electrical Steel Sheet for Rotors: "JNT™"

In the rotors of IPM motors, large stress is applied to the bridge structure by the centrifugal force of the magnet during high speed rotation. From the viewpoint of rotor strength, it is possible to expand the width of the bridge, but because expanding the bridge width increases leakage flux of the permanent magnet, which reduces motor efficiency, the width of the bridge structure is designed to be as narrow as possible within the range that satisfies rotor strength. Therefore, sufficient yield strength to withstand the centrifugal force during high speed rotation and fatigue strength under cyclic loading are necessary in the electrical steel sheets used as rotor materials [7]. Particularly in motors with concentrated windings, it is also necessary to reduce high frequency iron loss, because iron loss caused by higher harmonics occurs at the rotor surface.

JFE Steel developed 35JNT590TK as this type of high strength electrical steel sheet for rotors. **Figure 5** shows the properties of this high strength electrical steel sheet. High strength technologies such as solid solution strengthening and grain refining are applied in this

comparison with the JNHF Series, the JNRF Series has low iron loss at 400 Hz, which is equivalent to the operating frequency of EV traction motors, and also shows a large improvement in magnetic flux density. Thus, this product can contribute to high torque in combination with high energy efficiency in EV traction motors.

4. Conclusion

This article introduced the properties of electrical steel sheets used as core materials of EV traction motors. With further expansion of the EV market forecast in the future, it is thought that even higher efficiency and higher output will be required in traction motors. Although customers' requirements for electrical steel sheets used as core materials are also expected to become both more advanced and more diverse, JFE Steel will continue to contribute to higher performance in EV traction motors through the development of new materials that respond to those requirements.

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