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Gradient Si Super Core JNRF™ with High Magnetic Flux Density

1. Introduction

In recent years, demand for high efficiency in energy use and reduction of CO_2 emissions from the viewpoint of global warming prevention has also accelerated the trend toward higher efficiency motors.

Reduced iron loss is required in the electrical steel sheets used as materials for the iron cores of motors in the high-frequency range from the viewpoint of higher efficiency, and high magnetic flux density is also strongly required for higher torque (higher power output).

JFE Steel has developed a new material, gradient Si Super Core JNRF™, which has both a high magnetic flux density equivalent to that of 3% Si steel and low iron loss at high frequencies, by combining optimization of the Si concentration distribution in the thickness direction and crystal orientation control using the CVD process.[1)]

2. Magnetic Properties of JNRF™

Table 1 shows an example of the magnetic properties of the developed material 10JNRF with a thickness of 0.10 mm and the developed material 20JNRF with a thickness of 0.20 mm **Figure 1** shows the relationship between iron loss ($W_{10/400}$) at 1.0 T at 400 Hz and magnetic flux density (B_{50}) at a magnetic field strength of 5 000 A/m in comparison with the conventional Si-gradient steel sheet (JNHF™) and non-oriented electrical steel sheet. The developed material, JNRF™, has a higher magnetic flux density (B_{50}) at a magnetic field strength of 5 000 A/m, and is characterized by a higher magnetic flux density and lower iron loss in the 50 Hz to 1 kHz range than the conventional high-frequency low iron loss material JNHF, which is a Si gradient steel sheet.

Table 1 Magnetic properties of JNRF™ 1)

Material	Thickness (mm)	$W_{15/50}$ (W/kg)	$W_{10/400}$ (W/kg)	$W_{10/1k}$ (W/kg)	B_{50} (T)
10JNRF	0.10	1.65	7.50	25.5	1.65
20JNRF	0.20	1.55	9.50	37.5	1.68
10JNHF600	0.10	1.89	9.20	27.5	1.51
20JNHF1300	0.20	1.85	11.2	39.5	1.58
20JNEH1500	0.20	2.40	12.7	48.0	1.68

$W_{15/50}$: Iron loss at 1.5 T, 50 Hz
$W_{10/400}$: Iron loss at 1.0 T, 400 Hz
$W_{10/1k}$: Iron loss at 1.0 T, 1 kHz
B_{50}: Magnetic flux density at 5 000 A/m

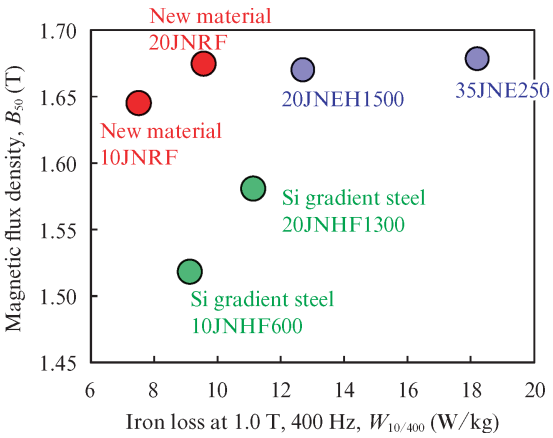
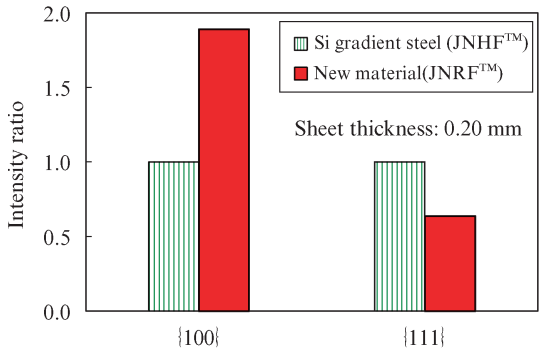


Fig. 1 Magnetic properties of JNRF™ 1)



※ Strength of {100} and {111} planes of JNHF™ is set to 1

Fig. 2 Ratio of X-ray intensity[1)]

Figure 2 shows the ratios of the X-ray reflection intensities of the {100} and {111} planes parallel to the sheet surface in product sheets of the developed material 20JNRF and the conventional Si-gradient steel sheet 20JNHF1300. It was confirmed that 20JNRF has fewer {111} oriented grains, which are detrimental to magnetic properties, and a larger number of {100} oriented grains, which are desirable for magnetic proper-

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Table 2 Specification of analysis motor

Items	Specification
Rated power output (kW)	15
Number of poles/slots	8/48
Outer diameter of stator (mm)	170
Stacking height (mm)	40
Winding connection	Three phase connection, distributed

ties.

3. Example of Application to EV/HEV Traction Motors

The traction motors of hybrid electric vehicles (HEVs), electric vehicles (EVs), and fuel cell vehicles require high torque during starting, climbing hills, and acceleration, and thus require high magnetic flux density in the high magnetic field region. On the other hand, from the viewpoint of higher motor efficiency, reduction of iron loss in the high-frequency range is required. JNRF, with its high magnetic flux density and low high-frequency iron loss, is suitable for these applications and is an advantageous material for high-torque and high-efficiency high-speed motors.

Table 2 shows the specifications of the motors analyzed. In this paper, the motor efficiencies of 10JNRF, 20JNRF, and 20JNEH1500 were obtained by a magnetic field analysis of the IPM motor, which is widely used in HEV/EV motors, when applied to the stator iron core. **Figure 3** shows the motor efficiency maps. The developed materials (10JNRF and 20JNRF) showed motor efficiency equivalent to that of 20JNEH1500 in the high-torque range, and a significant improvement in motor efficiency was confirmed in the high-speed and low-load range (rotational speed: 3 000 to 9 000 rpm, 7.5 Nm).

Based on the above, we believe that the developed material JNRF can contribute to higher torque and efficiency in HEV/EV traction motors.

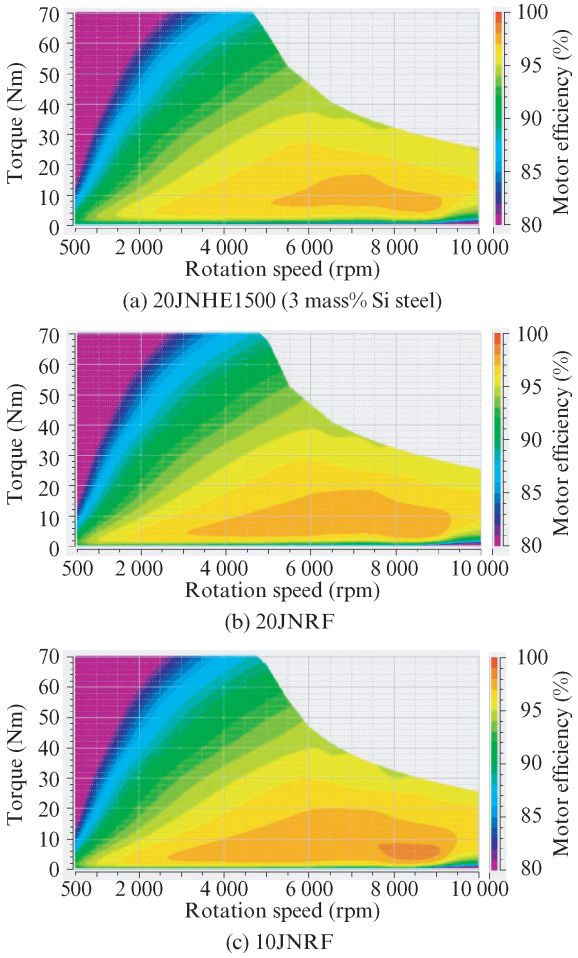

Fig. 3 Comparison of motor efficiency map[1)]

4. Conclusion

JNRF is suitable for EV traction motors and drone motors, and is expected to be used in the high-speed motor field where smaller size and higher output are required.

References

1) Zaizen, Y.; Oda, Y.; Okubo, T.; Kasai, S.; Tobe, T. Materia Japan. 2022, vol. 61, no. 1 p. 44–46.

For Further Information, Please Contact:

Electrical Steel Business Planning Dept., JFE Steel
Phone: (81)3–3597–3480 FAX: (81)3–3597–4779