# Non-Oriented Electrical Steel Sheet with High Magnetic Flux Density: JNP$^{\text{TM}}$ Series$^{\dagger}$

## 1. Introduction

In recent years, increasingly high requirements have been set for energy saving in response to environmental and energy problems, and moves to achieve higher efficiency in motors have also accelerated.

With the non-oriented electrical steel sheets which are used as core materials in these motors, motor efficiency improves as iron loss decreases, while torque increases with magnetic flux density. Therefore, non-oriented electrical steel sheets with a combination of low iron loss and high magnetic flux density have been demanded.

JFE Steel produces the JNE$^{\text{TM}}$ series of low iron loss, high magnetic flux density electrical steel sheets and has also developed the new non-oriented electrical steel sheet for high efficiency motors, "JNP$^{\text{TM}}$ Series" with higher magnetic flux density. The following introduces the "JNP Series."

## 2. Features of "JNP$^{\text{TM}}$ Series"

### 2.1 Required Properties

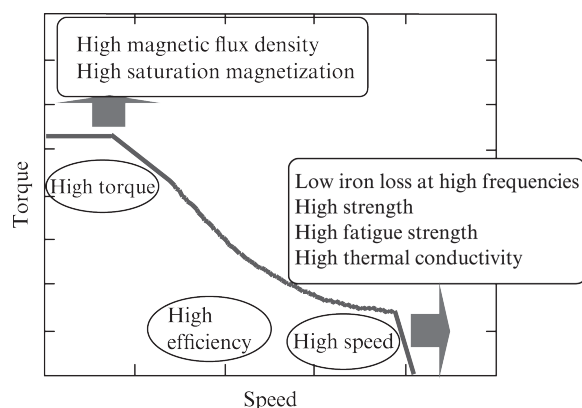The performance required in traction motors for



Fig. 1   Required properties for hybrid electric vehicle (HEV)/ electric vehicle (EV) and motor core materials[1]

hybrid electric vehicles (HEV) and electric vehicles (EV) and motor core materials are shown in **Fig. 1[1]**. In the traction motors of HEV/EV, high torque is required when starting, climbing hills and accelerating. Therefore, high magnetic flux density in the high magnetizing force area is demanded in non-oriented electrical steel sheets used in the iron cores of traction motors.

On the other hand, because the percentage of iron loss in motor loss becomes large when the motor reaches a high rotational speed, a material with low iron loss at high frequencies is required. Accordingly, while the optimum non-oriented electrical steel sheets will differ depending on which drive condition is given priority, high magnetic flux density and low iron loss in the material contributes to improvement of overall motor performance.

### 2.2 Properties of "JNP$^{\text{TM}}$ Series" and Techniques for Achieving High Magnetic Flux Density

The JNP$^{\text{TM}}$ series is a series of non-oriented electrical steel sheets with the distinctive feature of high magnetic flux density and low iron loss and is available in two sheet thicknesses, 0.35 mm and 0.50 mm. To make it possible to supply materials corresponding to the motor application, JFE Steel succeeded in developing two grades with different iron loss levels and further improving magnetic flux density at the same iron loss from the JNE$^{\text{TM}}$ Series, which is JFE Steel's conventional high flux density and low iron loss material.

**Table 1** shows an example of the magnetic properties of the JNP Series; **Fig. 2** shows the relationship between iron loss ($W_{15/50}$) at 1.5 T, 50 Hz and magnetic flux density ($B_{50}$) in a 5 000 A/m magnetic field, in comparison with conventional non-oriented electrical steel sheets (JN, JNE Series) . It can be understood that the magnetic flux density of the JNP series at the same iron loss level is approximately 0.02 T higher in comparison with the JNE series.

**Figure 3** shows the magnetization curves of 35JNP7 and 35JNE230. The magnetic flux density of 35JNP7 in the high field region is improved in comparison with 35JNE230.

In this JNP Series, improvement of magnetic flux

Table 1  Magnetic properties of JNP™ series[2]

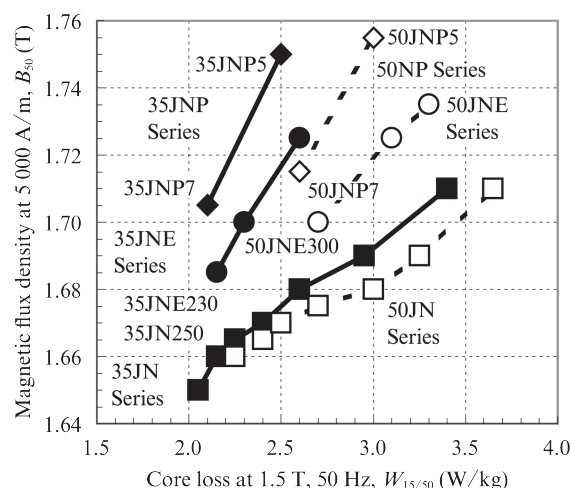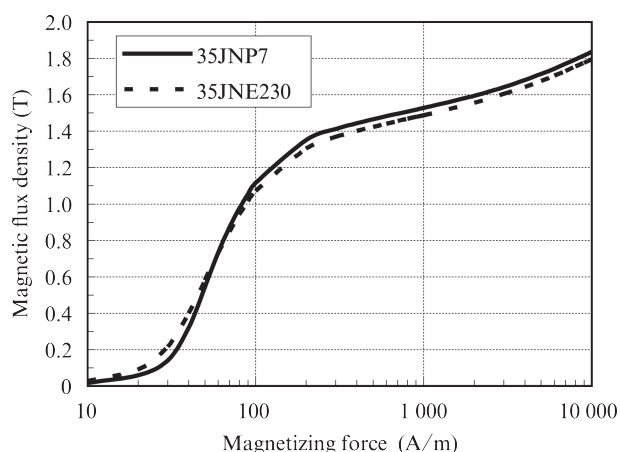| Grade | Thickness (mm) | $W_{15/50}$ (W/kg) | $W_{10/400}$ (W/kg) | $B_{50}$ (T) |
|---|---|---|---|---|
| 35JNP5 | 0.35 | 2.50 | 20.0 | 1.75 |
| 35JNP7 | 0.35 | 2.10 | 17.0 | 1.70 |
| 50JNP5 | 0.50 | 3.00 | 32.0 | 1.75 |
| 50JNP7 | 0.50 | 2.60 | 26.0 | 1.71 |

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



Fig. 2  Magnetic properties comparison of JN/JNE™ and JNP™ series[2]



Fig. 3  Magnetization curves of 35JNP7 and 35JNE230

density is achieved by optimizing the addition of alloy elements and reducing the content of impurities, in combination with texture control by applying a technology which mitigates the effect of impurities.

The results of a comparison of the recrystallization textures of 35JNP7 ($B_{50}$=1.70 T) and 35JNE230 ($B_{50}$=1.68 T), which has the same iron loss value, confirmed that the (111) orientation, which has an adverse effect on magnetic properties, is reduced in 35JNP7.

## 3. Applications of "JNP™ Series"

The high magnetic flux density and low iron loss JNP™ Series is not only suitable for the cores of traction motors of HEV/EV, in which high torque is required in starting, hill-climbing and acceleration, but can also be applied to induction motors.

Since induction motors use the magnetic field caused by the induction current which is generated in the secondary conductor of the rotor, without using magnets, the ratio of copper loss is higher. Therefore, improvement of motor efficiency can be expected by the copper loss reduction effect due to improved magnetic flux density.

## 4. Conclusion

The non-oriented electrical steel sheets of the JNP™ Series, which possess high magnetic flux density, are suitable as core materials for the traction motors of HEV/EV, in which high torque is required, and are also expected to contribute to high efficiency in induction motors and brushless direct current (DC) motors for use in air-conditioner compressors.

### References

1) Oda, Y.; Kohno, M.; Honda, A. Journal of Magnetism and Magnetic Materials. 2008, vol. 30, no. 20, p. 2430–2435.
2) Toda, Hiroaki; Oda, Yoshihiko; Kohno, Masaaki; Ishida, Masayoshi; Matsuoka, Saiji. Development of Electrical Steel Sheet JNP Core for High-efficiency Motor. Materia Japan. 2011, vol. 50, no. 1, p. 33–35.

### For Further Information, Please Contact(Dec.2021-):