***Abstract:***

in the high output region. A similar tendency was also confirmed with the induction motor.

The above results revealed that the contribution of iron loss to the efficiency of BLDC motors is large, and reduction of iron loss in the frequency region higher than the fundamental frequency (in the above results, approximately 4 times higher) is effective. On the other hand, with induction motors, it was ascertained that improvement of magnetic flux density, $B_{50}$, together with reduction of iron loss at around the fundamental frequency, makes a large contribution to higher efficiency. It was also found that high flux density material is advantageous for improving efficiency in the high output region. Because high efficiency under various driving conditions is required in drive motors for EV and HEV, it is important to select core materials in consideration of the output region in which the motor will be used.

### 2.2 Local Magnetic Measurement in Model Motors

To clarify the distribution of local magnetic properties in the interior of motor cores and obtain guidelines for the optimum core configuration and material selection, a technique for measuring the local magnetic properties inside the stator core was developed and used in measurements of a BLDC motor and induction motor. **Figure 3** shows a schematic diagram of the local magnetic measurement using the needle probe method and Hall probes. In this method, magnetic values in uppermost layer of the stator are measured.

The BLDC motor was the same type as the motor described in the previous section. A JFE Steel product, “35JNE300,” was used as the core material. As the induction motor, a single-phase, 2-pole, 24-slot motor with a driving voltage of 100 V and frequency of 60 Hz was used. In this case, the core material was JFE Steel’s “50JN400.” With both motors, the measurements were performed with the winding in a raised condition in order to insert the probes into the tooth area.

**Figure 4** shows the local flux density and magnetic field distributions in the BLDC motor in the radial direction and circumferential direction.[3] The maximum values of the radial and circumferential direction components of flux density and the magnetic field at a local point are indicated by $B_{rm}$, $B_{\theta m}$, $H_{rm}$, and $H_{\theta m}$, respectively. It can be understood that the flux density in the radial direction is high in the teeth and around the base of the teeth (joint with yoke), whereas the flux density in the circumferential direction is large in the yoke and the tips of the teeth. This distribution agrees with the results obtained from calculations by magnetic field analysis. However, the non-uniform flux density distribution ob as ] k side of the yoke, and in particular, large iron loss occurs at the tips of the teeth.[4,5]

The above results revealed that fux density and iron loss are highest in the teeth in both the BLDC motor and the induction motor, and fux density/iron loss is also moderately high in the vicinity of the tooth base. Based on these results, it is expected to be possible to improve motor effciency/performance by material selection and motor design which attach importance to the magnetic properties of the teeth.

In the future, improvement in the accuracy of predictions of motor characteristics is expected to be possible by comparing the results of local magnetic measurements by this method and calculations by magnetic feld analysis and clarifying the causes of differences between the two.

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Based on the experimental results with the model motors described in the previous chapter, it can be said that reduction of iron loss in the frequency range corresponding to the motor type and improvement of magnetic fux density, $B_{50}$ are important in automotive motors in which high effciency is required over a wide range of outputs. From this viewpoint, JFE Steel has developed the “JNE Series,” “JNP Series,” and “JNA Series” as product groups which realizes high magnetic fux density, $B_{50}$ while maintaining iron loss equivalent to that of the conventional JIS grade product groups. As thin products which give priority to low iron loss in the high frequency region, JFE Steel also developed the “JNEH Series.” **Cfdrob 4** shows the relationship between iron loss ($W_{15/50}$ and $W_{10/400}$) and $B_{50}$ in these products. Outlines of the respective products are presented below.

(1) JNE Series

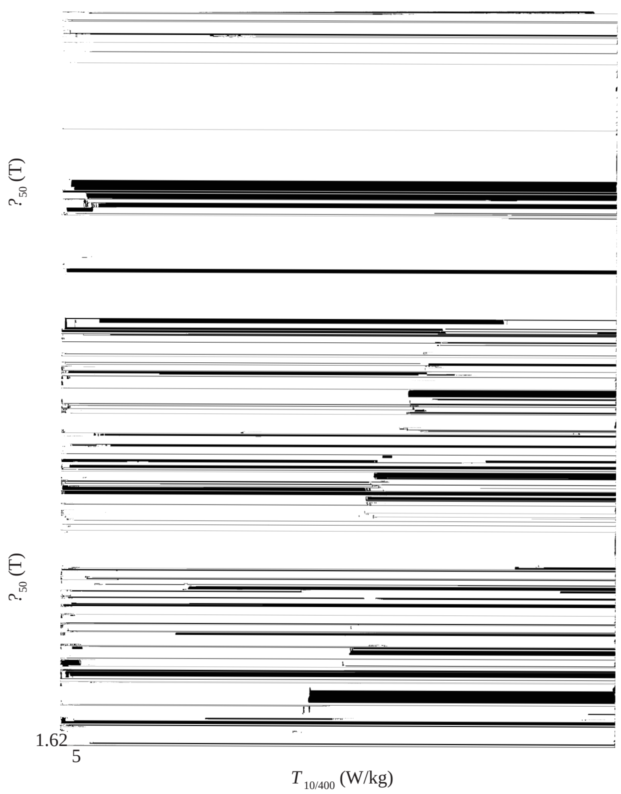
Material in which low iron loss/high magnetic fux density is achieved by control of inclusions and texture. The highest grade product, 35JNE230, achieves $W_{15/50} \leqq 2.3$ W/kg and $B_{50} \geqq 1.67$ T, while hardness, which deteriorates punchability, is HV $\leqq$ 200.

(2) JNP Series

Product group with the highest $B_{50}$ in JFE Steel’s product line. In the JNP Series, 50JNP1 achieves $B_{50} \geqq 1.77$ T in combination with $W_{15/50} \leqq 8.0$ W/kg.

(3) JNA Series

While securing high fux density, $B_{50}$, this material also pursues iron loss reduction after stress-relief



vibration of the core is reduced by this extremely low magnetostriction, realizing low noise. **Cfdrob ..** shows the noise measured in a single-phase stacked-type model transformer.[9] It can be understood that generated noise is extremely low in comparison with the GO which is generally used as a transformer material. Because of zero magnetostriction, deterioration in magnetic propertie s e posptrs