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# Electrical Steels for High-functional Automotive Electrical Components Corresponding to Energy Saving*

***Synopsis:***

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content was used as an index to determine whether core materials are electrical steels.

As shown in Fig. 2, whether a steel used in a motor core is an electrical steel or an ordinary steel has no relation to motor weight. SPCC class cold-rolled steels are used in power windows and wiper motors, and electrical steels containing not less than 1%Si are used in fuel pumps and motors for electrical power steering. **Photo 1** shows a power steering mechanism and rotor as examples of parts that contain electrical steels.

In power windows and wipers, which are not constantly used, inexpensive cold-rolled steels having are used as core materials in place of low-iron-loss electrical steels, in order to improve torque rather than motor efficiency. In contrast to this, low-iron-loss electrical steels are used in constantly operating fuel pumps to improve motor efficiency. In addition, electrical steels with reduced hysteresis loss are used in power steering systems to reduce torque loss during steering.[3,4]

It is expected that with the development of EV and HEV and the 42 V design of automotive power supplies, electrical steels will increasingly be employed in motors and generators for ISGs, power air conditioners and powder steering systems[5] that emphasize efficiency.

### 2.2 Application to Various Types of Actuators

Grain oriented electrical steels are used in the direct ignition cores of engine parts,[6] as will be explained in higher output current values. On the other hand, a stator core for alternators made of SPCC, a conventional material, is manufactured by a high-productivity helical winding process as shown in **Fig. 4**. The dimensional accuracy of products during this procedure is ensured by controlling the mechanical properties, particularly the yield point (Yp) of the materials.

To ensure the compatibility of improved efficiency with high productivity of the new alternator, a new steel (shown in **Fig. 5**) was developed which has $W_{10/400}$ of not more than 70 W/kg and $B_{50}$ of not less than 1.70 T as magnetic properties while maintaining workability of helical winding with Yp kept at conventional levels (180 to 245 MPa).

### 3.2 Essential Points of Material Developed

In general, the addition of Si to increase electric resistance is effective in lowering iron losses at high frequencies. Conversely, however, the addition of Si also reduces magnetic flux density and raises Yp, which decreases the workability of helical winding. Furthermore, Yp tends to vary due to age hardening caused by solute C, N. Therefore, in order to maintain the workability of helical winding, it is necessary to use the skinpass rolling process (SK) to suppress aging. For the development, Yp must remain in the target range even after skinpass rolling for stabilization while at the same time, high-frequency magnetic properties not provided by conventional steels must be ensured. For the newly-developed steel, the following technique, which ensures compatibility between high-frequency magnetic properties and workability, was adopted for a low-Si steel (Si 0.1%) with a Yp level equivalent to a conventional one.

#### 3.2.1 High-frequency low iron loss in which SK-induced strain is considered

**Figure 6** shows the results of an iron loss evaluation with SK-induced strains of up to several percent in which Yp control is considered. Yp changes substantially in proportion to the SK rolling reduction. On the other hand, although iron loss increases remarkably at an SK rolling reduction of 0.8%, iron loss deterioration is moderate at SK rolling reductions exceeding 0.8% and low in the high-frequency range of 400 Hz to 1 kHz, which provides the drive frequencies of the alternator, in comparison with the power frequency of 50 Hz. Therefore, it was thought that if the iron loss $W_{10/400}$ before skinpass rolling could be improved by about 30% over a target, it would be possible to obtain target magnetic properties even after an iron loss deterioration while simultaneously providing the mechanical property Yp by controlling the skinpass rolling reductions from 0.8 to 5.0%.

The total iron loss of the material is divided into hysteresis loss and eddy current loss and formulated by the following equation:[12)]

$$W = W_h \text{ (Hysteresis loss)} + W_e \text{ (Eddy current loss)}$$
$$\propto Af/D + BD\,^2 f^2/\rho$$

($A$, $B$: Parameter of structure factor)

($D$: Grain side; $\rho$: Electric resistance; : Sheet thickness; $f$: Frequency)

The reduction of eddy current loss by reducing sheet thickness is effective in improving iron loss in a high frequency range. In addition, coarsening the grain size and reducing the precipitates are effective in improving hysteresis loss, while strain in steels increases hysteresis loss.[13)] That is, the reason why the above deterioration in high-frequency iron loss by skinpass rolling was less than that in the power frequency of 50 Hz, was because the proportion of hysteresis loss to the total iron loss at high frequencies was low.

skinpass rolling, a reduction in sheet thickness (0.5 mm $\rightarrow$ 0.35 mm) for eddy current loss and structure control for reducing hysteresis loss were examined. **Figure 7** shows the effect of reducing in sheet thickness and structure control on the improvement of iron loss. For structure control, the C content which induces precipitate in steel was minimized to ultralow C levels to reduce hysteresis loss, and the sheet thickness was also reduced. This enables iron loss to be reduced by about 50% compared to conventional materials even after skinpass rolling.

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