Advanced Magnetic Material Requirement for Higher Efficient Electrical Motor Design

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In order to realize the energy saving society, higher efficient electrical apparatus is required. Magnetic material is used in it to obtain higher magnetic flux density [1].

3 kinds of electromagnetic theory are used in the electromagnetic apparatus [2]. The one is Faraday's law as shown in the next equation. A transformer.is considered to be its application.

$$rot\vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

The next is Maxwell stress as shown in the next equation. An electrical motor or generator is considered to be its application.

$$\vec{F} = \oiint_{ThinSTeelPlate} [T_m] \cdot \vec{n} dS \quad \text{, here} \quad [T_m] = \frac{1}{\mu_0} \begin{bmatrix} \frac{1}{2}\left(B_x^2 - B_y^2 - B_z^2\right) & B_x B_y & B_x B_z \\ B_y B_x & \frac{1}{2}\left(B_y^2 - B_z^2 - B_x^2\right) & B_y B_z \\ B_z B_x & B_z B_y & \frac{1}{2}\left(B_z^2 - B_x^2 - B_y^2\right) \end{bmatrix}.$$

The last is magnetic energy as shown in the next equation. A reactor in an electrical circuit is considered to be its application.

$$E = \int \vec{B} \bullet d\vec{H}$$

High magnetic flux density is usually obtained by the magnetization as shown in Fig. 1. The magnetization is derived by external magnetic field, and it is derived from a current which flows in magnetic coil within the electrical apparatus. The current is derived from a voltage in electrical circuit. The variable voltage and variable frequency are used in the electrical motor or smart grid, which are expected to be a future technology, and are realized by power electronics technology.

Usually, magnetic properties of magnetic material are measured by linear amplifier excitation with no harmonics components as shown in Fig.1. It is decided by JIS or IEC [3, 4]. However, an electrical circuit based on power electronics is applied to the electrical apparatus to realize the variable voltage and variable frequency. So the different magnetic properties from linear amplifier excitation are required for the 3 kinds of electromagnetic apparatus.

The electrical motor is usually excited by PWM inverter to obtain the variable velocity drive system. So the magnetic properties of magnetic material are shown in Fig.3. A lot of minor loos, which are derived from the carrier frequency of PWM inverter excitation, are observed in the major loop of the fundamental frequency. Iron loss becomes about 30 – 50% large [5].

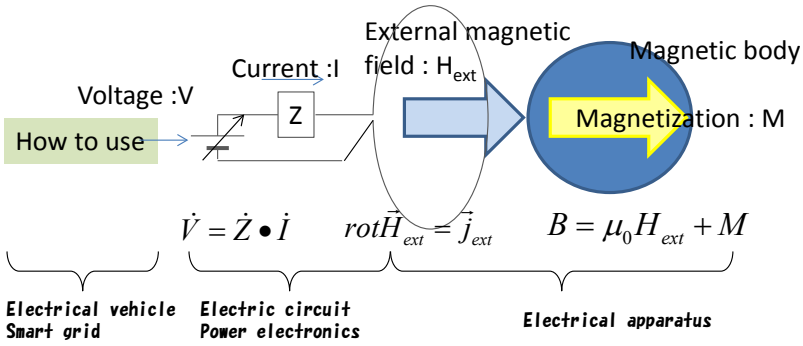

Fig. 1 Magnetic material application for electrical apparatus.

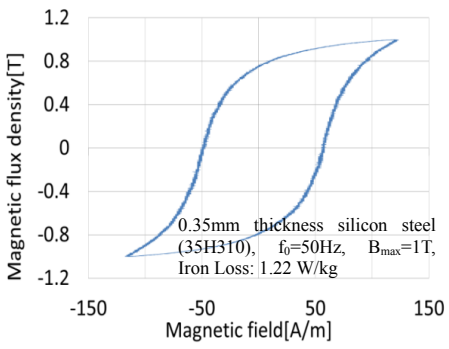

Fig.2 Magnetic hysteresis curve excited by linear amplifier.

The reactor is often used in the chopper circuit, where electrical energy from power source storages in some period of chopping carrier frequency. So the magnetic properties required for the reactor are only a small minor loop within the major loop.

Future transformer is expected to be operated in high frequency, which is possible to be realized by power electronics technology, in order to become small to be a one-100th or so [6]. So the required magnetic properties for the high frequency transformer are shown in Fig. 5. High frequency as well as high magnetic flux density is required.

Permanent magnet is also required for the dynamics magnetic properties in being applied to PM motor [7]. Because of space harmonics components and time harmonics ones, which are derived from the slot shape of stator core and the PMW inverter excitation, harmonics components of magnetic fields are supplied to the permanent magnet. They increase the loss of the electrical motor.

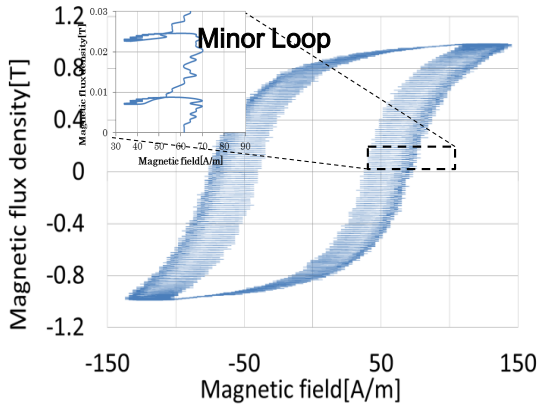

Fig. 3. Required magnetic hysteresis curve excited by PWM inverter (35H310, PWM inverter excitation (m = 0.8), Iron Loss: 1.65 W/kg)

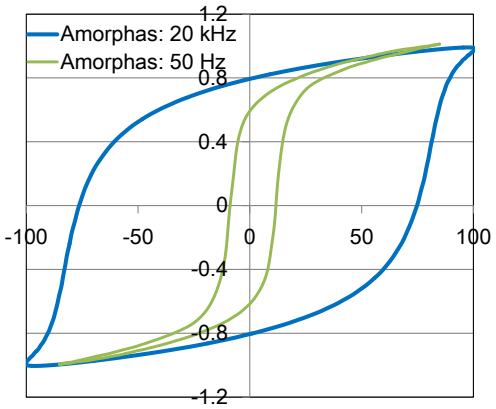

Fig. 5. Required magnetic hysteresis curve applied to high frequency transformer. (Amorphous, 2605HB1, Thickness: 23μm, B_{max}=1.0 %, f_0=50 Hz, 20 kHz)

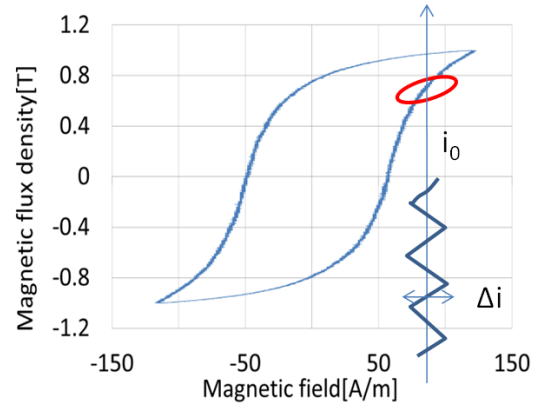

Fig. 4 Required magnetic hysteresis curve applied to reactor in chopper circuit.

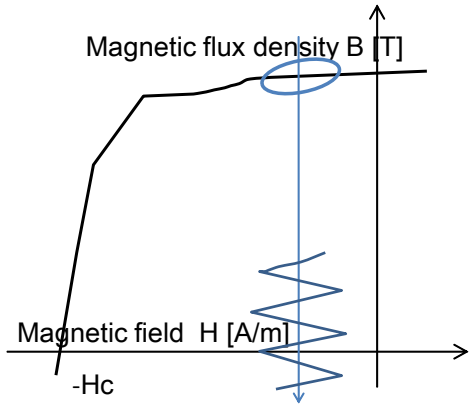

Fig. 6 Dynamic magnetic hysteresis curve of permanent magnet used in IPM motor

Reference

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