Optimal Design of a Magnetic-Field Generator at 20 kHz for Biological Research

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INTRODUCTION
Recently, induction-heating (IH) cooking apparatus (hobs) have come to be widely used in homes and restaurants. An alternating magnetic field with frequency range 20 kHz to 100 kHz is used the fundamental heating frequency for the IH cooking apparatus. Biological research undertaken by a university and a research center has evaluated the leakage flux from the IH cooking apparatus[1]~[3].

This paper proposes an optimal design of alternating magnetic-field generator at 20 kHz for biological research. The generator is used a voltage source inverter and a series LC resonant circuit.

System Configuration
Fig. 1 shows the circuit configuration of a magnetic-field generator that consists of an voltage source inverter and a series LC resonant circuit. The inverter rated at 280 V and 25 A is used as a single-phase full-bridge inverter. The duty ratio of the inverter was set to 50%, so that \( i_L \) was controlled by the DC voltage \( V_{DC} \). The generator produces alternating magnetic field with uniform distribution at 20 kHz inside the Merritt coil[4]. The strength of magnetic field depends on the current \( i_L \) and turn numbers of the coil. Here, \( L_r \) is the inductance of the magnetic field generating (air core) coil and \( C_r \) is the capacitance of the resonant capacitor. \( R \) is the resistance of the wire.

Fig. 2 shows the Merritt coil which can generate uniform magnetic field. The shape of the Merritt coils is a square type, and four square coils are connected in series. Here, \( \phi \) means a wire diameter, \( a \) is a side length, and \( x \) is a distance of adjacent coils. Fig. 3 shows the relationship between the wire diameter of the coil and the side length when the current density of the wire is set to 4 A/mm². Here, the red color means the strong magnetic field and the blue color is the weak magnetic field in the midpoint of the coil. The white line means construction limitation \((x_2=0)\) of the coil which can generate the strongest magnetic field in this coil structure. However, it is impossible to construct the coil the region of the under the white-line because of \( x_2 < 0 \).

Experimental Result
Fig. 4 shows the experimental waveforms. Here, the turn number of the coil is set to 74 turns, the inductance \( L_r \) is 900 nH, and the ritz wire is used. Furthermore the capacitance \( C_r \) of the capacitor is 70 nF, and the metalized polypropylene film capacitor is used. The point B of Fig. 3 is designed and constructed in this paper. The output voltage \( v_{INV} \) of the inverter circuit can produce a square voltage waveform, whereas the current waveform of the coil \( i_L \) and magnetic flux waveforms \( B_z \) are sinusoidal waveforms without any harmonic distortion. In this case, the inverter rating is 2.8 kVA, and the coil current is 19 A. Therefore, the magnetic field generator can produce 3.4 mT at the 20 kHz.
CONCLUSIONS

This paper shows an optimal design method of the magnetic field generator. It is confirmed that the effectiveness of the design procedure are shown, and the coil can generate 3.4 mT, 20 kHz magnetic field by the experimental results.

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REFERENCES


