

Magnetic Field Measurement of Induction Hobs

Hideki MORI*, Keiju MATSUI** and Isamu YAMAMOTO***

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Recently, domestic induction hobs have rapidly come into wide use in Japan. When cooking, a strong high frequency magnetic field is generated in the area of the induction hob. However, there are few reports of the measurement of the magnetic field during actual cooking. The magnetic field resulting from various working conditions of several types of induction hobs are reported here. Measurements of the magnetic field due to differences in various types of converter, the size and materials of the cooking vessels, and installation positions, were also performed. Results indicate an obvious difference in the spatial distribution of the magnetic field in the cooking work area. The measurements are compared with the reference level set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines in the subject area of the frequency characteristic of a magnetic field.

Keywords: magnetic field, induction hobs, induction heating, intermediate frequency

1. INTRODUCTION

Recently, domestic induction hobs have rapidly become widely used in Japan. Induction hobs are cooking devices using electromagnetic induction heating. The production of domestic induction hobs in 2003 is estimated to be over seven hundred thousand. Most people used gas as an energy source in the kitchen about tens years ago. However, it is estimated that 50% of houses which are rebuilt have induction hobs installed in the kitchen. These cooking systems use a resonant power inverter in the frequency range of 20 to 50 kHz, having capacities of about 5kW, or 2kW to 3kW per coil. When cooking, a strong alternating magnetic field radiates in the vicinity of the induction hob.

Since the induction hobs are used in homes there are concerns regarding the health implications of such magnetic fields. The properties of electromagnetic waves vary with frequency. Therefore, effects of electromagnetic waves on the

human body should be considered for all frequencies. The effects on the body of microwave ovens or radio broadcasts have been studied for many years. Various studies of extremely low frequency electromagnetic fields from, for example, electrical power supplies have been made from the 1990s onwards. Electromagnetic waves in the intermediate frequency band of 1k to 100kHz are seldom studied because there have been no applications of these electromagnetic waves. In order to analyse the health effects of such magnetic fields, research has been done into the currents induced in human bodies, with exposure experiments having been made on animals so far. However, there are few reports of the results of measurements made of the magnetic fields present in actual cooking.

2. CIRCUIT AND CONFIGURATION

2.1 Induction heating circuit

In discussing electromagnetic field radiation, it is useful to describe the circuits used in induction hobs. Fig.1. shows the main circuit of an induction hob. The input power supply is converted into

* Graduate Student, *Electrical and Electronics Engineering*

** *Department of Electrical Engineering*

*** *Frontier Research Organization*

continuous current through a rectifier circuit. This circuit is known as a full wave resonant circuit. Transistors switch the current at the resonant frequency of the capacitor/inductor circuit. Eddy currents are induced in the bottom of the cooking vessel. If the input power supply waveform is distorted, the eddy currents are also distorted.

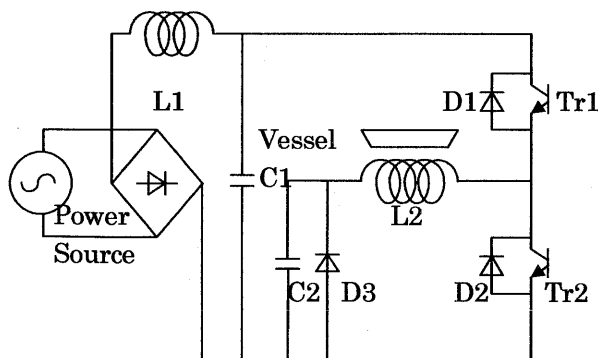


Fig.1. Main circuit of an induction hob.

2.2 Arrangement and magnetic flux of excitation coil

The excitation coil and the schematic diagram of the magnetic flux are shown in Fig.2. In almost all devices, the diameter of the excitation coil is about 16cm. In many cases, an inverter circuit is installed under the coil, with a ferrite shield installed between the coil and the circuit so that magnetic flux will not interfere with the circuit operation. A sheet or lines of a good conductor are installed on the coil side to prevent broadening of the magnetic flux. In this way, magnetic flux is concentrated on the vessel side. If the diameter of the vessel is smaller than the diameter of coil, the magnetic flux must overcome longer air gap in order to reach to the vessel. In this case, magnetic flux will be widely spread in the surrounding air space. Furthermore, the current which flows in the excitation coil is larger, so that the peripherally generated magnetic field also increases.

3. METHOD AND MEASUREMENT

3.1 Method

The method of measurement of the magnetic field is addressed by the International Electro-

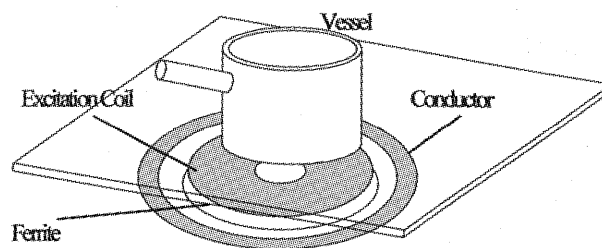


Fig.2. Schematic diagram of excitation coil arrangement.

technical Commission(IEC). The measurement referred to in the 62233 draft is insufficient because it applies to restricted conditions.

In the present measurements, since the IEC wished to know the extent of attenuation of the magnetic field, the 62233 draft was discarded in favor of measurements in the space surrounding the induction hob. A regulated alternating current power supply was used as a power source. A power supply position was sufficiently remote from the induction hob to prevent magnetic interference. The measurement instrument used was a model ELT-400, made by Narda Co. in Germany. This includes a three axis sensor probe with a cross section of 100cm². In order to perform frequency analysis, the output of the ELT-400 is hooked to an oscilloscope. A wave observation is performed with the oscilloscope, from which the signals are processed by Fast Fourier Transform (FFT) and sent to a computer. In order to specify measurement locations exactly, a measurement grid was used as shown in the Fig.3. The size of the measurement grid encloses a volume where the cook is working, extending to 1920mm in height, 840mm in length and in 690mm depth. The measurement grid divides space in intervals of 125mm.

3.2 Measurement

Five types of induction hob were measured. The vessels prepared for measurement were made from iron or stainless steel. In this paper, two representative types will be shown. The rest represented analogous characteristics to either of the presented ones. The difference between these models are due to the different converter and

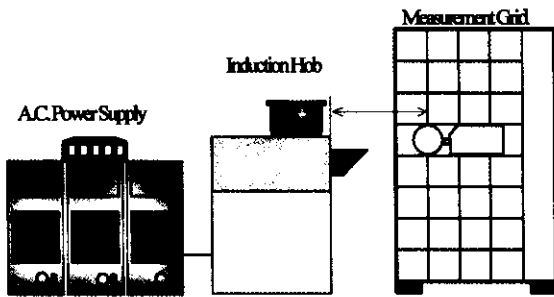


Fig.3. The schematic diagram of the of measurement system.

different shielding cover for equipment. The diameter of the vessels was either 15cm, which is the minimum size, or 20cm which is the most often used. The vessels were half filled with water and measurements were made at the boiling point.

4 RESULTS

4.1 Waveform of magnetic flux

Fig.4 shows waveforms of the measured magnetic flux. It can be seen from the waveforms that switching frequency of transistors are superimposed on the full wave rectified output of the power supply.

It seems that the smoothing circuit for filtering is not adequately performing its function on the magnetic field in the space. According to the material or the size of the vessel applied for the load, the characteristics of measured magnetic flux are barely varied. Thus, the stainless steel brings a little characteristic improvement compared to that of iron. The larger size vessel brings reduced magnetic field because of shielding effect against that.

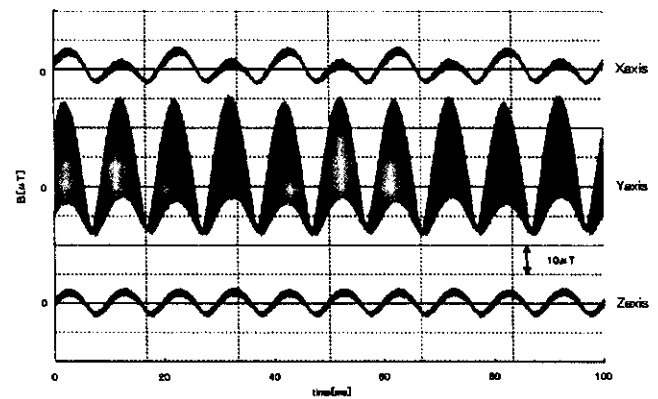


Fig.4. Measured space-magnetic flux.

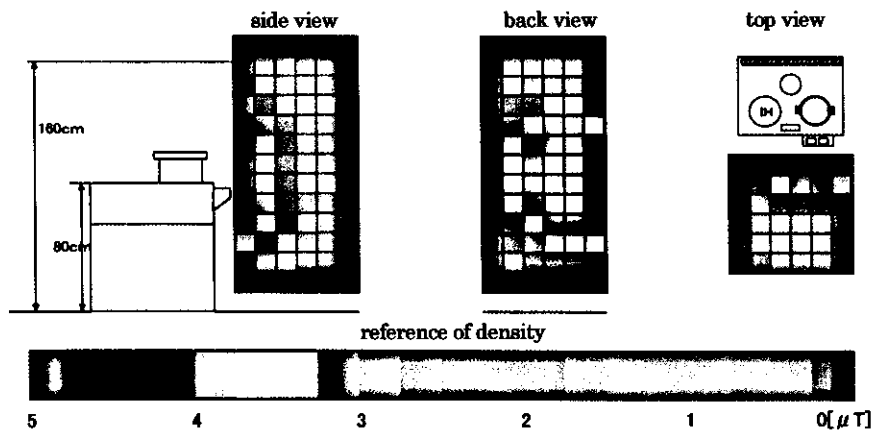


Fig.5. Flux density profile in model A.

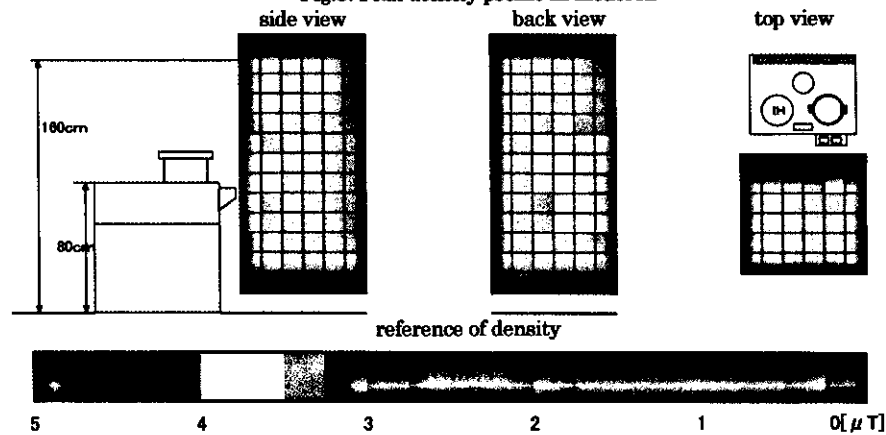


Fig.6. Flux density profile in model B.

4.2 Distribution of Magnetic Field

Fig.5 is the spatial distribution of the absolute value of flux density in model A. Fig.6 is the spatial distribution in model B under the same load conditions with constant input power. The density of color in the figure represents the absolute value of flux density in the measurement space. The absolute value of flux density was of the order of several μT , and decreased with distance. If we compare Fig.5 and Fig.6, it is clear that the appearance of spatial distribution differs even under the same load conditions. This is considered to be due to the difference in the position of the ferrite installed under the excitation coil.

4.3 Frequency Characteristics

The frequency characteristics of the magnetic fields of a certain model are shown in Fig.7.

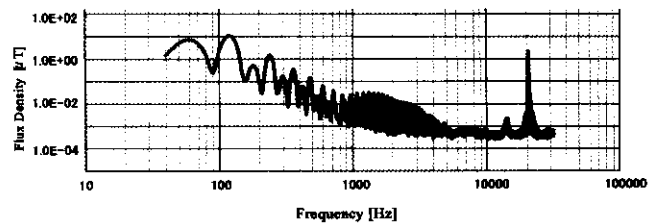


Fig.7. The frequency characteristics of the magnetic fields of model A.

The measurement point is located horizontally, separated by 10cm from the edge of induction hob model A. The frequency characteristic is given by executing the Fast Fourier Transform of the wave signals in Fig.4. In Fig.7, it is clear that the surrounding magnetic field consists of the power supply frequency component, that is, full wave rectification components and switching frequency component.

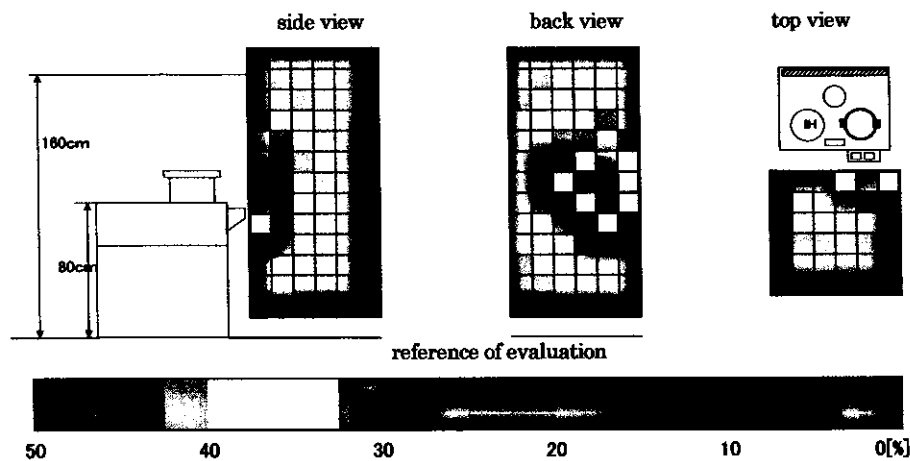


Fig.8. Time domain evaluation in model A.

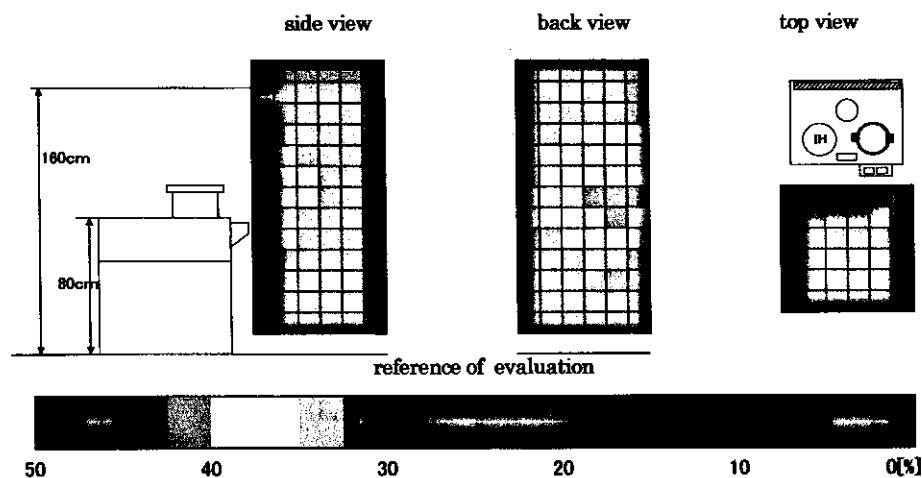


Fig.9. Time domain evaluation of model B.

4.4 Comparison with ICNIRP guidelines

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an independent special organization which investigates biological influences produced by exposure to electric and magnetic fields. Since the magnetic field surrounding induction hobs have two or more frequency components, we cannot simply refer to the ICNIRP guidelines. Thus, a technique was created, known as time domain evaluation, and compared with two or more frequency component guidelines. Comparison was made with the general public guideline. This was applied to each setup. Figs.8 and 9 are the time domain evaluations corresponding to Figs.5 and 6. Value of 100% is the guideline. With both it can be seen that the working area values were below the guideline values. It can be seen from Fig.8 that the attenuation with distance is greater than in Fig.5. It can also be seen that the high frequency component attenuation is significantly below the guideline requirement. Compared with the difference of Fig. 5 and Fig. 6, the difference of Fig. 8 and Fig. 9 is small. This shows that the difference of the effect on a living body is smaller than the difference of the values of surrounding flux density.

5. CONCLUSIONS AND DISCUSSIONS

The magnetic fields from several types of induction hobs having different converter and different shielding cover have been measured under various operating conditions. The magnetic fields due to the difference between various converter types, the size and the material of the cooking vessels, and installation positions, were measured. Since the measurement conditions were complex with many measurement parameters, the magnetic field around the induction hob was difficult to express quantitatively. The following parameters are now qualitatively understood.

- (1) A stainless steel vessel results in a magnetic field smaller than that associated with an iron vessel.
- (2) A larger vessel reduces the magnetic field reduced.

The following experimental conditions are required to obtain reproducible results. The power supply used should be sufficiently stabilized because the waveform of magnetic field could be superimposed on power supply frequency by the switching frequency. Consequently, synchronization cannot be made if the power supply is not stable, but cancellation of sampling occurs at the time of Fast Fourier analysis. Input power supply should be carefully monitored. Though the input from the induction hob to the vessel is previously programmed, setting conditions may differ from the actual output, for example, in a state of boiling.

Finally, in Japan, new models of induction heaters are coming into the market every year. When the circumferential magnetic fields are measured in newer models, their values are found, in general, to be smaller. Moreover, since finite sampling time is required by the sensor measuring fields around the vessel, and the input power to the vessel is always fluctuating, it is difficult to obtain reproducible measurements. As the output waveforms are composed of various frequency components, it would also be necessary to examine the variation of wave propagation of the magnetic field with frequency.

References

- [1] International Electrotechnical Commission (IEC) TC106 62233 DRAFT MAY 2002.
- [2] International Commission on Non-Ionizing Radiation Protection "GUIDELINES FOR LIMITING EXPOSURE TO TIME – VARYING ELECTRIC MAGNETIC, AND ELECTRO-MAGNETIC FIELDS (up to 300GHz) APRIL 1998.