DOSIMETRY OF INDUCED CURRENT DUE TO MAGNETIC FIELD IN THE PROXIMATELY OF INDUCTION HEAT HOB WITH NUMERICAL HUMAN MODELS

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1. Introduction

Induced heat (IH) hobs, which use 20kHz-60kHz time varying magnetic fields for heating frequency, increase in its number for general use because of their convenience for cooking. IH hobs are used in the proximately of a human body and the time varying magnetic field around IH hob induces electric field or current in the human body. Since basic restrictions are provided on electric current density to prevent effects on nervous system functions in ICNIRP guidelines[1], it warrants estimating induced current in the human body to compare basic restrictions.

The purpose of this study is to examine numerical dosimetry for induced current densities within the human body caused by magnetic field in the proximately of IH hobs with the impedance method (IM)[2], and to compare results of induced current density calculation with the current density values given in basic restrictions. We discuss the relation between induced current and incident magnetic field on human body to compare the relation between basic restrictions and reference levels given in guidelines.

2. Numerical Analysis of Induced Current

Two voxel models[3] of whole human-bodies based on the average Japanese adult male and female data are used to construct realistic cooking condition. Figure 1 shows cross sections of male and female models. These detailed human models have 2mm resolutions, and are composed of over 50 tissues and organs. Electric conductivities are provided for each tissue by use of parameter model[4]. These models are set up as shown in Fig. 2. The top of the IH cooker is located at 800mm position from the floor, and the front edge of IH cooker is placed 50mm away from the nearest surface of the human model. That is the nearest position where human can approach to an IH hob.

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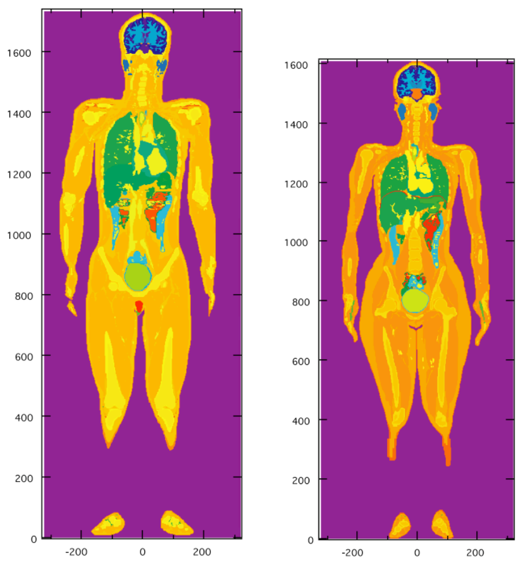
The fundamental heating frequency of IH hob is about 20kH-100kHz. In that frequency region, the quasi-static approximation method can be used to obtain induced current distribution, since wavelength of electromagnetic field is extremely larger than the human model size[5]. We have attempted to calculate induced current density distribution with IM which is one of the quasi-static approximation methods. Analysis objects, which are human models, are turned into discrete voxel representation in IM. Closed loop currents are assumed on each surface of voxel, and Kirchhoff voltage equations are written for each loop current. Simultaneous equation are obtained for all over the object. Here, succeeive over reluxization (SOR) method is used to solve simultaneous equation to obtain loop currents on the surface of voxel. In this study, if the value of norm of residual vector ε is smaller than 10^{-5}, the solution derived from SOR method is considered to be converged.

Magnetic flux density distribution is measured by the magnetic field probe in the proximately of IH hob to prepare for IM. The magnetic field probe can measure the three components of MF (B_x,B_y,B_z) within wide frequency range from 50Hz to 100kHz[6]. Magnetic field data at intervals of 50mm are obtained by actual measurement. Measured magnetic flux density of 50mm intervals are transformed into interpolated data with 2mm resolution by bi-cubic spline interpolation to adjust to the resolution of human models.

The most dominant frequency of the IH hob we have measured is approximately 23kHz, therefore induced current density is calculated under this frequency. Electric conductivities at 23kHz are provided for each tissue with parameter model of biological tissues[4].

Calculation results are required post processing, because in ICNIRP guidelines[1], it is stated that, "Current densities should be averaged over a cross-section of $1cm^2$ perpendicular to the current



(a) (b)

Fig. 1 Voxel models of the average Japanese adult male and female. (a) male model, (b) female model.

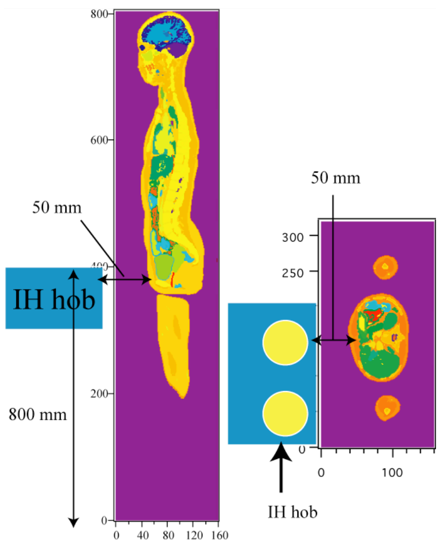


Fig. 2 Set up of human model for induced current analysis in front of the IH hob.

direction." Therefore, calculated data are averaged over a cross-section of $1cm^2$ to relax the influence of electrical inhomogeneity.

3. Result

Results of numerical simulation are shown in Fig. 3 and Fig. 4. Hot spots of induced current density are observed at a few cm inside from the surface in both models, because of inhomogeneous conductivity. The maximum values of current density obtained in trunk are 8.8 mA/m^2 in the male model and 5.3 mA/m^2 in the female model, respectively. The basic restriction of induced current for general public exposure given by ICNIRP is 46 mA/m^2 at 23 kHz, and induced current values are smaller than the basic restriction in this condition. We discuss the relation between induced current value and incident magnetic field value to evaluate the consistency with guidelines. The maximum incident magnetic field values on the human body are 2.3μT at male model and 2.5μT at female model.

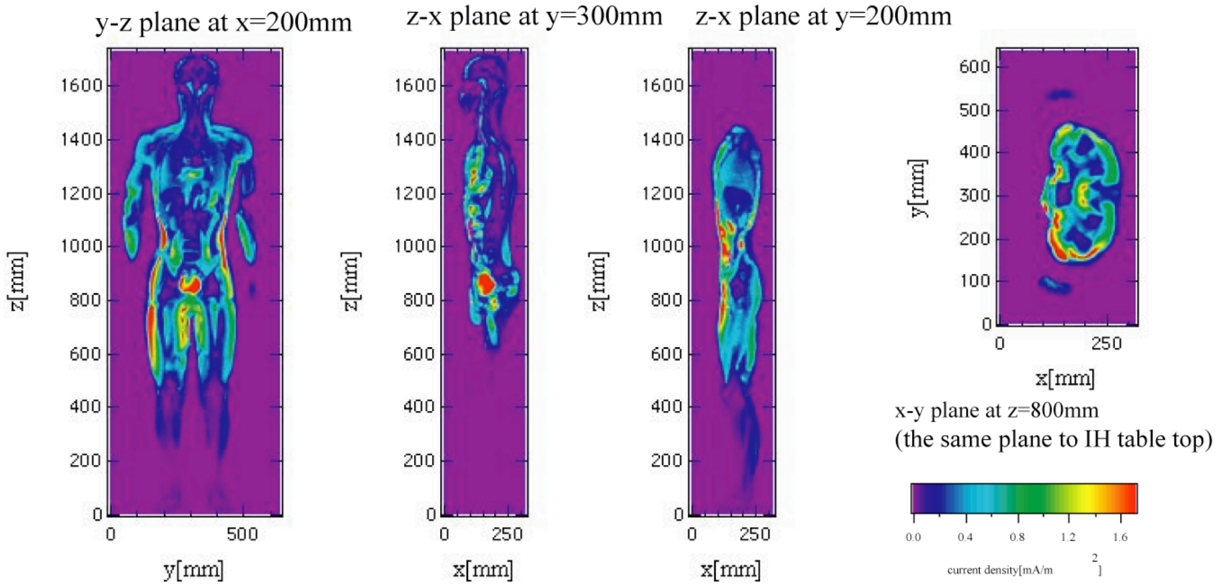


Fig. 3 Induced current density distribution for male model.

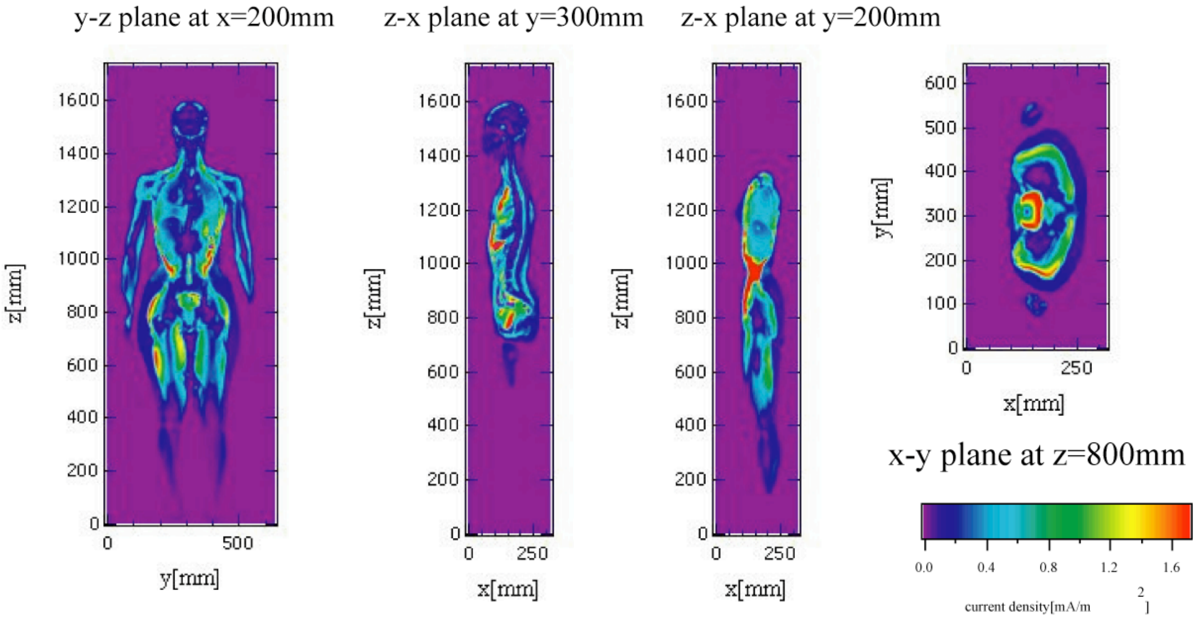


Fig. 4 Induced current density distribution for female model.

When these magnetic field values are normalized to 6.25μT, which is given in ICNIRP reference level for general public exposure, maximum values of induced current density are 25 mA/m^2 for male model and 13mA/m^2 for female model. If the maximum value of incident magnetic field is smaller than reference level, values of maximum current density do not exceed basic restriction for general public exposure, in this case of localized exposure due to IH hob.

4. Conclusion

Magnetic flux density distribution in the proximately of an IH hob is measured by the magnetic probe. Numerical dosimetries on induced current density are performed with IM by using measurement data as a case study. Two voxel models of the average Japanese adult male and female are applied to these analyses. It is found that hot spots of induced current density are observed at a few cm inside from human skin. In this case study, induced current densities estimated by numerical method do not exceed basic restrictions for general public exposure given by ICNIRP.

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