Design of Magnetic Shielding System for Cancer Treatment with Hyperthermia Inductive Heating

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Abstract

In this paper, we propose magnetic shielding system for cancer treatment with hyperthermia inductive heating. It is a technique to control magnetic field intensity and relocate the heating area by using a cylindrical metal shielding with aperture.

Keywords : Shielding Hyperthermia Inductive heating

1. Introduction

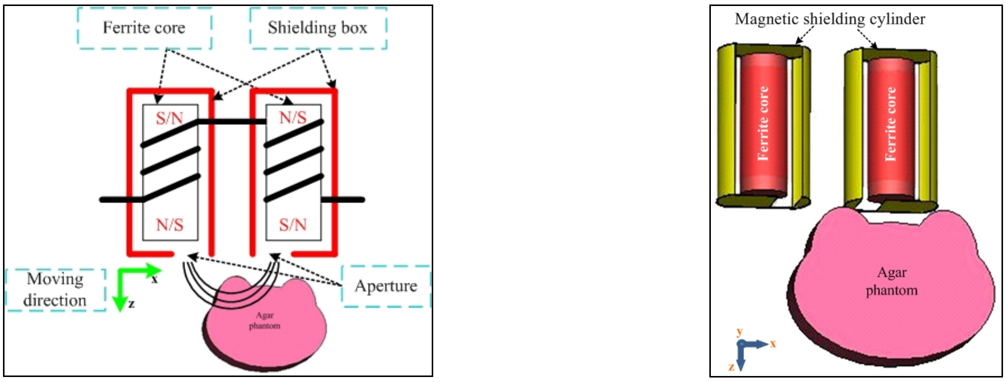
At present, cancer is one of leading cause of population death in worldwide. Cancer is the uncontrolled growth and spread of cells. It can affect almost any part of the body. Especially breast cancer, because of breast cancer has been increasing worldwide in every year [1]. Therefore, it is desirable to remove the cancer from the human body as soon as possible. Cancer can be treated effectively by various methods such as surgical excision, chemotherapy and radio therapy including hyperthermia [2] which is one of noninvasive techniques. There are few techniques for noninvasive deep hyperthermia. Most of microwave heating methods could not be used for deep hyperthermia due to skin depth effect. Low frequency technique is possible for deep treatment, however. The temperature in cancer cell can be increased by induction. To induce heat in the cancer cell, strong magnetic field has to penetrate the cancer cell to generate eddy current in the cell which can be visualized as electric loss. The eddy current will increase the cell temperature. The temperature of normal cells due to eddy current is constant since the cancer cell is more conductive than normal cell. Nevertheless, the direction of magnetic field is important for localizing the heating region. Because of high intensity magnetic field will side effects of neighbouring normal cells, which can have devastating to normal cells. Moreover, the magnetic field intensity is crucial for hyperthermia treatment since it controls tissue temperature. It has been shown that magnetic core orientation and position can control the field distribution in both horizon and vertical direction [3]. To concentrate magnetic field to a specific region, a shielding system is installed at the magnetic core [3]. The location of heating can be controlled by moving the ferrite core.

Resent the controlling heating position system in [3] utilizes two metal plates to control the vertical magnetic field. One metal plate is placed between two ferrite cores and other two metal plates are placed closed to the ferrite cores. This configuration provides control over the vertical field and, hence, the heating location can be determined by the ferrite cores location. However, the magnetic field will leak thought the unshielded side of the ferrite cores. The leakage of magnetic field results in difficulty of controlling the heating area and also effects normal cells that is nearby. Radio-therapy for breast cancer requires regional heating with specific temperature. The temperature is directly proportional to magnetic field intensity.

In this paper, we study the effect of cylindrical shield to heating area, depth and location of induction heating for breast cancer hyperthermia treatment. The heating area is determined by the aperture size of the cylindrical shield. To determine heat distribution in the breast, electric loss density is analyzed for various aperture sizes of the shielding cylinder. The applicator is a ferrite cylinder with diameter of 7 cm. In the simulation, the applicator is fed by a 4 MHz source. It is difficult to limit heating area when the applicator ferrite cores are unshielded. However, the heating efficiency is reduced as the aperture size decreases. If the small heating area is needed, it may require longer treatment time. Moreover, the heating location can be varied by changing ferrite core orientation. By moving the orientation of the ferrite core in x-axis and z-axis direction, the heating location and area are altered dramatically for unshielded ferrite cores whereas the heating position and area are slightly different for shielded cores. Simulations show that the heating position can be relocated from the top to the bottom and the left to the right of the breast by changing the orientation of the ferrite core with cylindrical shield. The cores vertical position has almost no effect on the heating area and position for shielded cores. In contrast, heating area and position is difficult to predict when unshielded cores are used. The proposed magnetic shielding system is suitable for prevent the effects of hyperthermia cancer treatment by induction heating.

2. Shielding System

The proposed magnetic shielding system consists of a shielding plate and two cylinders as shown in Fig. 1 (a). The shielding system in [3] consists of a metal plate to control the magnetic field from a single side of the core. Unlike the shielding system in [3], the proposed shielding system controls the vertical by enclosing the ferrite core with a cylindrical shield with aperture size of 3.5×8 cm. Since placing the shielding plate only one side of the ferrite core can control the magnetic field only one side, it will be magnetic field leak in the opposite side of the shielding plate. This magnetic field leakage results in spreading of the heating region. Thus, it is difficult to control the heating area. The proposed shielding system limits the magnetic field around the ferrite cores to confine the field in horizontal direction. Most of the vertical magnetic field will penetrate into the heating body via the aperture and, hence the heating region size can be determining by the aperture size. Moreover, the heating position can be relocated from the top to the bottom and the left to the right of the breast by moving the orientation of the ferrite core with cylindrical shield in x-axis and z-axis direction. The schematic of the simulation model is shown in Fig. 1 (b).



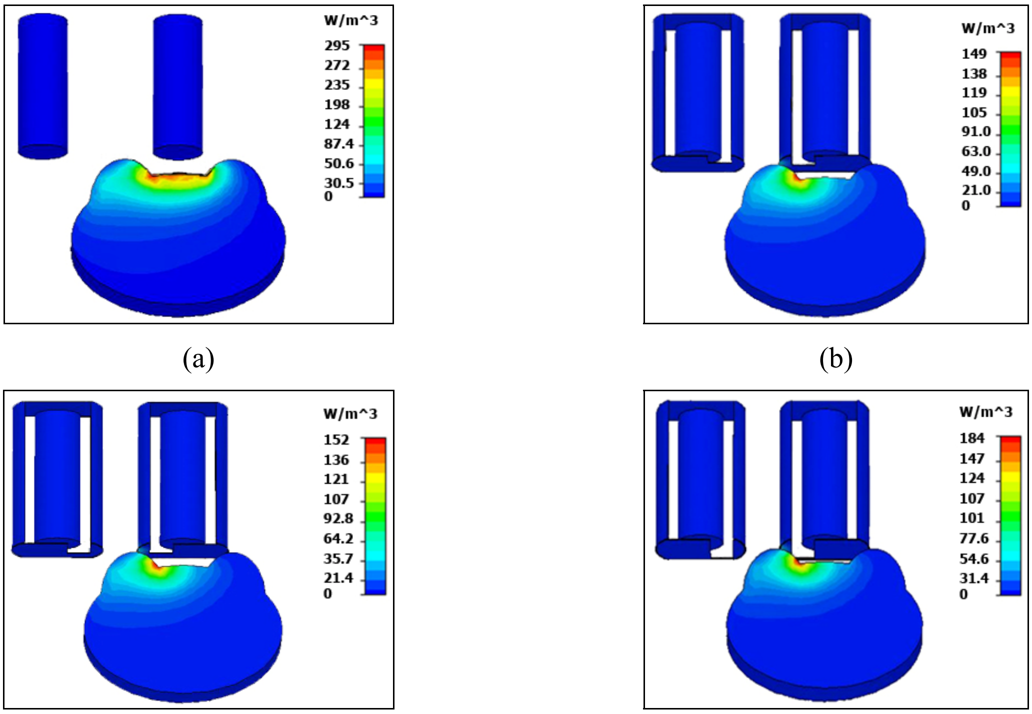
(a) (b)

Figure 1: Construction of magnetic shielding system (a) schematic of applicator system (b) simulation model

Fig. 1 represent the heating model is made from agar phantom with conductivity, relative permeability and relative permittivity are 0.62 s/m, 1 and 130 respectively. The magnetic shield plate and cylinders are metal with conductivity of 5.84e4 s/m. The ferrite core is a highly magnetic material with conductivity 0.001 s/m and relative permeability 200.

3. Simulation Results

The construction of magnetic shielding system to verify the field distribution on the heating model, full wave 3-D numerical simulation is performed using commercial software, CST EM Studio 2009. We evaluate electric loss density for the heating body. The ferrite core is excited by 4 MHz signal. The aperture sizes in the simulation are 5 cm, 7 cm and 8 cm. Electric loss density images for heating region of the ferrite core without shield and cylindrical shield with all aperture sizes are shown in Fig. 2.



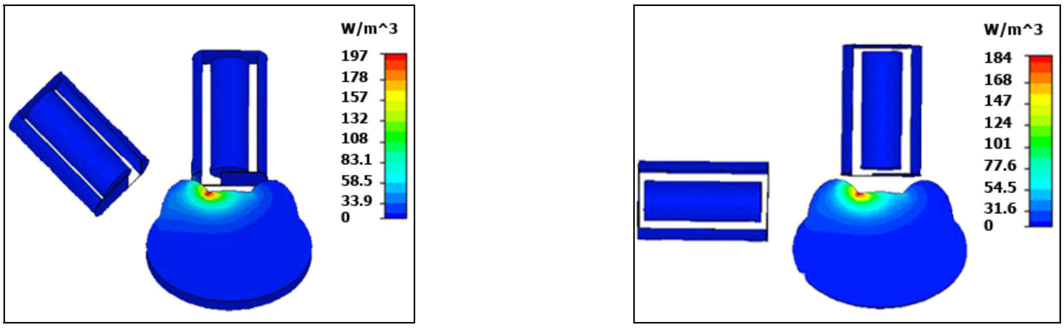
(a) (b)

(c) (d)

Figure 2: Electric loss density of the heating model (a) ferrite core without shielding (b) cylindrical shielding with 5 cm aperture (c) cylindrical shielding with 7 cm aperture (d) cylindrical shielding with 8 cm aperture

Fig. 2 represents the heating region of the ferrite core with and without cylindrical shield. The heating region has spread over the large area when the ferrite core is unshielded with cylindrical shield as shown in Fig. 2 (a). When the ferrite core is cylindrical shielded with various aperture size, the heating region size is confined in smaller area as shown in Fig. 2 (b) - Fig. 2 (d). The heating region size is reduced when the aperture size is smaller. It can be seen that the heating region is controlled by varying the aperture size.

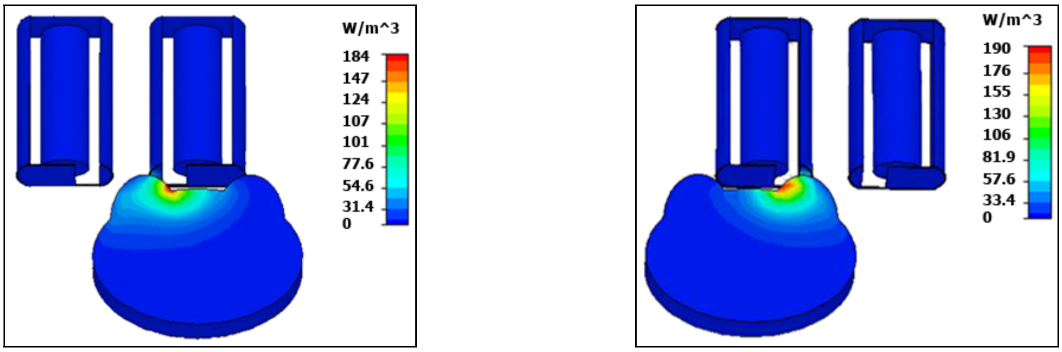
We further investigate the heating location by changing shielded ferrite cores orientation. The ferrite cores orientation with 45-degree and 90-degree are investigated as shown in Fig. 3.



(a) (b)

Figure 3: Electric loss density of the heating model for ferrite cores orientation (a) 45-degree (b) 90-degree

Fig. 3 shows the heating region when the ferrite core orientation with 45-degree and 90-degree. In the shielded cores, the aperture size is 8 cm in the simulation for both orientations. The maximum electric loss densities for the 45-degree and 90-degree orientation are more than the parallel ferrite core configuration. Furthermore, we investigate the effect of distance of the ferrite core in x-direction to the heating location as shown in Fig. 4.



(a) (b)

Figure 4: Electric loss density of the heating model for ferrite cores position in x-direction

The simulation results in Fig. 4 show that the heating locations can be relocated from the left to the right of the breast by changing the orientation of the ferrite core with cylindrical shield. The simulations show that the heating area can be controlled by aperture size. The heating area is proportional to the aperture size. It is difficult to limit heating area when the cores are unshielded. However, the heating efficiency is reduced as the aperture size decreases. If the small heating area is needed, it may require longer treatment time.

4. Conclusion

In this paper, the effect of cylindrical shield to heating area and location of induction heating for breast cancer hyperthermia treatment are presented. To determine heat distribution in the breast, which electric loss density is analyzed for various aperture sizes shielding cylinder. In the simulation, the inductive applicator is a ferrite core with diameter of 7 cm and excited by 4 MHz signal. The magnetic applicator is located inside this shielding cylinder. The simulations show that size of heating region can be controlled by varying the aperture size. Moreover, we investigate the position of heating region by varying the orientation of the ferrite core in x-axis and z-axis direction. Furthermore, we investigate the heating location by changing shielded ferrite cores orientation with 45-degree and 90-degree. The effect of vertical and horizontal position of the ferrite core to the heating location is also studied. Simulations show that the heating position can be relocated from the top to the bottom and the left to the right of the breast by changing the orientation of the ferrite core with cylindrical shield. The advantage of the magnetic shielding system is that it can be used to applied for prevent the effects of hyperthermia cancer treatment by induction heating.

References

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Acknowledgments

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