Mon-Af-Po1.15-11 [42]

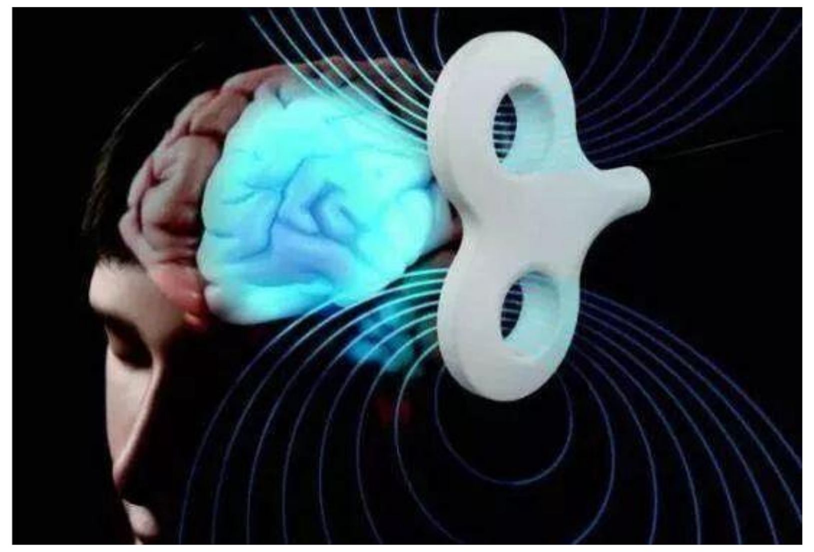
The Design of Transcranial Magnetic Stimulation Thin Core Coil based on Multi-objective Optimization

MT 26 International Conference on Magnet Technology
Vancouver, Canada | 2019

Chang Liu, Hongfa Ding, Xiao Fang, Zhixun Wang

Wuhan National High Magnetic Field Center，Huazhong University of Science and Technology, Wuhan, China， 430074

I. Introduction



Transcranial magnetic stimulation (TMS) has been proved to be effective in treating many psychiatric disorders. In order to improve the performance of the TMS coil, the magnetic core can be added to the existing coils to enhance the stimulus intensity and focality of the local space. In this presentation, the design of the C-type thin magnetic core coil for transcranial magnetic stimulation based on multi-objective optimization is proposed.

II. Methodology

A. Principle and Design of Transcranial Magnetic Stimulation thin core

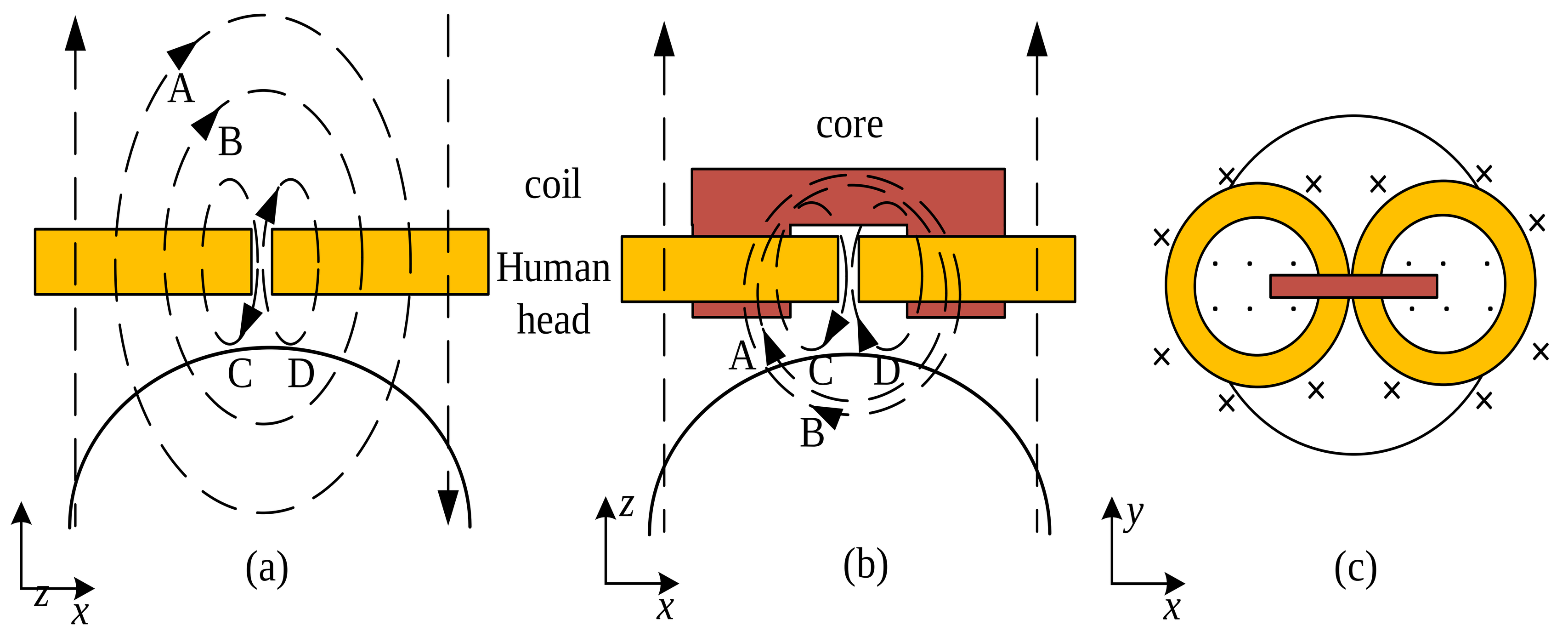


Fig. 1. Comparison before and after adding C-type thin core (a) without thin core (b) with thin core (x-z plane) and (c) with thin core (x-y plane)

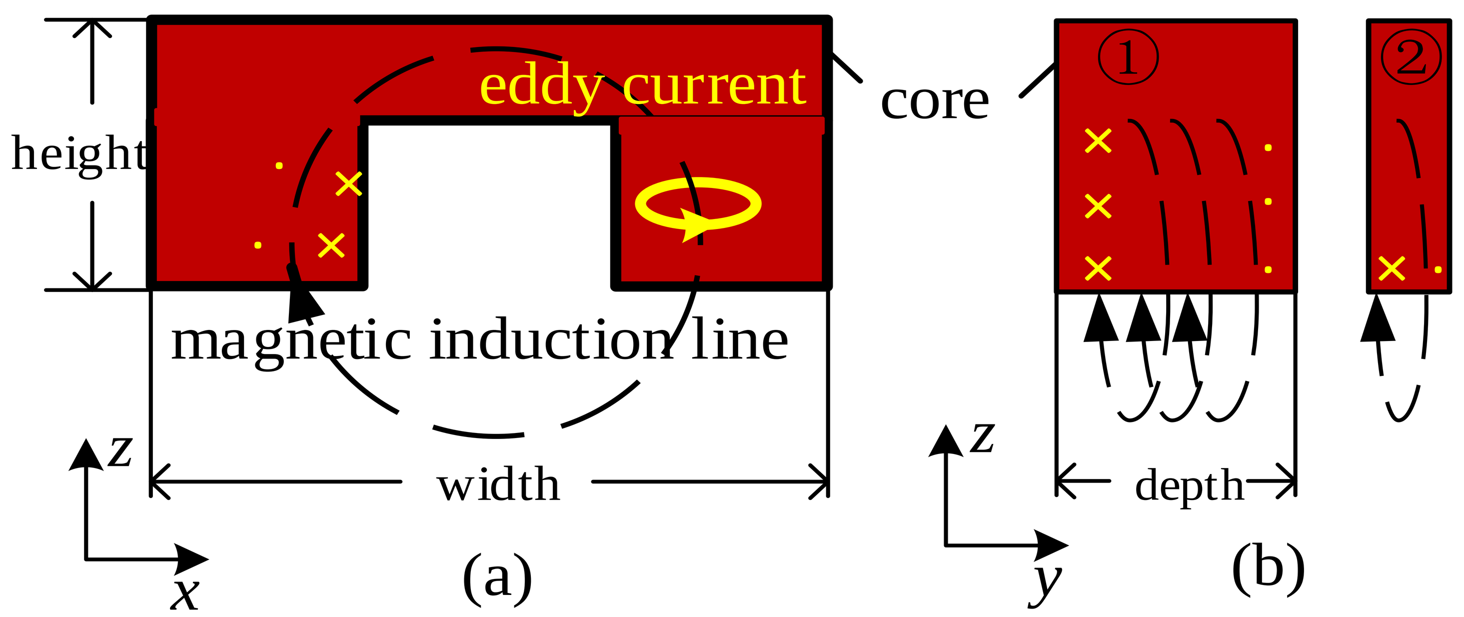


Fig. 2. Magnetic induction lines and eddy current inside the core(a) x-z plane (b) Y-Z plane (core 1 is thicker than core 2) in magnetic cores

In Fig. 1(a), the magnetic induction lines C and D pass through the air gap between the coils, while the magnetic induction lines A and B disperse in the air. After adding the C-type core, the divergent magnetic induction lines A and B prefer to pass through the high permeability magnetic core, which significantly improves the local induction magnetic field intensity under the coil(Fig.1 (b), (c)). However, geometric parameters (depth, width, and height) of the C-type core need to be further designed rationally, as shown in Fig(2).

B. Multi-objective optimization of core geometric structure

The definition of multiple conflict objectives of the C-type core are given:

1)The heating ratio of core coil (*H(n)*)

2)Focality (*S(n)*)

3)Induced electric field intensity (*E(n)*)

The multi-objective function in this paper is defined as:

$$F=\begin{cases}\min(-E(n))\\ \min S(n) \qquad n=1,2,\cdots,N\\ \min H(n)\end{cases}$$

After normalization, the above function is transformed as:

$$\begin{aligned}&\min F(n)=-\alpha E'(n)+\beta H'(n)+\gamma S'(n)\\ &\qquad n=1,2,\cdots,N\\ &\text{s.t.}\quad g(n)\le 0\\ &\qquad h(n)\le 0\\ &\qquad i(n)\le 0\end{aligned}$$

By solving above functions, the optimal solution of the core geometry structure can be obtained to achieve the optimum stimulation effect.

III. Results

In Fig.3, the example model is established. The intensity of the induced electric field (unit:V/m) is calculated in human head, the red arrows show the current direction in the coil, the solid black lines show the eddy current distribution. 64 sets of decision variables (i.e., geometric parameters) satisfying constraints are compared and screened one by one as shown in Fig.4

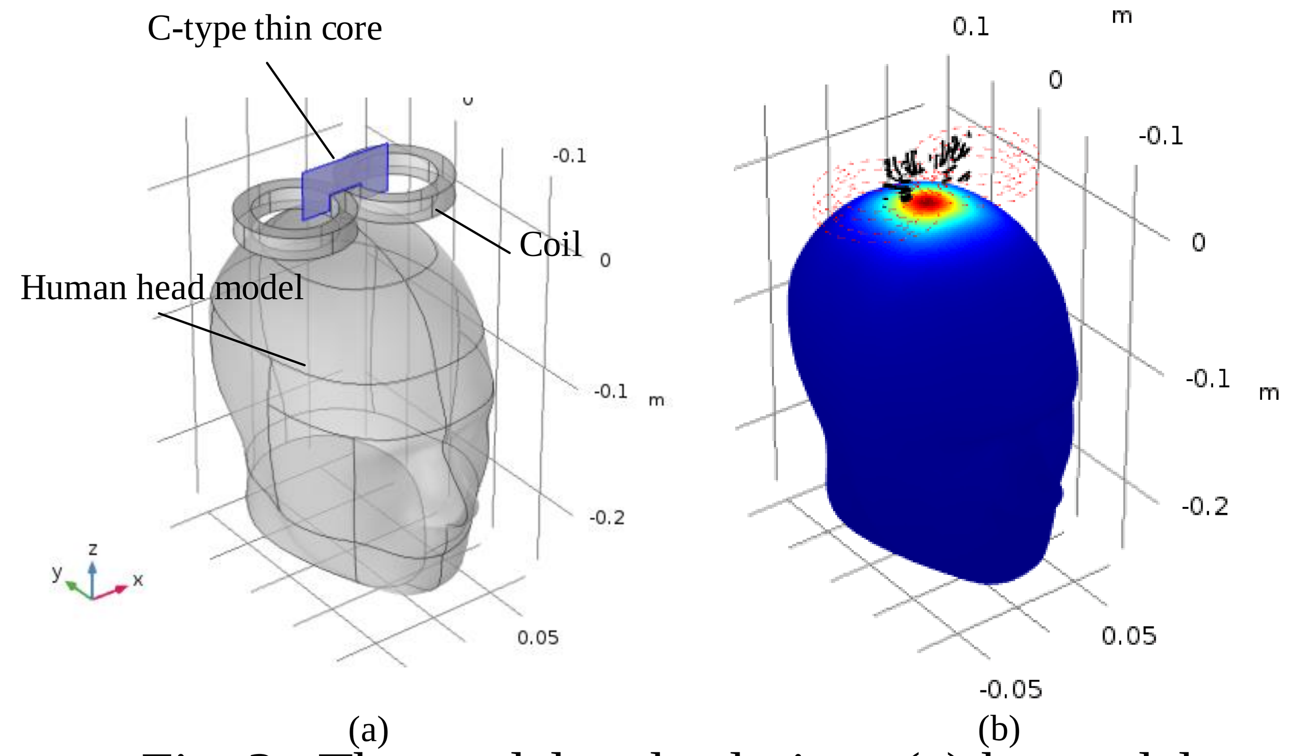


Fig. 3. The model and solutions (a)the model; (b)the solutions

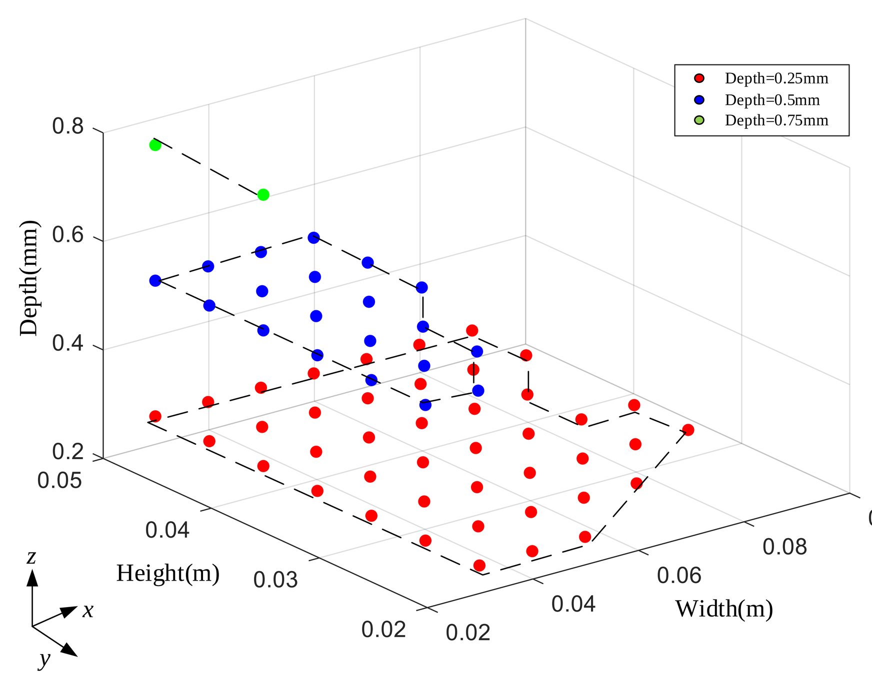


Fig. 4. Decision variables which satisfy constraints

The optimal geometric parameters satisfying different priority orders are selected(design A~F). The corresponding $S_{1/2}$, E_{max}, and heating ratio are also calculated. The comparison of optimum designs and other coils are shown in Fig.5. The focality, the induced electric field and the heating ratio of all the optimized design of C-type core coils are significantly better than those of other coils.

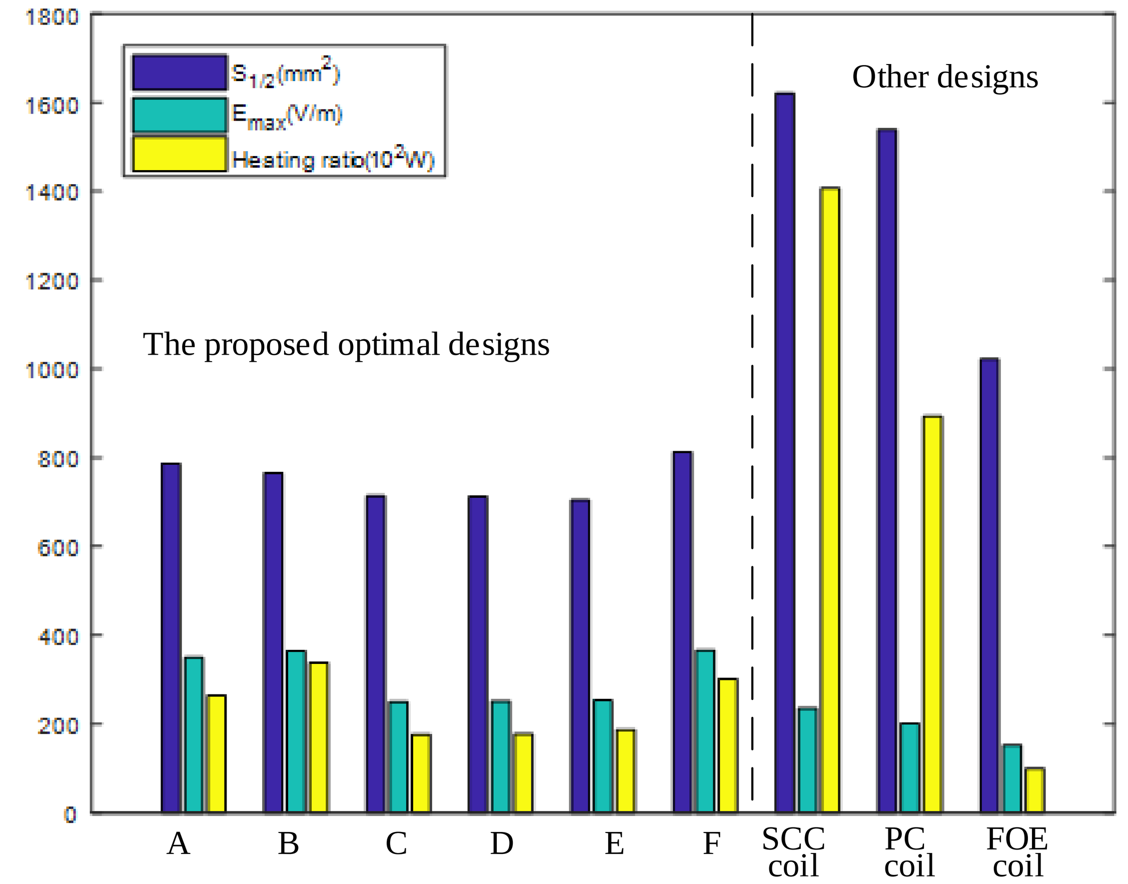


Fig. 5. Comparison of optimum designs and other coils

IV. Conclusion

Compared with the traditional FOE coil, the focality of the C-type thin core coil is increased by 20.4%~31.0%, and the maximum in-ducted electric field intensity is increased by 64.1%~140.3%. Compared with other magnetic core coils, the overall coil heat is reduced by 62.1%~87.4%, the focality is increased by 39.3%~56.5%, and the maximum induced electric field intensity is increased by 1.72%~81.7%.

V. References

1.Fang X, Ding H, Huang Y, et al. Improved Intracranial Induced Electrical Field in Transcranial Magnetic Stimulation With Semiellipse Coil Pair[J]. IEEE Transactions on Applied Superconductivity, 2018, 28(3): 1-6.

2.Rastogi P, Lee E G, Hadimani R L, et al. Transcranial Magnetic Stimulation-coil design with improved focality[J]. Aip Advances, 2017, 7(5):056705.