Mon-Af-Po1.15-11 [42]
The Design of Transcranial Magnetic Stimulation Thin Core Coil based on Multi-objective Optimization

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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 coil

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:
\[
F = \begin{bmatrix}
\min(-E(n)) \\
\min S(n) \\
\min H(n)
\end{bmatrix} \\
n = 1,2,…,N
\]

After normalization, the above function is transformed as:
\[
\min F(n) = -\alpha E'(n) + \beta H'(n) + \gamma S'(n) \\
s.t. \quad g(n) \leq 0 \\
\quad h(n) \leq 0 \\
\quad l(n) \leq 0
\]

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

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 inducted 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