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少数個の磁気センサー信号による大型ヘリカル装置磁場分布の逆推定
Reconstruction of magnetic field profile in LHD with a small number of magnetic sensor signals

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Introduction: In the 3D Cauchy-condition surface (CCS) method analysis to reconstruct the magnetic field profile in the LHD, an impractically large number of sensors was assumed [1]. To reduce the number of sensors, a possible measure is the reduction in the number of unknowns.

In the method, the boundary integral equations are discretized and converted to a matrix equation $\mathbf{Dp} = \mathbf{g}$. The matrix is decomposed as $\mathbf{D} = \mathbf{U}\Lambda\mathbf{V}^{\mathrm{T}}$, where Λ is a diagonal matrix with non-negative singular value components. The regularized solution is given by $\mathbf{p} = \mathbf{V}\Lambda_k^{-1}\mathbf{U}^{\mathrm{T}}\mathbf{g}$, where Λ_k means that the singular values smaller than λ_k are omitted so that the condition number (the ratio λ_1 / λ_k) is not larger than a certain value.

Behavior of the singular values: Figure 1 shows the singular value behaviors when assuming 440 field sensors and 126 flux loops. The vertical axis represents the singular values whose maximum value is normalized to unity. There is a gap in the vicinity of 10^{-2}, independent of the number of boundary elements set for the CCS.

It was found that the most accurate results of reconstructed field are obtained when all the singular values smaller than the gap threshold are filtered out.

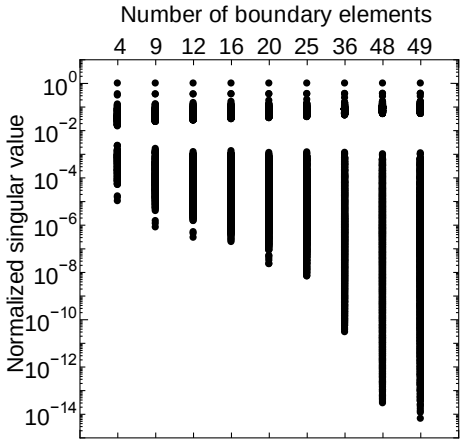

Fig. 1 Singular value behavior as a function of the number of boundary elements

Reduction in the number of sensors: To enable an analysis with only 110 field sensors and 25 flux loops, we used only 12 boundary elements. Even in this case, the gap was found in the vicinity of 10^{-2}. The field results were compared with the reference HINT2 code [2] solution. Figure 2 shows (i) the maximum errors of the field and (ii) the portion of the area where the error is larger than 0.02T, as a function of the condition number. The error tendencies were investigated for the region $1.0 < \rho < 1.1$ in the minor radius (ρ) space. The accuracy is higher than that reported in Ref. [1].

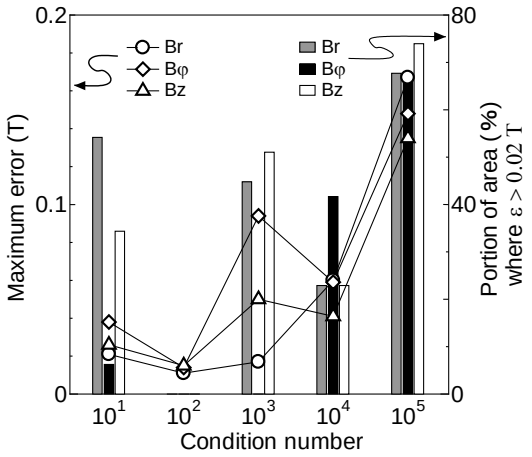

Fig. 2 Error tendency when assuming a small number of sensors with 12 boundary elements

Conclusion: Accurate field results are obtained even with the above small number of sensors by cutting off the singular values smaller than the gap threshold. The numbers of field sensors and flux loops can be further reduced to 58 and 13 respectively if the symmetry of the field profile in the LHD is considered. This required number is almost the same as the number of sensors installed in the LHD, so that present results suggest the possibility of actual application to the LHD.

References

[1] Itagaki, M., et al. 2012 *Plasma Phys. Control. Fusion* **54**, 125003.

[2] Suzuki, Y., et al. 2006 *Nucl. Fusion* **46** L19.