Plasma boundary reconstruction using topological asymptotic expansion

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The real-time reconstruction of the plasma magnetic equilibrium in a Tokamak is a key point to access high performance regimes. The problem of the plasma equilibrium in a Tokamak is a free boundary problem in which the plasma boundary is defined as the last closed magnetic flux surface. Inside the plasma, the equilibrium equation in an Axisymmetric configuration is called the Grad-Shafranov equation.

Due to its economic importance, the plasma control problem has long been receiving considerable attention by engineers and mathematicians [1].

Therefore, the most developed methods deal with control theory or parametric optimization. In this work, we propose a new method. Our approach is based on the topological sensitivity analysis [2]. The plasma domain is reconstructed by inserting some holes inside a fixed initial one. The location and shape of the inserted holes are defined by a level curve of a scalar function, called the topological gradient. The topological gradient is calculated from a topological asymptotic expansion for the Grad-Shafranov operator.

More precisely, the topological gradient is derived as the leading term of a cost function variation with respect the insertion of small hole in the initial domain. The proposed approach leads to a fast and accurate numerical algorithm. The efficiency of the proposed method is illustrated by some numerical examples.

References

[1] Blum J. "Numerical simulation and optimal control in plasma physics with applications to the tokamaks", Wiley/Gauthier-Villars Series in Modern Appl. Math. (1989).

[2] Ben Abda A., Hassine M., Jaoua M., Masmoudi M.: "Topological sensitivity analysis for the location of small cavities in Stokes flow", SIAM J. Contr. Optim. **48** (2009), 2871-2900.