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Implementation and testing of stellarator-capable models in JOREK

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The JOREK nonlinear MHD code [1,2], which currently only supports tokamak simulations, is being extended to stellarators. This is a two-part process. First, a stellarator-capable reduced MHD model, i.e. a reduced model that does not make any assumptions on the underlying geometry, needs to be implemented. The second part involves modifying the currently implemented axisymmetric flux-aligned grids to allow alignment to non-axisymmetric flux surfaces.

We have derived a hierarchy of stellarator-capable reduced and full MHD models expressed in terms of a shared set of variables. These models have better conservation properties than most presently used models, but also a different and more complicated mathematical structure [3].

In the course of the implementation work, we introduced two modifications to the original model derived in Ref [3]. Due to the peculiarities of the projection operators used, a static field compression term had to be added to the momentum equation to maintain force balance. Also, the full energy conservation equation was replaced with the simpler and more numerically stable pressure evolution equation. These changes do not affect the favorable conservation properties of the original models [4].

In preparation for stellarator simulations, we first tested the simplest stellarator-capable model, which only allows for an ExB flow, in the tokamak limit. The tests include tearing mode and ballooning mode simulations in a circular cross section toroidal plasma. Both the ordering-based and ansatz-based versions of this model were tested and compared to each other and the standard JOREK reduced MHD model for tokamaks [4].

Comparison to standard reduced MHD is sufficient, as the predictions of full MHD and standard reduced MHD are nearly identical for the test cases considered [5]. In general, the stellarator-capable models show good agreement with standard reduced MHD in both the linear and nonlinear regimes, with the ansatz-based model being more robust than the ordering-based one.

The non-axisymmetric flux-aligned grid infrastructure has also been implemented [6]. Work is currently underway to import three-dimensional equilibria into JOREK and carry out stellarator simulations with the new models.

References

[1] G.T.A. Huysmans and O. Czarny. MHD stability in X-point geometry: simulation of ELMs. *Nuclear Fusion* 47(7):659, 2007.

[2] M. Hoelzl, *et al.* The JOREK non-linear extended MHD code and applications to large-scale instabilities and their control in magnetically confined fusion plasmas. *Nuclear Fusion*, 2020. (in preparation)

[3] N. Nikulsin, *et al*. A three-dimensional reduced MHD model consistent with full MHD. *Physics of Plasmas*, 26:102109, 2019.

[4] N. Nikulsin, *et al*. Verification of the new JOREK stellarator-capable model in the tokamak limit, 2020. (in preparation)

[5] S. Pamela, *et al*. Extended Full-MHD Simulation of Non-linear Instabilities in Tokamak Plasmas. *Physics of Plasmas*, 2020. (submitted).

[6] R. Ramasamy, *et al*. Studies of current driven disruptions in W7-A using the JOREK code, 2020. (in preparation).