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FOURIER-SEM SOLVER OF FLUID MODELS IN TOKAMAKS

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The goal is the numerical simulation of turbulence transport in the edge plasma of tokamaks using (i) a two-fluid model with Braginskii closure and (ii) a discretization method well adapted to turbulent flows and complex geometries. We indeed focus on the ITER configuration, i.e. the magnetic field and plasma geometry in the poloidal plane are not simply circular, as they are for TORE-SUPRA, but show the X-point configuration.

The two fluid physical model, developed in close connection with “l'Institut de Recherche pour la fusion par confinement magnétique” (IRFM), is based on the electrostatic assumption, i.e. the magnetic field is given (the magnetic field induced by the plasma itself is negligible), and on the hypothesis of electroneutrality (the density of ions and electrons are proportional). On the basis of the conservation equations of density, electron and ion momentums, electron and ion temperatures and electrical charges, a set of 10 non-linear coupled partial differential equations (PDE) can be set up.

A high order Fourier-SEM (Spectral Element Method) method has been developed to solve this set of PDEs in a 3D toroidal geometry. The torus section is discretized with quadrangular elements, within which the polynomial approximation degree is arbitrary, and Fourier expansions are used in the toroidal direction. In time one uses an RK3 (third order Runge-Kutta) IMEX (Implicit-Explicit) scheme, so that the Lorentz terms are handled implicitly. The capability of this approximation to handle an anisotropic diffusion in a 3D toroidal geometry has been tested. The strongly non-linear Braginskii closure is implemented. The Bohm boundary condition at the plates is also considered, i.e. the Mach number based on the ionic velocity equals or is greater than one. Fig. 1 shows snapshots of the ionic velocity and of the current for an axisymmetric computation done in the jet tokamak geometry, using here an Euler closure of the governing equations.

A parallel version of the code is currently developed. In order to improve the robustness of our algorithms we also plan to implement an efficient stabilization strategy. This could be based on the so-called entropy viscosity technique which makes use of a strongly non-linear viscosity based on the residual of the entropy equation. Up to our knowledge, this Fourier-SEM code is the first code that fully implements a two fluid ion-electron approximation with Braginskii closure of the governing equations.

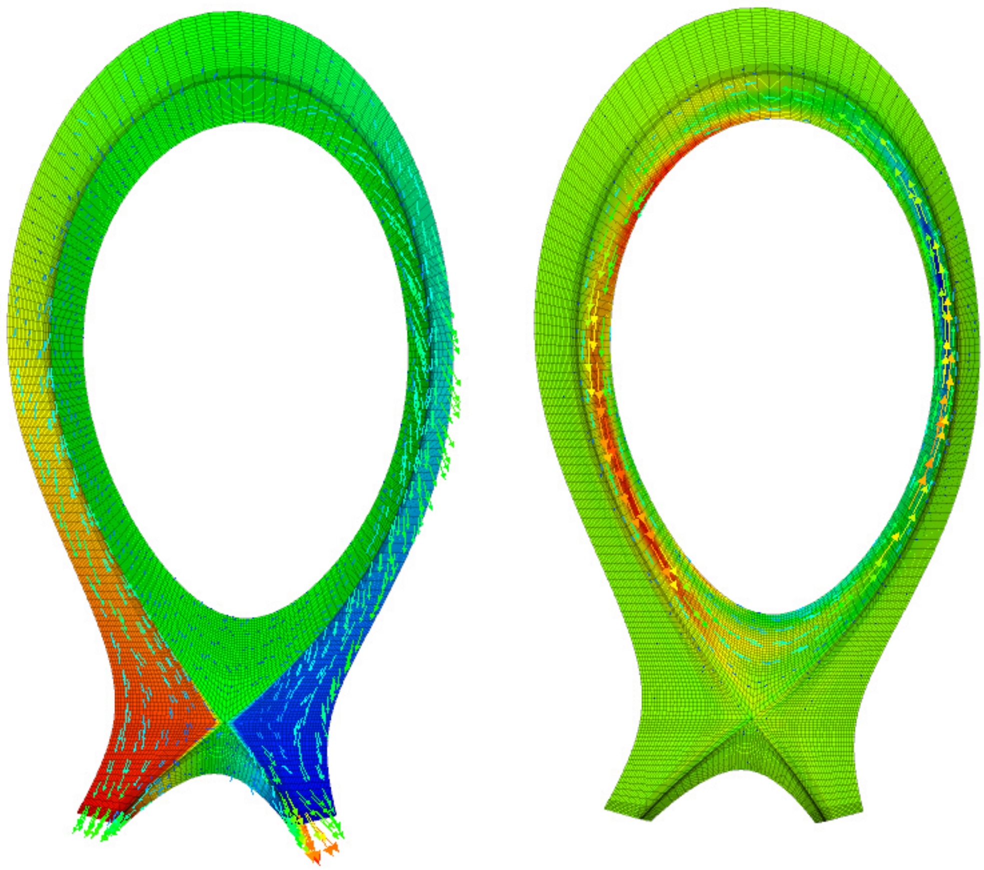

Figure 1: Ion velocity (at left) and current (at right). The vectors display the poloidal component and the color the toroidal one. SEM ($N = 2$) - RK3 IMEX scheme. The "Bohm boundary condition" $M \geq 1$ is imposed at the plates.

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