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GVEC: A new MHD equilibrium code for three-dimensional magnetic confined plasma states

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The computation of ideal magneto-hydro-dynamic (MHD) equilibria plays an important role in fusion research. It is a basic step in the modelling of a tokamak (toroidally axisymmetric) and a stellarator (three-dimensional torus-shaped). The MHD equilibrium is a non-trivial steady state of the ideal MHD equations, where magnetic forces balance the pressure gradient of the plasma, and where the contours of constant pressure form a set of nested tori or ''flux surfaces''. For the computation of such equilibria, one resorts to dedicated solvers which can take into account the coil field, current and pressure profiles inside the plasma. In the case of tokamak configurations, the axisymmetry allows the reduction of the problem to a two-dimensional nonlinear PDE (the Grad-Shavranov equation). This is not possible for three-dimensional plasma shapes in stellarators. Here, a different strategy using the minimization of total energy has been successfully applied within the famous VMEC code [1, 2], under the main assumption that a set of closed nested flux surfaces exists.

Adopting the same strategy as VMEC, a new 3D MHD equilibrium code GVEC (Galerkin Variational Equilibrium Code) was developed from scratch. A main difference to VMEC is the radial discretisation. In VMEC, the radial grid spacing is uniform in the normalised flux, which leads to a higher resolution at the outer boundary and a lower resolution at the axis. In comparison, in GVEC, B-Splines on a general non-uniform grid are used, allowing to accurately resolve the full radial domain including the magnetic axis and allowing local refinement of the grid. The B-Splines can be of arbitrary polynomial degree with high continuity, allowing accurate solutions with a small number of radial grid points. The regularity of the B-splines allows a natural calculation of radial derivatives, needed to evaluate equilibrium quantities such as metrics and magnetic field.

In the talk, we will present details of the discretization and minimization algorithms used in GVEC, and demonstrate its applicability to three-dimensional stellarator equilibria.

REFERENCES

[1] S.P. Hirshman, J.C. Whitson, *Steepest-descent moment method for threedimensional magnetohydrodynamic equilibria*,Physics of Fluids (1958-1988) 26, 3553, 1983

[2] S.P. Hirshman, W.I. van Rij, P. Merkel, *Three-dimensional free boundary calculations using a Spectral Green's function method*, Computer Physics Communications 43, 143—155, 1986