Contribution ID: **48** Contribution code: **P1.24** Type: **Poster**

Piecewise field-aligned finite element method in particle simulations

Tuesday 3 October 2023 16:24 (4 minutes)

To enhance the computational efficiency of particle codes in performing multi-n nonlinear simulations, piecewise finite elements have been developed in tokamak plasma, along with previous work [1,2,3]. Clebsch coordinates are constructed depending on the toroidal domain, which is consistent with the finite difference scheme [1]. In this work, the cubic spline finite element is adopted [3]. The grid is defined in (r, ϕ, θ) coordinates as shown in Fig. 1, where r, ϕ and θ are radial-like, toroidal, and poloidal coordinates. However, the basis functions are aligned along the magnetic field in (r, ϕ, η), where $\eta = \theta - \int_{\phi_i}^{\phi} d\phi'/q(\theta')$, with i denoting the index of the toroidal domain, q representing the local safety factor, and the integration performed along the magnetic field. In addition to the benefit of avoiding grid deformation and reducing the grid number in one direction [1], the scheme can be extended to higher-order finite element methods. Furthermore, the (r, ϕ, θ) grid is defined without a shift, allowing easy application of Fourier filters for linear benchmarking purposes. The gyrokinetic electrostatic model and the electromagnetic model using the $p_{\|}$ formulation have been implemented. The matrix construction for equations is carried out in Clebsch coordinates, employing Monte-Carlo integration. Since the particles are represented in (r, ϕ, θ) while the fields are defined in (r, ϕ, η), the field interpolation and density/current projection are performed using these two sets of coordinates. The linear benchmark using the Cyclone-like parameters shows reasonable agreement with previous work.
The capabilities of this scheme in multi-n nonlinear simulations are demonstrated, and its potential future applications in electromagnetic simulations in the MHD limit [3, 4], as well as employing unstructured meshes for whole volume simulations [5], are discussed. Furthermore, the connection to ongoing gyrokinetic studies is illustrated [6,7].

Figure 1: grids in (x, y), i.e., (ϕ, θ) (left); basis functions along B in (x, y) (middle) and in torus (right).

References:

[1] B.D. Scott, Physics of Plasmas, 8, 447 (2001)
[2] Z.X. Lu, F. Zonca, A. Cardinali, Physics of Plasmas, 19, 042104 (2012)
[3] Z.X. Lu, G. Meng, R. Hatzky, M. Hoelzl et al, Plasma Phys. Controlled Fusion 65, 034004 (2023)
[4] R. Hatzky, R. Kleiber, A. Könies, A. Mishchenko et al, Journal of Plasma Physics. 85, 1 (2019)
[5] Z.X. Lu, Ph. Lauber, T. Hayward-Schneider, et al, Physics of Plasmas, 26, 122503 (2019)
[6] G.T.A. Huijsmans et al, Comparing linear stability of electrostatic kinetic and gyro-kinetic ITG modes, EPS conference (2023)
[7] A. Mishchenko et al, Plasma Phys. Controlled Fusion 65 (6), 064001 (2023)

Author: ZHIXIN, Lu (Max Planck Inisititute of Plasma Physics)

Co-authors: Dr MISHCHENKO, Alexey (Max-Planck Institute of Plasma Physics); Prof. SONNENDRÜCKER, Eric (Max-Planck Institute of Plasma Physics); ZONCA, Fulvio (ENEA); Prof. HUIJSMANS, Guido (CEA, TU Eindhoven); Dr MENG, Guo (Max-Planck Institute of Plasma Physics); Dr HOELZL, Matthias (Max Planck Institute for Plasma Physics); Dr HATZKY, Roman (Max-Planck Institute of Plasma Physics)

Presenter: ZHIXIN, Lu (Max Planck Inisititute of Plasma Physics)

Session Classification: Poster session: 01