3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Self-consistent simulation of transport and turbulence in tokamak edge plasma by coupling SOLPS-ITER and BOUT++

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Abstract:

The method and the procedure of coupling the fluid plasma/neutral 2D transport code SOLPS-ITER and the fluid 3D turbulence code BOUT++ are reported, and the preliminary results of coupling the transport code SOLPS-ITER and 3D turbulence code BOUT++ are shown. The coupling has involved the profiles of ion density, ion temperature, and electron temperature and the profiles of the radial particle transport, radial ion heat, and electron heat transport coefficients in the computational regions. The self-consistent simulation of turbulence and transport in tokamak edge plasmas by coupling SOLPS-ITER and BOUT++ is carried out in order to illustrate the coupling procedure. The MHD equilibrium at the shot time t=5.55 s in the shot 56129 on EAST tokamak with the lower single-null configuration is used in the simulation for the production of the computational meshes in SOLPS-ITER and BOUT++. Both codes simulated the same edge region of EAST, which is from $\Psi_N = 0.85$ to $\Psi_N = 1.05$. The mesh number we used in SOLPS-ITER is 200×64, with 200 grids in the radial direction and 64 grids in the poloidal direction. BOUT++ has another 64 grids in the toroidal direction. First, we use SOLPS-ITER to provide the density and ion/electron temperature profiles for BOUT++. The initial particle transport coefficient and heat transport coefficients for SOLPS-ITER are set to $D_r = 0.5m^2/s$ and $\chi_i = \chi_e = 1.0m^2/s$. In turn, BOUT++ provides the particle transport coefficient and ion/electron heat transport coefficients for the SOLPS-ITER code with additional neoclassical transport coefficient terms. An iterative scheme is used that each system is evolved on its own characteristic time scale.

In different iterations, the profiles of density, ion temperature, and electron temperature show fluctuations. After eight or nine iterations, the profiles of density, ion temperature, and electron temperature show a weaker variation with the increasing iteration number, which can indicate that the iteration procedure approaches a quasi-steady-state. It is interesting to note that the particle and heat transport coefficients of ions and electrons are quite small in the second iteration of BOUT++, compared to the third iteration, while the profiles of density, ion temperature, and electron temperature are enhanced in the third iteration from SOLPS-ITER. We may conclude that small particle and heat transport coefficients may elevate the profiles of density and temperature, while the large particle transport coefficient and heat transport coefficients may depress the profiles. In turn, the transport coefficients are also influenced by the density and temperature gradients. Small gradients will lead to small transport coefficients, while large gradients will result in large transport coefficients. Large values of particle and heat transport coefficients provided by BOUT++ appear near the lower X-point, especially for particle and ion heat transport coefficients, but they do not have a significant influence on the overall solution.

SOLPS-ITER and BOUT++ have own mesh generation modules, and they generate computational meshes for themselves independently. In the present coupling simulations, the computational domains produced are controlled so as to be as similar as possible. The SOLPS-ITER/BOUT++ common mesh generation may be important, which may be done in future for more accurate research on SOLPS-ITER/BOUT++ coupling.

References

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This work was supported by the National Natural Science Foundation of China (No. 11575250).