§15. Edge Plasma Simulation of Stellarator System with UEDGE

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Magnetic configuration at the edge of a stellarator is very complex and contains a mixture of closed flux surfaces and stochastic field lines. At present, there is no plasma transport code that can handle highly complicated case. Moreover, it is even not very clear what kind of set of transport equations can be used for these purposes. At the same time, it is feasible that due to a strong anomalous cross-field plasma transport and convective plasma flows, rather detailed features of stellarator magnetic topology do not matter much for averaged plasma parameters. Therefore, it is worth to try a simple approach to the modeling of stellarator edge plasma based on "averaging" of edge plasma parameters along the magnetic axis and introducing effective two-dimensional flux surfaces. In this sense, we substitute the stellarator edge with that what can be called a stellarator-equivalent tokamak (SET) edge. We apply this approach to edge plasma modeling for Large Helical Device (LHD). We simulate the LHD-stellarator-equivalent tokamak with 2D edge plasma transport code UEDGE[1].

This method has following properties:

- Double null (bottom and top X-points) configuration,
- Same large aspect ratio,
- Same plasma cross-section elongation,
- Similar position of X-points, strike points at divertor plates, and plasma axis,
- Same radial gradient of magnetic flux in the core region adjacent to separatrix, and
- Similar compression factor for the edge magnetic flux tube, that is, the relation between the characteristic width of magnetic tube at the SOL mid-plane and its width in the divertor near strike points.

In the SET configuration, the characteristic connection length L_{SOL} of magnetic field lines from the SOL mid-plane to the divertor plates is typically set equal to the characteristic connection length in the real stellarator configuration calculated with 3D magnetic field line tracing code and averaged over a certain part of the "SOL".

The UEDGE code solves in 2D the fluid equations for plasma transport and reduced set of Navier-Stokes equations for neutral particle transport. The plasma sources are the ionization of recycling atoms and flux from NBI-fuelled core plasma. Plasma is neutralized at the divertor plates and walls and the corresponding boundary condtions are similar to that in tokamaks[2]. The combied effect of small-scale magnetic islands, stochastic magnetic field layers as well as of intermittency (infrequent but large-scale transport events) on cross-field plasma transport is modeled in UEDGE by prescribing the 2D profiles anomalous convective velocity V_{conv} and anomalous diffusivities ($D_\perp$, $\chi_\perp$) and by adjusting these profiles in order to match the experimental plasma profiles and recycling data[2].

Figure is a simulation result (ion density) of the case with the following conditions: B_t=3[T], R_0=3.75[m], n_{ec}=4.0x10^{19}[m^3], $P_e = \gamma_{ei} W_0$, $P_i = (1-\gamma_{ei}) W_0$, γ_{ei}=0.4, $W_0 = W_{NBI} - W_{rad}$, W_{NBI}=3.5[MW], W_{rad}=0.5[MW]. In the obtained steady-state solutions, the plasma flux through core interface is equal to the neutral flux plus the NBI fuelling rate F_{NBI}. Anomalous diffusivity for this case is $D_\perp$=0.20[m^2/s], $\chi_\perp$=0.40[m^2/s].

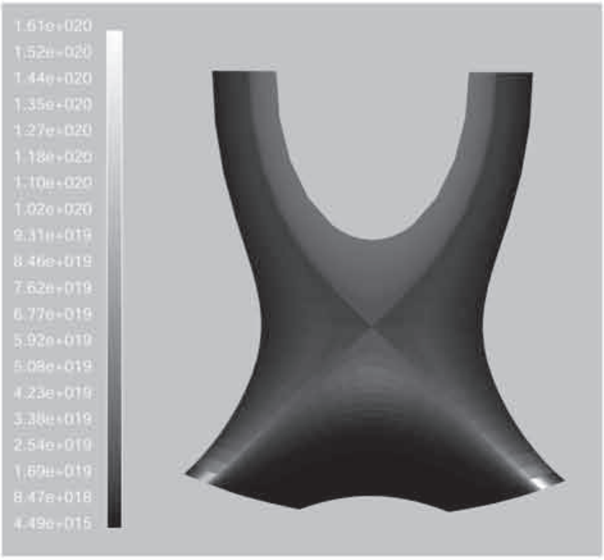

Figure Ion density n_i profile

References

1) Rognlien, T.D. *et al.*, J.Nucl.Mater. **196** (1992) 345.
2) Pigarov, A..Yu. *et al.*, J.Nucl.Mater. **313** (2003) 1076.