Modelling of H-mode EAST edge plasma with impurity seeding by SOLPS-ITER 3.2.0 on wide grid

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In future tokamaks-reactors with metal plasma facing components (PFC) it is crucial to control particle and heat fluxes to the first wall and divertor plates. Impurity seeding is a widely accepted technique to reduce divertor heat loads via a radiation, and it is assumed to be essential in future reactors like ITER, CFETR and DEMO. corresponding experiments are performed on many tokamaks to investigate impurity transport and impurity seeding compatibility with different tokamak operational regimes. In particular, of importance is not only a core-edge compatibility but also a far SOL transport. Even though fluxes to wall elements [1,2] are expected to be several times less than fluxes to targets [3,4], net erosion of wall material might be of the same order as target erosion simply due to bigger wall area.

However, for a long time in most tokamak edge transport codes, and in SOLPS-ITER as well, the computational domain ended at so-called last flux surface before reaching the wall and couldn’t be further extended. Thus, a gap between the computational domain boundary and PFC existed, and some extrapolation of the plasma solution was needed to estimate fluxes onto the wall. Additionally, the location of this computational domain boundary was somewhat arbitrary, and, since in the modeling recycling and sputtering took place at this boundary rather than on real wall, the obtained solution depended on the location of this boundary and on arbitrary parameters of the boundary conditions applied here. In particular, for the magnetic equilibria with two X-points within the vacuum vessel, which is a typical operational regime of EAST, an attempt to place this computational boundary within the secondary separatrix, thus working in SN (single null) topology, might lead to big difference with respect to solutions obtained on the DDN (disconnected double null) meshes. The underlying reason for that is skipping an important part of the far SOL and introducing artificial recycling and/or erosion sources too much close to the separatrix.

To better understand the far SOL transport much efforts have been spent recently on the development of plasma edge transport codes [5, 6, 7] in order to extend their computational domains up to the first wall, thus avoiding a problem of a computational boundary choice mentioned above. In the case of SOLPS-ITER, this grid extension required a transition to new internal data structures, new numerical methods, new approaches to boundary conditions etc [8], so to include all the physics routinely used in previous SOLPS-ITER versions (3.0.9 and earlier) into a new version (3.2.0) appears to be not so easy [9].

In the present report the SOLPS-ITER 3.2.0 on extended grids is applied to model H-mode discharges on EAST tokamak #116109 and #116114 with Ne and Ar seeding correspondingly, for the first time including full drifts and currents, impurities and kinetic neutrals. The modeling results are compared with the corresponding results obtained by SOLPS-ITER 3.0.9 on standard DDN mesh. Both meshes are presented in Fig. 1. It appears that even for the 5 cm width of this DDN standard mesh (as measured at the Outer Midplane, OMP), the arbitrary choice of the boundary conditions parameters on the virtual computational domain boundary representing a wall might affect the results of simulations. However, with a proper choice of these parameters it is possible to make plasma solutions obtained on standard and unstructured meshes close to each other.

The difference between two solutions is most pronounced in the inner target, where plasma flow is restricted by real wall elements rather than the structured mesh boundary. Accordingly, the ionization spatial source distributions are different due to difference in neutral flow patterns, since neutral recycling sources are located on real walls and not on the structured mesh boundary.

Modeling demonstrates that to match the Langmuir probe signals on the outer target, OT, together with discharge power big radiation losses are required. Assuming that these losses are due Ne, Ar or C impurity radiation remaining in the vacuum vessel, it appears that the amount of such impurity is also big, leading to big values of core effective charge ($Z_{eff} \approx 3.0$ with Ne, $Z_{eff} \approx 1.9$ with Ar and $Z_{eff} \approx 2.1$ with C). However, these values of Z_{eff} are close to ones experimentally measured by Bremsstrahlung radiation before the intensive impurity seeding.

Such a big amount of impurity leads to a clearly seen formation of the radiating spot at the top of the machine, illustrated in Fig. 2. The exact location of such a spot slightly varies with transition from standard to unstructured meshes, indicating the importance of wall recycling. The particle and energy balance analysis based on modeling results confirms this suggestion.

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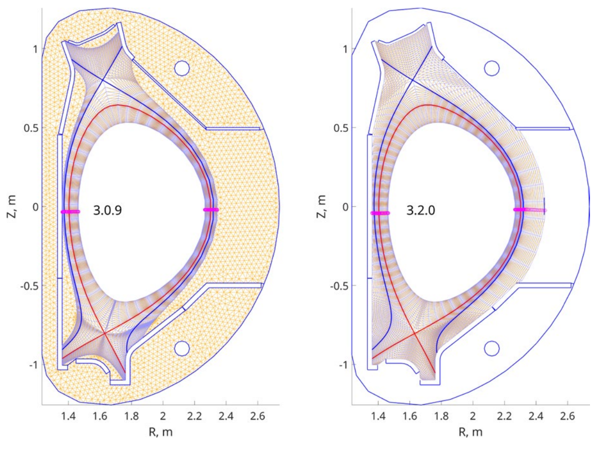

Fig.1 Standard and unstructured meshes for SOLPS-ITER 3.0.9 and 3.2.0 correspondingly

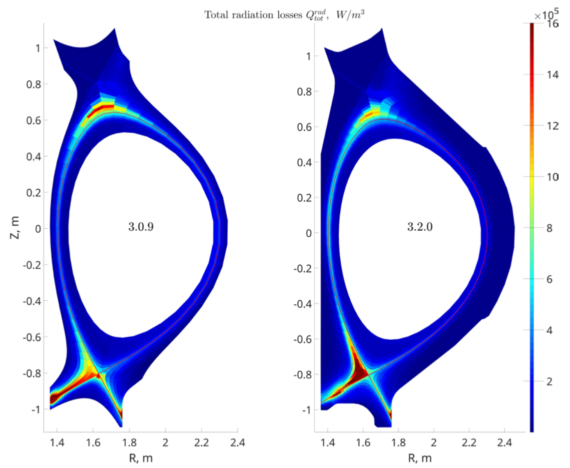

Fig.2 Radiation losses power density for Ne seeded cases computed by SOLPS-ITER 3.0.9 and 3.2.0