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Recent extensions and applications of the EMC3-EIRENE code

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The 3D edge Monte Carlo transport code EMC3-EIRENE [1] has been extended by implementing a selfconsistent treatment of impurity transport. The effects of different impurity concentrations on a high-density divertor plasma have been studied under the typical island divertor condition of a very small field line pitch (≈ 0.001 for W7-AS compared to ≈ 0.1 for tokamaks). Calculations are carried out for two hydrogen plasma upstream densities, $n_{e,up} = 6x10^{19}$ and $8x10^{19}$ m^{-3}. Carbon released from the targets via sputtering processes is assumed to be the only impurity species. The sputtering yield is controlled by a sputtering coefficient S_c which, as a free parameter, is varied from 0.5% to 5%. A total power of 1 MW entering the island SOL is kept fixed for all computations.

In the lower density case, the carbon radiation initially increases almost linearly with S_c up to 3.1% and then jumps to a high level at which carbon radiates more than 80% of the SOL input power. Simultaneously, the downstream temperature, pressure and recycling flux sharply drop indicating detachment. By decreasing S_c from the detached state, the plasma goes back to the attached state. However, the backward transition occurs at a lower value of S_c than the forward transition. If $n_{e,up}$ is increased to $8x10^{19}$ m^{-3}, the value of S_c needed for detachment is shifted down to 1.5%, showing a roughly square dependence of the radiation on density. In addition, the transition becomes much smoother and the hysteresis effect vanishes. In both density cases the radiation layer jumps from the target to the separatrix when detachment occurs. No stable solution exists in between within the given parameter range.

The physics behind these effects is strongly related to the predominant role of the cross-field transport associated with the small size and field line pitch of the islands. The cross-field diffusion smoothes the plasma and carbon density distribution in the island. A simple 1D radial energy transport model assuming a constant plasma density and carbon concentration can reproduce the mentioned effects. Therefore this model is used as a guideline to illustrate and discuss the detachment physics in details, including the detachment conditions, the stabilization of the radiation layer and the thermal instability during the transition.

The code is presently being extended to arbitrary SOL configurations including open island structures and ergodic magnetic fields by using a flux-tube defined grid geometry and a fast, highly accurate field-line mapping technique at the ends of the open flux tubes. The method correctly reproduces closed islands of any size over a high number of toroidal turns and inherently avoids numerical diffusion of parallel transport into the radial direction. Mapping examples are shown for W7-AS, W7-X, LHD and TEXTOR DED and the new technique is applied, in a first step, to solve the coupled heat conduction equations for typical ergodic SOL configurations .

References

[1] Y. Feng, F. Sardei, J. Kisslinger, J. Nucl. Mat. **266-269** (1999) 812

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