Divertor plasma detachment: past and future

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Large heat flux to and fast erosion of plasma facing components as well as tritium retention are critical issues of plasma material interactions (PMI) for future magnetic fusion reactors. Detached divertor regime, which is characterized by large reduction of both heat and plasma particle fluxes to divertor targets, suggests a plausible solution at least for some of the PMI issues. Even though divertor detachment was studied extensively for almost three decades, still there are some controversies with the roles of different processes including impurity radiation loss, cross-field plasma transport, plasma-neutral interactions, and plasma recombination in the reduction of plasma flux to the target. In addition, detached divertor regimes can be subject to different instabilities, resulting in significant fluctuation of plasma parameters, and the bifurcation-like phenomena causing the jumps of detachment front and MARFE formation, which, potentially, can cause disruption of the discharge. The physics of such instabilities and bifurcations is not very clear yet, although different models were suggested in the literature. Finally, it is plausible that some synergistic effects of plasma and wall physics play an important role in detachment related issues. We note that all of these can be complicated by ELM effects.

In the talk we outline the physical picture of divertor detachment and discuss the role of each physical process resulting in the redaction of plasma flux to the target. We also emphasize how these roles could change in advanced divertors in comparison with current tokamak divertors. We review existing models predicting instabilities and bifurcation phenomena in detached and semi-detached regimes, compare them with existing experimental data and give the projection for advanced divertor designs. Finally, we discuss the most crucial gaps in our understanding of edge plasma physics and how they may affect our assessment of divertor performance in future tokamak reactors.