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Overview of boundary plasma asymmetries in conventional and spherical tokamaks

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Divertor design for future reactors is machine defining [1-3] and requires reliable models to assess the energy flux reaching the targets. Evaluating the asymmetries in the power deposition between the different divertor legs, both in single (two legs) and double null (four legs), is therefore critical. We provide a theoretical, numerical and experimental analysis of the subject, using novel models and experimental results from MAST-U. A new theoretical model based on a 1D representation of the Scrape off Layer will be introduced. It includes the effect of geometry as well as several corrections not usually considered in similar calculations, such as the contribution of advection, the average pressure, surface recombination energy, currents and drifts. We find that the Scrape Off Layer collisionality, together with the magnetic geometry and the temperature at the target, play an important role in determining the plasma regime and the overall asymmetries. In particular, we find that the magnetic geometry [3,4], specifically for spherical tokamaks, tends to reduce the in/out asymmetry in single null and disconnected double null configurations, thus allowing longer outer connection lengths solutions, and making Super-X and X-divertor solutions more viable. The theoretical model is supported and complemented by numerical simulations carried out with SOLPS and describing the behavior of the plasma in the region of validity of the model as well as in deeply detached conditions. A database of numerical simulations with plasmas in different conditions and geometries is used to test the assumptions of the theoretical model. Finally, we provide an overview of experimental observations collected in MAST and MAST-U, describing and characterizing the asymmetries in disconnected double null configurations. The relative distribution among the in/out and top/bottom divertor legs will be discussed as a function of the separation between the main and secondary separatrix, both in conventional and Super-X configurations. Preliminary results or recent experiments show that the inner legs receive a smaller fraction of the total power even when the separation between the separatrices is of the order of the heat flux decay length (λ_q), which is aligned with the new theoretical model.

References
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