Progress in integrating ITER-relevant core and edge plasmas within the constraints of an ITER-like Wall

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The goal of the international ITER project is to produce ~500MW of fusion power. To achieve this without exceeding the power handling capability of the divertor requires seeding of the plasma with impurities to radiate about 75\% of the total power from fusion and external heating systems which are deposited in the plasma. High confinement is required in the core (H-mode) this associated with high plasma pressures at the edge (the pedestal) and periodic crashes in edge pressure leading to high transient heat loads in the edge plasma (ELMs). In combination with a tungsten divertor this creates a number of contradictory pressures which have been the focus of recent studies in JET with its ITER-like Wall.

In L-mode plasmas (low confinement without ELMs) in JET, injecting nitrogen initially increases the tungsten sources produced at the divertor targets due to the increased momentum transfer to surface tungsten atoms. But as the divertor plasma cools due to nitrogen radiation, the sputtering decreases to very low level. In H-mode plasmas nitrogen seeding produces similar cold “partially detached” divertor plasmas between ELMs but during ELMs the impurities carried with the ‘finger’ of hot plasma are transiently pushed down to the surface and generate the dominant source of tungsten by physical sputtering. At the same time it has been found that in contrast to the situation with the carbon wall, nitrogen seeding can improve the energy confinement of the main plasma via its effect on the H-mode pedestal. Recent data shows that while this effect is strongest in high triangularity plasmas (~40\%), a weaker effect is also present for low triangularity plasma shapes (~15\%). This effect, which is not described by current physics models for the pedestal, seems to largely reverse the loss of confinement seen for the ITER-like Wall in ITER baseline H-mode scenarios (with ITER relevant normalised beta). However, the first JET experiments showed that there was a price to be paid for this. The tungsten source generated by ELMs is enhanced both by the nitrogen ions and by the increased pedestal pressure and hence ELM size. At the same time the improved core confinement makes it harder for the main plasma to flush out the tungsten via radial transport. Finally, the low level of central heating in neutral beam only heated plasmas meant that tungsten could accumulate with time eventually leading to radiation collapse.

Recent JET experiments have successfully tackled the problem of making nitrogen seeded plasmas stationary for 7s with respect to core radiation / tungsten accumulation by adding 3MW of central ICRH heating to the 15MW of neutral beams. These H-mode discharges are a significant step towards an integrated scenario achieving fractional radiated powers up to 60\%, density normalised to the Greenwald value of 80\%, normalised plasma pressure $\beta_{N} \sim 1.6$, normalised energy confinement factor $H_{98(y,2)} \sim 0.85$ and effective charge $Z_{eff} \sim 1.6$ with very low target power / partial detachment between ELMs. The inter-ELM plasma parameters in the edge and divertor have also now been modelled using coupled EDGE2D/EIRENE multi-fluid/Monte-Carlo neutral codes. Simulations of key diagnostic data show that the main features of the experiment can be reproduced. The lack of carbon as a significant radiating species greatly simplifies this work compared to simulation of seeded carbon wall discharges. The latest progress in comparing the role of divertor geometries and different seeded impurities in experiments and simulations will also be presented. This work was part-funded by the RCUK Energy Programme and by EURATOM and carried out within the framework of the EFDA. The views and opinions expressed herein do not necessarily reflect those of the European Commission.