Impact of tungsten and its transport on H-mode plasmas, experiments and modelling

Clemente Angioni

Max-Planck-Institut für Plasmaphysik, 85748 Garching bei München, Germany

The choice of tungsten as plasma facing material has several, highly recognized, essential advantages for the operation of a fusion reactor. At the same time, such highly radiating element produces important effects which can impact the plasma operational conditions, the control requirements, the domains of existence and accessibility of the confinement regimes and overall, directly or indirectly, the plasma confinement and performance. The properties of tungsten transport play an important role in this context, particularly in the H-mode, where, at least in present devices, the pedestal can strongly contribute to the increase of the tungsten concentration in the plasma core.

In this presentation, first the properties of tungsten transport, which are particularly important for H-mode confinement and operation, are reviewed. From the walls, where the tungsten source is located, to the plasma core, the tungsten behavior strongly couples the periphery with the center of the plasma, in both directions. Operational solutions to limit the increase of tungsten concentration and the possible central accumulation can and have to act both at the edge and at the center. These operational, control room developed, solutions are now understood from a theoretical standpoint and can be reproduced by modelling. In particular, the different roles of collisional and turbulent transport in the pedestal and in the core are highlighted, contrasting the conditions of present tokamaks with those expected in a fusion tokamak reactor.

The presence of tungsten, in combination with the operational requirements to avoid accumulation, impacts the operational domains of accessible plasma parameters, as well as the H-mode access and H-mode sustainment. The impact of tungsten on the H-mode global confinement is then examined. Here, one important element is connected with the need of disentangling direct effects, produced by the presence of tungsten and the consequent radiated power losses, from indirect effects, which are produced by the operational conditions, which are required to maintain the tungsten contamination limited and the H-mode operation stable. These are often common to those, which are required for a viable power exhaust. Differences are examined between H-mode regimes characterized by the absence and by the presence of type-I ELMs, in view of the potential impact of a W environment on their accessibility and on their confinement.

The possibilities of understanding and of reproducing the observations with modelling approaches, which are mainly based on theoretical elements, are finally discussed. For a complete prediction of the experiment, not only tungsten sources, transport and consequent radiation have to be consistently included, but also the effects, which are produced by the operational conditions and which are required to keep the W concentration under control.

Overall, the presentation highlights the need of a comprehensive approach in the integration between core and edge from the experimental and operational standpoints, as well as an integrated understanding of the plasma from the walls, where the tungsten source is located, to the core. As already underlined, the W behavior strongly couples the different regions of the plasma. Such an integrated understanding has to be accompanied by increasing efforts in an integrated modelling approach, which consistently couples edge and core.