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PLASMA-WALL INTERACTION IN RFX

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The control of the plasma-wall interactions has a particular relevance in present day Reversed Field Pinch experiments where an ohmic input power of tens of MW is applied and where the peripheral region of the plasma appears to play an important role on the confinement properties of the configuration. This paper describes the principal features of the plasma-wall interaction in RFX, its impact on plasma performances, the methods adopted to reduce this impact and the results obtained.
In RFX (a=0.46 m, R=2 m , Ip<1 MA, T_e~200-400 eV, n_e ~ 1-8 $10^{19}m^{-3}s^{-1}$) the large heat load associated to the typical ohmic power input of 20 MW is unevenly distributed onto the graphite tiles of the wall armour due to a number of asymmetries in the plasma-wall interactions. These include the radial shift of the plasma column, local error fields corresponding to the presence of holes and gaps in the external conducting shell and particularly the presence of a helical magnetic perturbation locked to the wall, that dissipates up to 40% of the power input onto a relatively narrow region of the wall surface. As a consequence the power density to the wall may locally be very high and in the region of the locked deformation may reach values of 100 MW/m^2. At high currents (Ip≥ 800 kA) such heat loads often give rise to enhanced recycling or to carbon bloom events that increase the plasma resistivity up to becoming an operational limit.
The plasma performances have in general improved with the progressive reduction by means of passive and active methods of the field errors, especially those generated by the gaps in the conductive shell, with the reduction of the horizontal shift of the plasma column and with the optimisation of the operational mode. With these techniques the locked perturbation remains the main factor determining the interaction of the plasma with the wall in RFX and the results described below are obtained in these conditions. Recently however, we have demonstrated the possibility of moving the perturbation during the shot with a beneficial effect on the plasma wall interaction.
Due to the non uniformity of the power deposition to the wall, a good diagnostic coverage of the plasma surface has been necessary to assess quantitatively impurity influxes and radiation losses. The radiated power is usually a negligible loss channel (5-10 % of the input power) except at very high densities where it could be responsible for the observed saturation of global confinement with density. The region of the helical deformation may be responsible of approximately 30 to 50% of the total power lost by radiation. Similarly, the impurity influxes from the wall-mode locking region is of the order of 50% of the total one.
Despite the large power load to the graphite, in standard discharges the effective charge of the plasma is relatively low and similar to what found in tokamaks for the same electron densities. The main contribution to Zeff comes form oxygen and carbon, while metals have only seldom shown up in the spectra. In fact, after wall boronisation Zeff values approach unity and the radiation barrier moves towards higher densities, in the parameter region where the best confinements are found. The beneficial effect of the boronisation procedure lasts about a hundred shots. The reduced capability of trapping oxygen has been associated to the formation of hydrogenated carbon-rich layers, originated by erosion phenomena due to localised plasma-wall interaction. Among the various conditioning procedures, boronisation with diborane together with carefully dosed glow discharge cleaning in helium and hydrogen has been particularly effective in improving the control of the hydrogen recycling, otherwise heavily determined by the graphite wall. Further recycling control capability has been gained with hot wall operations (T=280 °C) especially at high currents.
Impurity penetration studies have been performed by puffing various gases into the plasma; in the case of neon a radiated power of the order of several MW can be reached at the plasma edge without deterioration of neither confinement time nor β_p. Experiments with other elements (Xenon and CH_4) are in progress. Simulations of the plasma edge via a Monte Carlo code are being carried out in order to evaluate whether finite Larmor radius effects may contribute to the impurity screening.
The relatively large Larmor radius of ions has instead been identified as an explanation of the origin of the wall current that flows in the RFX vessel during the whole discharge and represents a specific aspect of plasma-wall interaction in RFX, and likely for RFP's in general. These currents are usually higher at the locking position and originate from a radial current generated by the plasma as a consequence of a different deposition profile of plasma electrons and ions to the wall. The influence of this mechanism on the plasma momentum balance has also been assessed and it turned out to be a possible cause for the existence of the edge sheared electric field layer.