Modelling the Neutraliser Plasma of ITER Negative Ion Beams

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The reduction in neutralisation efficiency of positive ion beam systems is now known to be largely due to gas heating effects [1]. The neutraliser gas target is not heated directly by the beam but as a result of processes involving the particles of the plasma created by the beam in the neutraliser, as described by Paméla [2]. Two of the most important processes are molecular dissociation by the plasma electrons and acceleration of plasma ions across the sheath at the neutraliser wall and their subsequent reflection as energetic neutrals. The heating of the neutraliser gas in the presence of a negative ion beam can therefore be predicted from the characteristics (density, electron temperature and plasma potential) of the resulting neutraliser plasma.

A model, originally developed for positive ion systems, has been adapted for application to ITER relevant negative ion beams, i.e. the heating (HNB) and diagnostic (DNB) cases. The beam is regarded as the source of ionisation, the negative, neutral and positive components being considered individually. The stripped electrons are treated separately to the plasma, as it is shown that for both ITER beams, these electrons are not thermalised by inelastic and coulomb collisions. Power balance between the rate of energy transfer from the three beam components (stopping power) and the power deposited on the neutraliser walls by the plasma and stripped electrons provides an expression for the electron temperature and the plasma potential follows from the boundary condition at the wall.

The results of the modelling imply a relatively weakly ionised plasma for the HNB with $n_i \sim 10^{15} m^{-3}$, $T_e \sim 1.5 eV$ and $f \sim 5V$ (n_i is plasma density, T_e electron temperature and f plasma potential); as a consequence the gas heating is effectively zero. For the DNB the plasma parameters are similar to those in the neutraliser of the JET positive ion system, $n_i \sim 10^{16} m^{-3}$, $T_e \sim 20eV$ and $f \sim 80V$. In the JET system these plasma parameters lead to gas temperatures of the order 800K but for the ITER DNB, the gas heating effect is mitigated by the large wall area and the gas temperature is predicted to rise by only a few tens of degrees Kelvin.

[1] E Surrey & B Crowley, Plasma Phys. Control. Fusion, **45**, 1209 (2003)
[2] J Paméla, Rev. Sci. Instrum., B57B, 1066 (1986)

This work was conducted under EFDA and funded by Euratom and the UK EPSRC