Modelling of particle injection and edge plasma flows : detachment, transport and turbulence

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Plasma fuelling is a major issue for future tokamaks, particularly in the perspective of ITER. Beside pellet injection, an efficient method that has been experimented is supersonic injection. It has been shown on TORE SUPRA, that this efficiency is linked to a transient detachment of the plasma during the injection, allowing the neutral beam to enter further in the plasma before being ionized (burn through effect) while parallel losses in the SOL collapse. In this presentation, particle injection and transport is studied following two complementary approches.

First, we adress the detachment using multi-reservoir models. Divertor and limiter configurations are compared. In both cases, a bifurcation to a transient detached plasma regime is observed during a strong injection, linked to the collapse of the ionization rate when the plasma temperature decreases under 10 eV because of ionization losses. For lower injection magnitudes, a stable intermediate radiative regime is also possible due to the shape of the radiative loss function of carbon. A 1D radial model has also been developped to study the propagation of the ionization front. It shows the existence of a critical magnitude of the source : under the threshold, injections lead only to the detachment of the outer SOL, whereas above the threshold, detachment propagates into the confined plasma.

Another issue is the response of the plasma to the localized particle source. In particular, one can expect 3D changes in turbulence and transport properties. In order to analyse this aspect of the problem, we have devised a 3D fluid code modelling transport and turbulence in the edge plasma, the ”edge” including both the SOL and the outermost closed magnetic surfaces. The model is based on four balance equations : matter, charge, parallel momentum and current. Electric and diamagnetic drifts are included for both electrons and ions, the polarisation drift being considered only for ions. The plasma is assumed isothermal in a first step. The equations are solved in toroidal geometry for a toroidal limiter SOL with concentric flux surfaces. No retroaction of the plasma on the magnetic field is taken into account (electrostatic turbulence). One of the key points of the model lies in the boundary conditions chosen at the limiter and at the wall, based on the Bohm criterion. The code is spectral along the toroidal direction but uses finite differences for the two other directions, even poloidaly because of the non-periodic boundary conditions in the SOL. A second order time-splitting scheme is used so as to be able to handle nonlinear terms explicitely while diffusive terms are solved implicitely. We present here preliminary results on the validation of the code. A particular attention is given to conservation laws (matter and momentum). We also compare simulated linear growth rates to analytical ones derived for several representative instabilities. Thus, the Kelvin-Helmholtz and SOL interchange instabilities are investigated as well as the development of large scale poloidal modes linked to curvature.