Kinetic Simulation of Heating and Collisional Transport in a 3D Tokamak

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Microwave plasma heating has a strong influence on collisional transport, both in tokamaks and stellarators, as has been shown experimentally [1]. The exact estimate of the interplay between heating and collisional transport implies to solve a 5D kinetic equation (2D in momentum space and 3D in real space), which is a difficult task [2]. In this work we apply the Langevin equation approach using the ion guiding center equations with ion-ion collisions. The whole system is studied following many independent test particle trajectories. An extra stochastic term to simulate the quasi-linear wave-particle interaction [3] has been introduced in the equations. To do that, we have modified the ISDEP (Integrator of Stochastic Differential Equations for Plasmas) code [4] to include ion cyclotron heating effects (ICH). In this way, we can solve the collisional transport and heating equations for any fusion device, due to the geometrical versatility of the code. Although ISDEP was originally designed for stellarators (and succesfully applied to TJ-II in CIEMAT), a small tokamak has been taken as case study, whose 3D geometry is given by the ripple and the microwave antennae, thus showing the usability of these stellarator tools in 3D problems that appear in tokamaks.

In order to calculate the heating effects in a realistic way we have to leave the linear approximation, implicit in the Langevin approach, and modify the background temperature profile. Otherwise we would never find a real increase in the temperature because collisions would tend to thermalize every test particle. This obstacle is avoided by performing several simulations and updating the background temperature with the test particle temperature from the previous simulation. We stop when a stable temperature profile is reached. With this method we can solve nonturbulent transport and heating equations for fusion devices in a non-linear way. The European Computer Grid (EGEE) has been used to perform the calculations.

The main results of this work are the calculation of transport quantities and the velocity probability distribution function as a function of the toroidal angle. We have compared these results in the cases with and without heating, and investigated the differences between them. There are two main conclusions: firstly, the increment of the temperature cause an increase of the outward fluxes, which implies a reduction of the confinement. Secondly, the deviations of the velocity distribution function from the Maxwellian, both in the bulk and in the wings in the presence if ICH. The distribution function with ICH becomes wider, showing an increase in the amount of suprathermal particles. We also have checked that the toroidal transport is fast enough to eliminate any toroidal asymmetry. This computer code can be easily adapted to other geometries and plasma characteristics (like other stellarator geometries or tokamaks as ITER or ASDEX-U) and many other features can be taken into account in the ion dynamics (collisions with electrons, NTM and Alfvén instabilities).

[1] Z. A. Pietrzyk et al. Physical Review Letters **86** (2001) 1530.
[2] S. Murakami, Nucl. Fusion **45**, 221 (2003)
[3] F. Castejón and S. Eguilior. Plasma Phys. Control. Fusion **45** 159 (2003).
[4] F. Castejón *et al*. Plasma. Phys. Control. Fusion **49** 753 (2007)