Coupled nonlinear MHD-particle simulations for ITER with the JOREK+particle-tracking code

D.C. van Vugt[1,2], G.T.A. Huijsmans[1,3], M.Hoelzl[4], N.J. Lopes Cardozo[1], A. Loarte[2]

[1] *Eindhoven University of Technology, Eindhoven, The Netherlands*
[2] *ITER Organization, 13067 St. Paul Lez Durance Cedex, France*
[3] *CEA Cadarache, IRFM, 13108 St. Paul Lez Durance Cedex, France*
[4] *IPP Garching, Boltzmannstraße 2, 85748 Garching bei München, Germany*

There are many effects in tokamak physics which cannot be described with solely a magnetohydrodynamic (MHD) code or with particle tracking methods. These include heavy impurity transport, behaviour of fast ions and neutral particles, radiation modelling, and impurity production by sputtering, especially in a non-stationary background plasma and with feedback to this plasma. Their consistent modelling is very important to reproduce plasma behaviour, particularly for future tokamaks such as ITER. For instance the behaviour of W (production by sputtering, transport, ion/recombination balance, radiation emission, etc.) can be modelled in a stationary or time-varying MHD plasma background by coupling to a particle tracer model.

In this paper we present the extension of the non-linear MHD code JOREK [1] with a particle tracking code. This code follows particles with a kinetic 6D full-orbit or 5D guiding-center approximation in the JOREK mesh. Additionally the code contains modules to calculate the ionisation and recombination probabilities of atoms/ions in the plasma, as well as the corresponding radiated power emitted, with the rates for the atomic processes from ADAS data. Particle collisions (e.g. between W and background DT ions) are modelled with the binary collision model (BCM) [2], which has been found to reproduce key impurity transport mechanisms such as the thermal force and the corresponding temperature screening effects. Sputtering sources are implemented using the Eckstein formulation. The particle density and radiation is finally projected onto the JOREK finite element representation.

The JOREK+particle-tracking code can be used either one-way (evaluation of the consequence of the JOREK plasma behavior on particles) or through a coupled run, where the projected quantities from the particle distributions are used as source terms in the MHD equations in JOREK. Such simulations are required, for example, when the modelled W radiation levels are high and can decrease the plasma temperature, when fast particles affect MHD stability, etc. Examples of both one-way and coupled simulations will be shown in the paper.

References

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