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Self-consistent integration of plasma transport and divertor physics in the SOLEDGE3X-EIRENE code: status, results and prospects

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Heat and particle exhaust in tokamaks is determined by a complex interplay between plasma transport processes, including turbulence, and a set of physical phenomena due to the interaction between the plasma, the solid wall, recycling or injected neutrals and intrinsic or seeded impurities. The comprehensive modelling of the physics at play requires a consistent integration of each of these mechanisms in a single numerical tool together with a realistic description of both the magnetic and the wall geometries. Due to the complexity of such task, the state of the art has for long been divided between mean-field codes, lacking a self-consistent description of transverse transport, and turbulence codes, ignoring most of the other aspects of the physics and most often in simplified geometries. Nevertheless, significant progress has been made in the last few years with 3D turbulence codes reaching the capability to run in realistic magnetic geometries [1]. The integration in these tools of the rest of the relevant physics is currently the focus of numerous teams in the community.
In this contribution, we report on such effort with a review of recent progress in the development and applications of the SOLEDGE3X-EIRENE code package [2]. The main features of the code are presented together with the numerical solutions that were adopted to address specific issues.
The SOLEDGE3X plasma solver solves fluid equations based on collisional closures. Both the standard Braginskii and the Zhdanov closure have been implemented and are showed to coincide for simple hydrogenic plasmas. Using the Zhdanov closure, multi-component plasmas with an arbitrary number of ion species can be modelled, each with individual temperatures and possibly at non-trace concentrations. Neutrals can be included either via fluid neutral models embedded in the plasma solver or via a coupling to the EIRENE Monte-Carlo kinetic code. Specific schemes have been developed to improve the robustness and efficiency of simulations with kinetic neutrals up to reactor relevant detached plasmas. Electrostatic fluid drifts can be activated on request.
A key asset of the code is its geometrical flexibility. The option is offered to run simulations in 2D or in 3D in arbitrary toroidally magnetic configurations, either limited or with an arbitrary number of X-points. This is in practise made possible by the use of a structured flux-surface-aligned mesh combined with a domain decomposition. The wall shape is arbitrary, 2D or 3D, and imposed through the use of mask functions inspired from penalization methods. We discuss the pros and cons of these discretization choices that were made as a compromise between contradictive demands between turbulence and divertor modelling.
Finally, the capabilities offered by the code are illustrated by recent application results on medium sized tokamaks (WEST, TCV, AUG) as well as on ITER relevant cases.

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