Application of modified ASTRA-SPIDER code to simulation of free boundary equilibrium evolution

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In our studies a coupling of the equilibrium solver with a transport code is considered. In such 1.5D codes the evolution of poloidal magnetic flux, density and temperatures of plasma species are simulated in 1D approximation on the flux grid and with metric coefficients calculated consistently by 2D equilibrium solver. Our simulations are based on the Automated System for Transport Analysis (ASTRA) [Pereverzev et al 2002 IPP Report 5/98] and equilibrium solver SPIDER [Ivanov et al 2005 32nd EPS Conf. on Plasma Physics vol 29C (ECA) P-5.063]. In the original coupling of the SPIDER to ASTRA7.0 [E Fable et al 2013 Plasma Phys. Control. Fusion 55 124028] the evolution of the poloidal magnetic flux is computed outside the equilibrium solver. We modified the iteration loop to include the poloidal flux evolution into the internal iteration loop of the equilibrium solver and circuit equations using the grid adapted to magnetic fluxes. The comparison has shown that such a modification noticeably improves the convergence reducing number of iterations in the equilibrium solver with evolving shape and profiles. It also reduces the total computational time of 1.5D transport evolution, where 2D equilibrium is the most time-consuming part. Such a modification noticeably improves the convergence for the cases with strong pressure and current density gradients near the edge for H-mode operation in tokamak plasmas thus proving to be the most efficient approach to free boundary simulations with 1.5D transport codes. The efficiency of the proposed scheme further increases for highly shaped plasmas and fast evolution of plasma parameters.

As an application of the modified 1.5D solver we demonstrate free boundary simulations of plasma evolution with increasing elongation in the tokamak ST40 [M. Gryaznevich, et al 2017 Fus. Eng. & Des. 123 177-180]. Plasma density, temperature and current density evolution is simulated with the coupled transport and equilibrium code consistently with the free boundary plasma shape change. The scenario of current and voltage control in the poloidal field coils is developed. The dependence of the plasma shape evolution on the scenarios of plasma heating, fueling and the initial plasma current value is discussed.