DOI: 10.34854/ICPAF.51.2024.1.1.058

2D-4D SIMULATIONS OF NEUTRAL PARTICLES PENETRATION INTO CENTERAL PLASMA REGION IN THE L-2M STELLARATOR. VERIFICATION OF RESULTS USING THE ASTRA CODE *)

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In [1], 2D and 3D simulations of neutral particles penetration into plasma were performed using the program that takes into account experimental conditions in the ohmic heating regime at the L-2M stellarator. The radial distributions of neutrals concentration and model energy spectra of the flow of neutrals escaping from the plasma were obtained. When performing 2D simulations, we used the plane-layered plasma model with one-dimensional distribution function of neutrals in velocity space. 3D simulations assumed the cylindrical plasma model and two-dimensional velocity distribution of neutrals.

For verification of the program operation, control simulations were performed using the well-known ASTRA code. In the ASTRA code, when calculating the penetration of neutrals from the wall, the plane-layered plasma model with one-dimensional distribution function in velocity space is also used [2]. At the same time, the coefficient √3 is introduced into the kinetic equation in two places in order to bring the calculation results obtained assuming one-dimensional distribution function in velocity space closer to those obtained assuming three-dimensional distribution function in the velocity space:

$$v\frac{\partial f_N}{\partial x} + \left(s_{ion}^{(e)} n_e + s_{ion}^{(i)} n_i + s_{cx} n_i\right) f_N = \frac{\sqrt{3}}{2} n_i (s_{cx} N + s_{rec} n_e)\delta\left(v \pm \frac{v_{Ti}}{\sqrt{3}}\right), \quad (1)$$

where v and v_{Ti} are the velocity of neutrals and ion thermal velocity, respectively, N is the concentration of neutrals, n_e and n_i are the electron and ion densities, respectively, f_N is the velocity distribution function of neutrals, s_{ion} is the ionization rate by electron and ion impact, s_{cx} is the charge exchange rate, and s_{rec} is the recombination rate.

Using both programs, for the same plasma parameters, the penetration of neutrals from the wall to the center of the plasma column was calculated. Based on the verification results, the systematic discrepancy in calculation results obtained using the above programs was obtained: calculations using the ASTRA code give the higher concentration of neutrals in the central plasma regions. The discrepancy can be eliminated if, in the program written for the L-2M stellarator, the coefficient $\sqrt{3}$ is similarly added to the right-hand side of equation (1). This shows the correct operation of the program written for L-2M.

Simulations of neutral particles penetration using the plane-layered plasma model and two-dimensional and three-dimensional velocity distribution functions of neutrals were also performed (3D and 4D simulations). Simulations have shown that when using the two-dimensional velocity distribution function of neutrals, the penetration of neutrals into the central plasma regions coincides with the results of calculations using the one-dimensional velocity distribution function of neutrals, if the thermal velocity of neutrals is reduced by $\sqrt{3}$ times. In other words, the introduction of the $\sqrt{3}$ coefficient makes it possible to bring the results of one-dimensional (in terms of speed) calculations closer to those of two-dimensional (but not three-dimensional) ones.

References

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