Structure of plasma flows in tokamak in dissipative MHD model

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Many modern tokamak experiments demonstrate self-consistent development of plasma flows, moreover, large toroidal plasma velocities (up to several km/s) are observed even in the absence of external sources of momentum [1, 2]. A number of mechanisms were proposed for explanation of such flows. In particular, in papers [3, 4] the plasma flows occurred naturally in numerical solution of equations of the single-fluid MHD with allowance for dissipative effects (viscosity and resistivity). It is believed that such a mechanism can be present indeed in existing tokamaks, but due to roughness of the model an exact match between theory and experiment should not be expected.

This paper brings an analytical basis for the numerical results of [3, 4] and generalizes them. We studied the system of stationary equations of single-fluid dissipative MHD in toroidal geometry with axial symmetry and built its solution by method of successive approximations in the form of a series in the small parameter ε - inverse aspect ratio. It was found that for incompressible plasma flows are described by the following formulas (for tokamak with circular cross-section):







Here  is the inverse aspect ratio, is the small radius, is the large radius, is the radial coordinate, is the poloidal angle, is the toroidal angle. We also built a solution of the system for the case of tokamak with asymmetric cross section and showed that in this case the integral of toroidal angular momentum is not equal to zero, which is in good agreement with numerical calculations and experimental data.

References

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