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Electromagnetic transport of blobs in tokamak SOL plasma

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Intermittency is one of the key features of turbulent transport at the edge of fusion devices. Experimental observations show that plasma can be ejected in the form of thin filaments, strongly elongated along the direction of the magnetic field lines.[1] Such structures, called blobs,[2] can significantly contribute to the overall particle and heat fluxes impinging the plasma facing components of the fusion machines, such as tokamaks and stellarators, limiting their operational lifespan.

Over the past two decades much effort has been put into the study, both experimental and theoretical, of the physics of birth and propagation of blobs in experimental facilities [3, 4]. Theoretical analysis of the filament propagation focused mainly on the dynamics of isolated (seeded) blobs. Albeit electrostatic MHD models were largely used for the analysis of plasma dynamics, recently attention of the researchers has been drawn to the problems of the electromagnetic regimes of blob motion in the fusion machines.

The impact of electromagnetic effects on setting plasma dynamics is considered significant if the plasma parameter β is high enough, so that $\beta > m_e/m_i$.[3] In such regimes, dynamics of dense pellet clouds (resembling globs) were analyzed in Refs. [5, 6]. Magnetostatic forces on ELM filaments at the edge of tokamaks were consider in Ref. [7]. Ideal one-fluid MHD was employed for theoretical analysis of blob motion in [8]. Electromagnetic dynamics of blobs were considered in the ideal and resistive cases of high-β plasma in studies [9, 10].

Recently, it was analytically demonstrated that electromagnetic regimes can also noticeably impact the motion of blobs in low-β ($\beta < m_e/m_i$), yet sufficiently hot edge plasma of a tokamak. Such plasma behavior is attributed to the interplay between the collisional skin effect and the propagation of Alfvén waves along the open magnetic field lines.[11] Numerical simulations of blob dynamics in low-β plasma with parameters relevant for the edge of MAST[12] and DIII-D[11] tokamaks have indeed shown the motion of filaments characteristic for the electromagnetic regime.

The physical model, which was used to describe the motion of filaments in Ref. [11], incorporated the electrostatic sheath boundary conditions, modified to take account of the electromagnetic effects. Such a model neglects the interaction of electromagnetic waves excited in the filament and the sheath region of plasma, which, in general case, can lead to the reflection of waves from the conducting surfaces of the installation,[6,13] with which blobs contact in the course of their motion.

In this contribution, dynamics of plasma filaments hot low-β edge plasma of fusion devices is analyzed. Along processes of electromagnetic wave excitation and propagation in plasma bulk, the interaction (reflection) of electromagnetic waves from the plasma facing components is also considered. The physical model describing dynamics of an isolated blob is formulated. The physics of electromagnetic wave reflection and the possible modifications of the sheath boundary conditions (such as, e.g., the metallic wall BC, the effective RF-sheath impedance BC)[13] on the electrostatic potential and current flowing into the sheath are discussed. The estimates of the blob motion parameters are shown. Analytical results are compared with results of numerical simulations of isolated filament dynamics in conditions similar to the conditions of the tokamak edge plasma.

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