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Dependence of Turbulent Blob/Hole Dynamics on the Collisionality in Tokamak Plasmas

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Plasma density blob/hole dynamics near tokamak separatrix is of striking importance in determining the boundary transport in tokamak plasmas since the blobs and holes violently cause heat and particle transport to the scrape-off-layer (SOL) across the separatrix or last closed flux surface(LCFS). Recently, blob/hole simulations and theories have predicted many common features, which have been also verified experimentally[1]. Hence, blob/hole control is critical in handling boundary transport. In this work, we simulate the effects of plasma collisionality on the turbulent blob/hole dynamics and validate the simulation predictions through experimental observations on the HL-2A tokamak to explore new approach of transport control. Focusing on the underlying physical mechanism of the blob/hole dynamics, an extended 2-region (edge/SOL) fluid model [2] is employed in the simulations. We perform parametric scans of blob/hole transport on the ion-electron collision rate ν_{ie} and also ion-neutral collision rate ν_{in} in the boundary plasmas around the LCFS. It is found that blob/hole transport is sensitively influenced by the plasma collisionality. Namely, the holes are enhanced in highly collisional edge whereas the blobs are weakened at the SOL, causing larger particle convection. These blob/hole dynamics are closely correlated with potential dipoles. The trends are experimentally evidenced on the HL-2A tokamak[3]. As the electron density increases (corresponding to ν_{ie} increasing), the skewness of the probability distribution function (PDF) of density fluctuations changes the sign from positive to negative over a critical density. Meanwhile the blob birth rate decreases whereas hole birth rate increases then both finally arrive at a quasi-steady state. These trends qualitatively agree with the simulation predictions, exhibiting a structure selection of blobs/holes. Furthermore, as the neutral-ion collision rate ν_{in} increases, the blobs at the SOL tend to develop into streamers propagating outwards with reduced amplitude while the holes inwards are suppressed, showing a key role in nonlinear structure regulation and resultant transport suppression. Such results suggest that adjusting the plasma collisionality by fueling, e.g., gas puffing, or the supersonic molecular beam injection (SMBI) could serve as a method to nonlinearly select turbulent structures, i.e., blobs, holes or streamers, to access the control of boundary transport.

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