26pEA-15

Turbulent structure selection and transition in tokamak boundary plasmas

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Edge turbulent transport due to blob/hole dynamics in boundary plasma (a region covering core-edge, separatrix and scrape-off-layer (SOL)) dominates the global confinement performance of magnetic fusion devices through the pedestal formation and L-H transition. Understanding and controlling intermittent blob/hole transport are considered to be essential for the H-mode operation. In this work, we simulate the blob/hole dynamics including structure selection and transition based on a reduced fluid model aiming at exploring a new approach to probably control the blob/hole dynamics and edge transport through utilizing nonlinear self-organization processes.

Our simulations are focused on the effect of the ion-neutral collision as well as the electron-ion collision on the turbulent structure selection and transition. It is observed that the holes are enhanced in highly collisional core-edge region whereas the blobs are weakened in the SOL, causing large particle convection across the separatrix/LCFS. These blobs/holes are correlatively steered by the potential dipoles. On the other hand, the ion-neutral collision can dramatically suppress the zonal flows and develop the blobs into streamers with reduced amplitude. Meanwhile, the holes inwards are inhibited, showing a key role of the neutral ingredients in nonlinear structure regulation and transport suppression. Moreover, a blob cascading is proposed to understand the evolution of blobs with the generation of secondary holes. These findings imply that governing the plasma collisionality by fueling, e.g. supersonic molecular beam injection (SMBI), could serve as a method to nonlinearly select coherent structures, i.e., blobs, holes or streamers, thereby accessing the control of boundary transport. The comparison of simulation predictions with experimental measurements in the limiter discharges on the HL-2A Tokamak will be also presented.