Experimental and Simulation Study of I-mode Detachment in Magnetic Confinement Fusion

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Abstract: The I-mode has both the high energy confinement similar to the H-mode but not the edge localized modes (ELMs) which appears only in the H-mode and the low particle confinement similar to the L-mode. Considering the long-term operation of tokamaks, the divertor target will face prolonged erosion from plasma transported from the core, leading to a diminished capacity to withstand thermal loads. Additionally, ionized impurity particles can diffuse across magnetic field lines into the core, contaminating the plasma. The detachment method can mitigate these issues. Therefore, I-mode detachment is crucial for the future operation of

tokamaks. The I-mode detachment phenomenon in EAST shot #115526, both before (2.5s) and after (5s) gas puffing, was simulated using the SOLPS-ITER program. By adjusting the transport coefficients, the simulated electron temperature and density profiles at the outer midplane were aligned with the experimental data. The simulation results at 2.5s indicate that the inner target has achieved detachment, which aligns well with the experimental data. Subsequently, an electron density parameter scan at the outer midplane was conducted at 2.5s. It was found that when $n_{e,OMP}^{sep} = 2.9\text{e}19m^{-3}$, both the inner and outer target achieved detachment, with a significant decrease in the heat and particle flux to the outer target. However, at this point, $n_{e,OMP}^{sep}$ was higher than the experimental data. Currently, most I-modes on EAST are naturally in a detached state, so the so-called detachment density is inaccurate. Considering that many physical processes in I-mode are closely related to turbulence, it is necessary to consider the turbulent effects within the SOL region, which enhance the transport in the SOL. Our calculations indicate that when the overall transport coefficients are increased to 4.5 times the original simulated values, the outer target achieves detachment, and the heat flux on the outer target is reduced by 50%. In the 5s simulation, a D2-Ne mixture gas was injected from the outer target. As a result, both the inner and outer target achieved detachment, alleviating the heat flux on the target. The simulation indicates that I-mode detachment can significantly reduce the heat and

particle fluxes at the target, effectively lowering the thermal load and greatly extending the target's lifespan.

Keywords: I-mode, detachment, SOLPS-ITER, EAST