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Simulation study of tearing mode instabilities after pellet injection in Tokamak device

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The tearing mode instability can destroy the magnetic surface, trigger strong transport, and degrade the plasma confinement, especially entering the nonlinear stage, it may cause the plasma disruption[1]. Shattered Pellet Injection (SPI) is considered one of the effective means of disruption mitigation and experimental results have demonstrated that the interaction between injected pellets and rational surfaces can induce or control MHD instabilities[2]. Thus, MHD dynamics after SPIs has been concerned in recent years. However, most of the results are based on 1.5D or 2D simulation, and the interaction process and coupling mechanism between PI and MHD mode under 3D effect need to be analyzed.

Hence, we focus on the effects of pellet on m/n = 2/1 tearing mode, and the 3D nonlinear simulations with CLT code are performed[3]. Based on typical pellet parameters and ablation theory, the pellet ablation module was developed. It is found that magnetic flux surfaces are destroyed when the pellet enters the lower order of the magnetic island and the field randomization is appeared, which releases free energy of system, as is shown in Figure 1. Meanwhile, the pellet excited high poloidal/toroidal mode numbers (m, n) harmonics is also found, leading to significantly broadened mode structures and enhanced mode coupling. And the dominant MHD destabilizing mechanism is identified as the local helical colling at lower rational surface as pellet passes through them.

Lastly, we investigate tearing mode instabilities following pellet injections at varying toroidal angles, and the results reveal that when pellets are injected from different toroidal angles, the O-point of the 2/1 magnetic island consistently aligns with the pellet's position as it traverses low-order rational surfaces. By examining the temporal evolution of amplitude and phase for dominant modes across physical quantities, we observed that the phase of the external 4/1 mode's radial velocity changes first during pellet injection from q=5 to q=4, and this perturbation then propagates to the magnetic field, and subsequently affects current modifications. Thus, the phase shift in the 2/1 mode is likely influenced by its higher harmonic, the 4/1 mode.

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References

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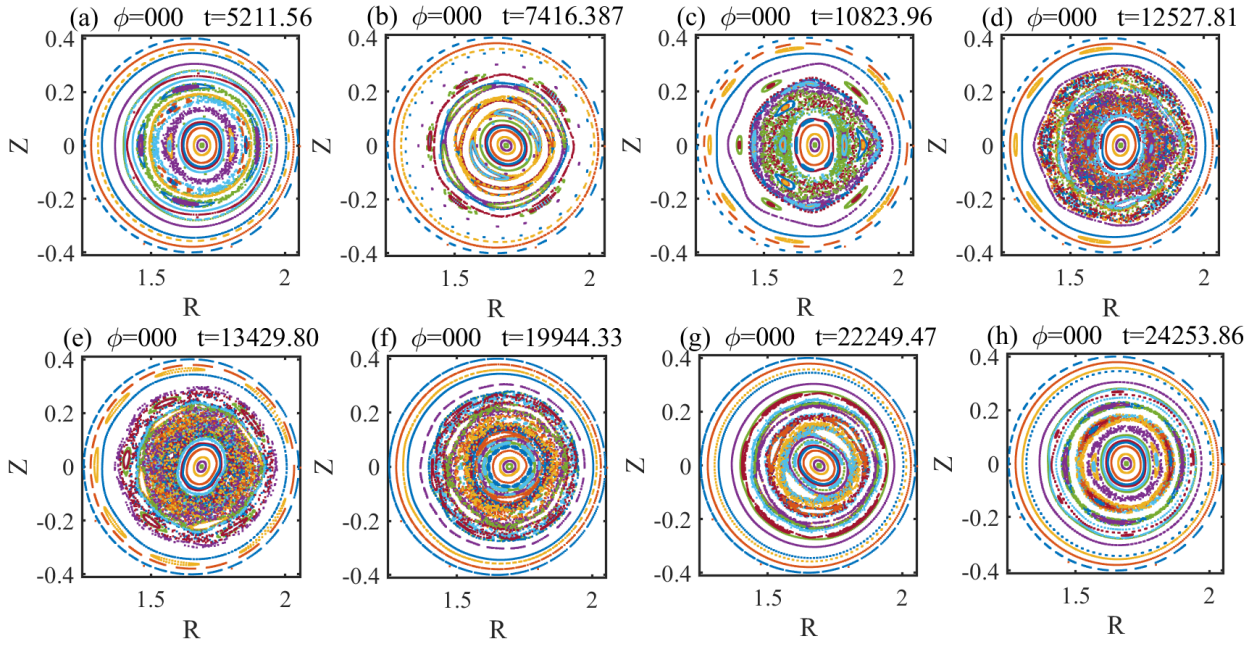

Figure 1. Poincare plot of magnetic field lines for m/n=2/1 mode with different time when pellet injected into plasma at magnetic flux surface of ϕ=0