Distribution function analysis of fast ions during the frequency chirping of Alfvén eigenmodes

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Kinetic-magnetohydrodynamic (MHD) hybrid simulations of fast-ion driven Alfvén eigenmodes (AEs) were conducted to clarify the physical mechanism of frequency chirping of the AEs in tokamak plasmas. The hole-clump structure formation in fast-ion distribution function integrated in poloidal and toroidal angles was demonstrated with the kinetic-MHD hybrid simulations [1]. In this work, we investigate the fast-ion distribution function on a poloidal plane (R,z) where R and z are radial and vertical coordinates. For the distribution function analysis of the simulation results, particles with a constant magnetic moment μ and a constant E' are collected although the initial fast-ion distribution is an isotropic slowing-down distribution in the simulation. Here, μ is an adiabatic invariant for the interaction with low-frequency waves such as the AEs, $E' = E - (\omega/n)P_\varphi$ is a conserved variable during the wave-particle interaction, E and P_φ are particle kinetic energy and toroidal canonical momentum, and n and ω are toroidal mode number and angular frequency of the AE. The conservation of E' is valid when we can neglect the frequency chirping and the amplitude variation of the AE. The particle orbit frequencies were also analyzed and the resonant particle orbits are drawn on the poloidal plane along with the fast-ion distribution function fluctuations. The resonant fast ion distribution function fluctuations and the distribution flattening due to the particle trapping at the saturation of the instability were observed for the evolution without frequency chirping [2]. In this work, we focus on the frequency chirping of the AEs and examine the distribution function fluctuations of fast ions on the (R,z) plane to identify the hole-clump structure.

References

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