Simulation study of energetic particle-driven magnetohydrodynamic instabilities in a low magnetic shear helical axis stellarator/heliotron, Heliotron J

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Magnetohydrodynamic (MHD)-energetic particle (EP) simulation code, MEGA[1], is applied to Heliotron J configuration for the first time. Heliotron J is an advanced stellarator/heliotron device with low magnetic shear, helical axis and vacuum magnetic well. Due to low shear, only global Alfvén eigenmode (GAE) has been dominantly observed (along with energetic particle mode (EPM)) in the experiments. The objective is to study the interaction between EP and MHD wave in complex plasma topology, especially on the effect of magnetic island on EP and Alfvén eigenmode. Application of MEGA to Heliotron J device is advantageous, since MEGA does not assume nested flux surface, and radial extent of magnetic islands is large for low shear device. In the initial step, benchmark is required. The first target is to reproduce experimentally observed n/m=1/2 & 2/4 GAEs and EPM, which are excited at the plasma edge[2,3]. Two MHD equilibria have been considered: (1) a MHD equilibrium with n/m=4/7 magnetic islands induced by finite beta effect ($\langle\beta_0 = 0.4\%\rangle$), and (2) a nested flux surface equilibrium ($\beta_0 = 0.3\%$). In equilibrium (1), n/m=4/7 magnetic islands overlap with the extremum of experimentally observed n/m=1/2 and 2/4 continua; therefore, only an eigenmode in the core region is focused, which is n/m=3/5 beta-induced Alfvén eigenmode (BAE). Due to strongly shaped plasma, upshift of low frequency continuum by ion acoustic wave coupling is strong for low beta plasma[4]. In equilibrium (2), extremums of n/m=1/2 & 2/4 GAEs have been reproduced at the plasma edge; nonetheless, no destabilization has been observed. Crosscheck of the calculated continua was done by destabilizing eigenmode in the core region, which is n/m=2/3 GAE. Destabilization has been observed with consistency with the continuum. In addition, n/m=2/4 mode has been found with the same frequency, but is not presented in the continuum. After saturation of the n/m=2/3 mode, other modes become dominant. They correspond to the extremum in continua that are adjacent to the spatial gradient of equilibrium EP distribution. They are destabilized by flattening of EP distribution at the n/m=2/3 mode, since the spatial gradient of distribution function moves to the core and edge regions. Based on these results, only eigenmodes in the core region can be destabilized by the current model. In the next step, time evolution of computation marker's weight for particle with large orbit width will be focused. Application of full-f method is planned for collisionless plasmas, where the marker weight is time-invariant.

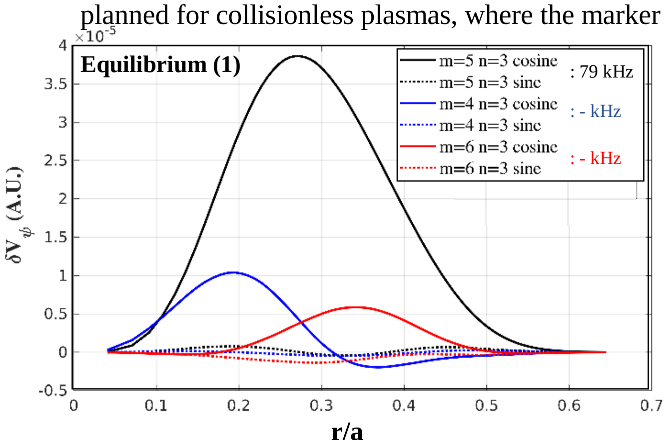

Figure 1: *Spatial profile of radial velocity harmonic of n/m=3/5 BAE in equilibrium with n/m=4/7 magnetic islands.*

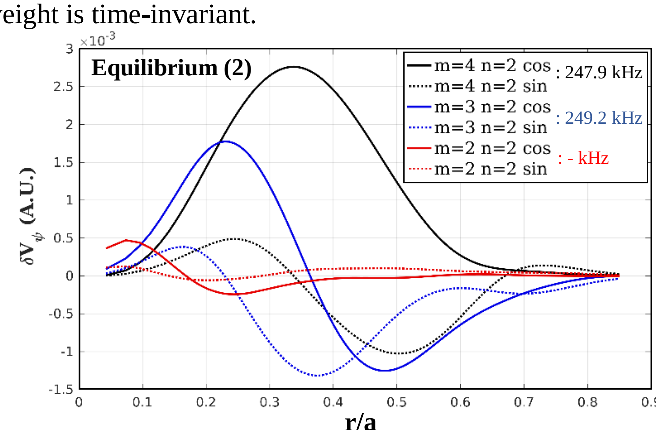

Figure 2: *Spatial profile of radial velocity harmonic of n/m=2/3 GAE in nested flux surface equilibrium.*

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