Cross-Verification Study of Gyrokinetic Codes for the L-mode discharge in KSTAR

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Gyrokinetic codes have been employed to investigate the physical mechanisms underlying the turbulence stabilization by fast ions in fusion plasmas [1]. However, despite decades of extensive verification studies for gyrokinetic codes [2], the fast ion effects on turbulence predicted by gyrokinetic codes have not been verified. This motivated our cross-verification study, wherein we compared linear and nonlinear simulation results from two widely-used gyrokinetic codes in the fusion community, GENE [3] and CGYRO [4]. The study was conducted on a neutral beam injection (NBI)-heated L-mode discharge in KSTAR, where fast ion effects can be investigated. Additionally, we sought to verify gyrokinetic predictions of the rotation effects on turbulence, as previous research indicated discrepancies among gyrokinetic codes in nonlinear simulation results [5].

For our verification study, we considered four cases based on the inclusion of rotation and fast ion effects, as shown in Table 1. At r/a=0.5 (where a is the minor radius), linear stability analysis was performed for cases I-IV, as depicted in Fig. 1. In all cases, the most unstable mode exhibited a positive real frequency, which indicates the electric diamagnetic direction in this study, in both GENE and CGYRO results. Good agreement between CGYRO and GENE results was observed in case I. The inclusion of rotation effects (case II) showed consistent results, with both codes matching within ~0.02 [c_s/a] where c_s is a sound speed of the main ion. 5%. Furthermore, both codes predicted the reduction of linear growth rate and the appearance of a long-wavelength ion mode with the addition of fast ions (cases III and IV, compared to cases I and II). However, a discrepancy in the growth rate of the long-wavelength ion mode was observed when fast ions were included. Overall, we observed a good agreement in the real frequency of the most unstable mode regardless of the inclusion of rotation effects and fast ions while the inclusion of fast ions can result in discrepancy in the linear growth rate of the long-wavelength mode, which can be relevant to the fast ion mode.

	Rotation	Fast ion
Case I	X	X
Case II	O	X
Case III	X	O
Case IV	O	O

Table 1 Four cases used in the verification study

In this presentation, we will also compare nonlinear simulation results between two codes, analyzing their predicted energy fluxes and turbulence structures. Additionally, we will discuss the discrepancies observed between the results of the two codes.

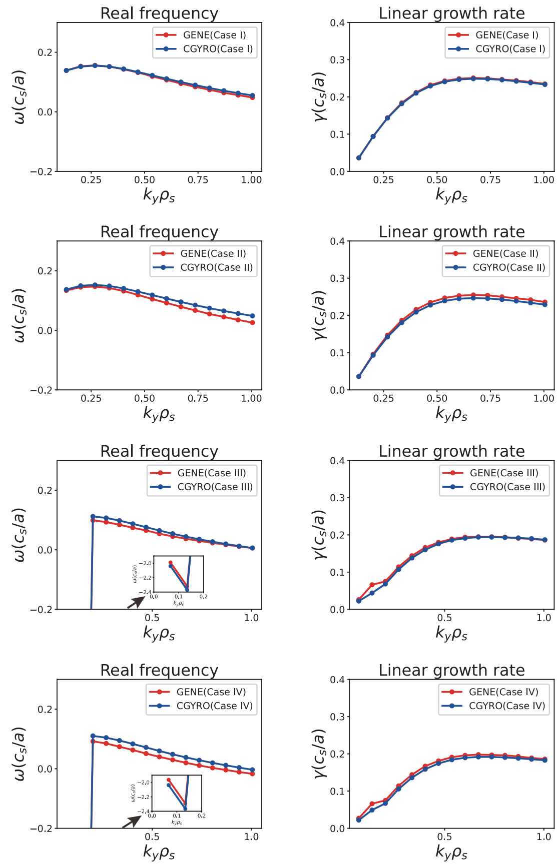

Figure 1 Real frequency (left) and linear growth rate (right) of the most unstable mode for case I to IV predicted by GENE (red) and CGYRO (blue)

Computing resources were provided by the National Supercomputing Center with supercomputing resources including technical support (KSC-2022-CRE-0161, KSC -2022-CRE-0392, KSC-2023-CRE-0075) and on the KFE computer KAIROS, funded by the Ministry of Science and ICT of the Republic of Korea (KFE-EN2241)

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