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# Global gyrofluid simulation of ITG turbulence by parallel mean velocity shear in Tokamak

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Profile stiffness is an obstacle to achieve a high temperature plasma. Even though high power is injected, ion temperature profile usually does not change after its gradient reaches a certain critical value. In experiments, however, Ti profile stiffness has been found to be mitigated, i.e., 'destiffening' occurs when rotation is high at low magnetic shear[1]. A numerical study showed that the ratio of external torque to heating power is an important parameter for the destiffening[2]. When it is beyond a critical value, confinement degradation, i.e., restiffening arises[2]. In this work, we numerically investigate the effect of parallel mean velocity shear on thermal confinement of tokamak plasmas.

We develop a global gyrofluid simulation code based on `3+1' moment model[3] using BOUT++ framework[4]. In the code, the gyrokinetic Poisson equation is solved with the 4th order finite difference method and the 4th order Simpson's rule in a global toroidal geometry. To study the effects of parallel velocity shear on ion temperature gradient (ITG) driven turbulence at low magnetic shear, we carry out nonlinear simulations with fixed temperature and density profiles but varying parallel mean velocity gradient using parameters in Fig. 1. Figure 1(a) shows the scale lengths, $R/L_{T_i}$ and $R/L_{n_e}$, of the temperature and density used in the simulations, where R is the major radius. The profiles of safety factor q and magnetic shear s are given in Fig. 1(b). Parallel mean velocity gradient $|U'_{||,0}|$ increases from 0 to 0.9 by 0.1 in $c_s/a$ unit, where $c_s$ is the ion sound speed and $a$ is the minor radius.

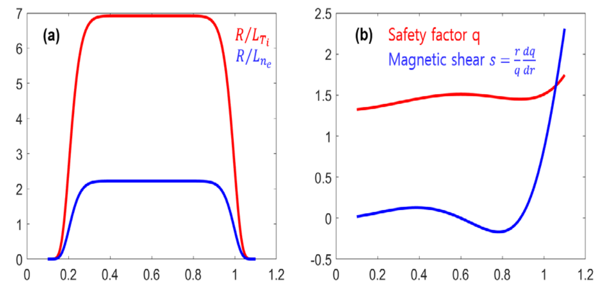

Figure 1 (a) Scale lengths, R/Lti = (R/Ti)dTi/dr (red) and R/Lne = (R/$n_e$)d$n_e$/dr (blue), of ion temperature and density, (b) safety factor q (red) and magnetic shear s (blue).

Figure 2 shows global nonlinear simulation results on ion thermal transport, ExB flow shear, potential and parallel velocity fluctuations. These quantities are measured in nonlinear phase after 100 $a/c_s$. Figure 2(a) shows that as $|U'_{||,0}|$ increases up to 0.6, the ion heat conductivity $\chi_i$ decreases. This observation implies the improvement of ion thermal confinement by the parallel velocity shear, which might be relevant to the experimentally observed destiffening at high rotation. Meanwhile, $\chi_i$ increases when $|U'_{||,0}| > 0.6$, as shown in Fig. 2(a). This is consistent with the simulation results in Ref. 2, showing restiffening at high parallel velocity shear. Figure 2(b) shows the ExB shearing rate, whose increase or decrease for $|U'_{||,0}| < 0.6$ or $> 0.6$ explains the dependence of $\chi_i$ on $|U'_{||,0}|$. Fluctuation intensities in Figs. 2(c) and (d) show a similar trend to $\chi_i$.

A mechanism for the destiffening has been proposed as the conversion of parallel flow compressibility to zonal vorticity[5]. To investigate this, we perform a detailed energetics analysis among potential fluctuation, parallel velocity fluctuation, and zonal flow. The results will be presented in the conference.

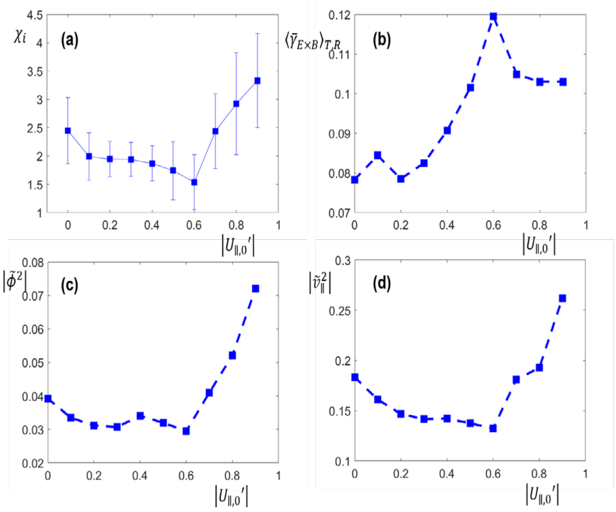

Figure 2 (a) ion heat conductivity with standard deviation, (b) ExB shearing rate, (c) potential fluctuation intensity, and (d) parallel velocity fluctuation intensity.

## References

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