§10. Fluid Simulation Study of Kinetic-fluid Closure Models

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Fluid simulation is attractive because it is much faster than the kinetic simulation. However, it is known that classical fluid models such as two fluid model cannot give accurate transport level, as is also understood from the fact that the model includes viscosity coefficients as parameters.

In order to develop a fluid model with high accuracy, Beer et al. [1] developed a closure model, which is so called gyrofluid model. They concentrated on the unstable modes, and the closure coefficients are determined to satisfy the linear dispersion relation. However, Rosenbluth-Hinton [2] pointed out that the transport level by this model is not accurate because zonal flow is not correctly treated. In order to correctly treat zonal flow (ZF) modes in the long time limit, Sugama et al. [3] developed a fluid closure.

In this study we develop new fluid code for the fluid simulation of tokamaks based on a mixture of above fluid closure models. That is, for unstable modes (finite k_θ), we use a gyrofluid model [1], on the other hand, we use a closure model [3] for zonal modes (k_θ=0). The models include physically valid coefficients so that it is expected that the simulation results such as transport level are comparable to those of kinetic result. Linear benchmark results of these closures are shown in Ref.[4]

In the nonlinear simulation, we had problem on the numerical instability. This is because the model does not include explicit viscosity terms at all. As an initial test, rather large viscosity is added artificially. The results with and without ZF closure [3] are compared in Fig.1 where time history of energy diffusion coefficient is plotted. After the linear phase, the time average of results between different closures are not clearly seen, because of the large artificial viscosity. Snap shot of perturbed density is shown in Fig.2. As the ZF closure does not work, linear mode structure is clearly seen where the density contour is extended in the radial (x) direction. It is important to reduce the artificial viscosity.

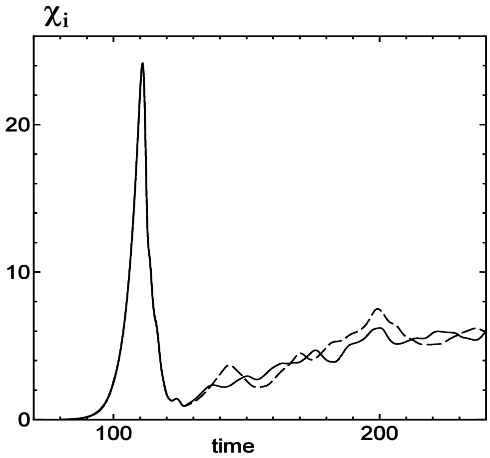

Fig. 1. Diffusion coefficients in GyroBohm unit. Solid and dashed line shows closure with and without zonal flow (solid and dashed lines respectively).

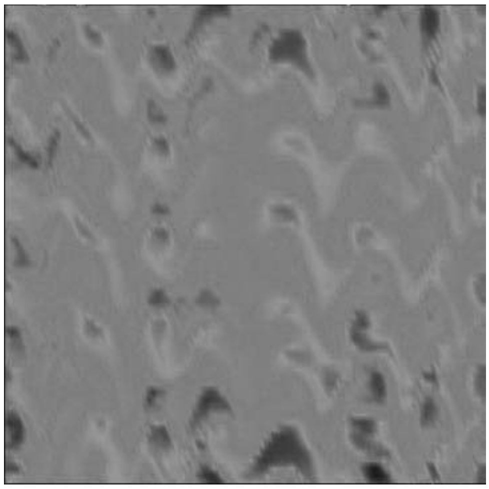

Fig. 2. Snap shot of density perturbation in a fixed theta position.

1)M.A.Beer and G.W.Hammett, Phys.Plasmas **3**,4046 (1996)

2) M. N. Rosenbluth and F. L. Hinton: Phys. Rev. Lett. **80** (1998)

3) H. Sugama, T.-H. Watanabe, and W. Horton: Phys. Plasmas **14** (2007) 022502

4) O.Yamagishi and H.Sugama, Phys. Plasmas **19**, 092504 (2012)