Variation of turbulent spot structure with aspect ratio in a 3D Yukawa liquids – A Molecular Dynamics Study

Suruj Kalita[1], Rajaraman Ganesh[2]
[1,2] Institute for Plasma Research, HBNI, Bhat, Gandhinagar, Gujarat, India-382428
e-mail: suruj.kalita@ipr.res.in

In three dimensional (3D) Hydrodynamics plane Couette flow (PCF) is found to be stable linearly at all the Reynolds number [1] . However, PCF is known to become unstable nonlinearly upon applying a finite-amplitude perturbation. Thus PCF in HD belongs to a class of "subcritical'' systems [2] which exhibit abrupt transition from laminar to turbulent regimes, often showing co-existence of both laminar and turbulent flows resulting in a "turbulent spots''.

In the present work, using classical "first principles'' Molecular Dynamics (MD) simulation evolution of PCF in a 3D Yukawa liquid is addressed. Using a 3D finite-amplitude [2] velocity perturbations, the PCF state is perturbed and the resultant dynamics of the system is studied using MD simulation [3] with screened Columb potential. In Yukawa liquids, kinematic viscosity(ν) [4] is known to be a function of correlation strength Γ and range of interaction κ. In a driven, dissipative system such as PCF, for a given κ, as Γ evolves, so does the kinematic viscosity ν. Therefore we have a unique quench study of Reynolds number (Re) changing with time. Recently, starting with small aspect ratio (Stream wise length/half width of the bounded direction) ∼ 20 and with high Re we have demonstrated the formation of turbulent spot [3]. The spot is found to spread spatially with time demonstrating the co-existence of laminar-turbulent regions in 3D Yukawa liquids. It is seen that at comparatively large range of interaction, the results tend to match qualitatively with that with the hydrodynamical results.

In HD, the nature of spot formation, its structure and dynamics has been shown to depend on the system aspect ratio - both experimentally [5,6] and via fluid simulations [7,8]. In the present work, starting from an aspect ratio of 20, we have addressed the dynamics of turbulent spot formation in 3D Yukawa liquids as a function of system aspect ratio. For a given interaction length scale, it is found that for increasing aspect ratio, the structure of the spots is dominated by "short scale streak-like'' features within the global structure of the spot, if the system is perturbed. We also investigate possibility of "spontaneous'' structure formation as function of aspect ratio. This and related details will be presented in this work.

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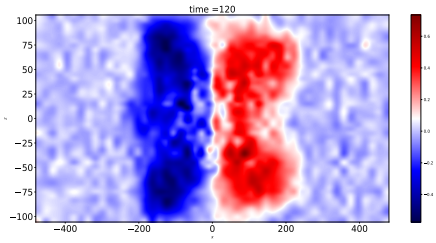

Fig 1 : Instantaneous stream-wise fluid velocity V_x, at aspect ratio 40.

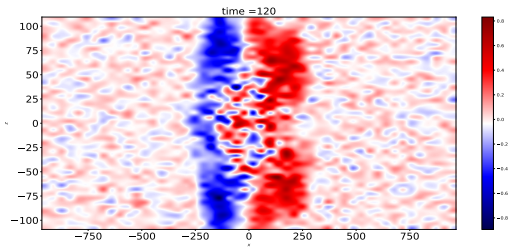

Fig 2 : Instantaneous stream-wise fluid velocity V_x, at aspect ratio 80.