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MODAL AND NON MODAL STABILITY OF STRATIFIED FLOWS

ABSTRACT: Fluids in which the viscosity varies in space and time can exhibit complex and unexpected characteristics that strongly affect the flow properties. The non constancy of the viscosity can be due to several factors such as non constant temperature/composition or when the viscosity depends on the pressure or on the shear history experienced by the fluid. Examples of fluids with varying viscosity are blood, mucus, muds, glaciers, magma and to a lesser extent the oceans and the atmosphere. One of the most striking manifestation of a varying viscosity is the alteration of flow stability, as in the case of model shear flows in which large-scale shears are capable of suppressing (or generating) instabilities. Hydrodynamic stability theory is of central importance in establishing if the perturbation of a flow state can produce irreversible modification that will eventually lead to turbulence or will decay to the unperturbed state. In this optic, linear modal analysis provides a simple and effective way to investigate the reaction to small disturbances revealing the long-term behavior of the system. However, modal analysis gives no information on the short-term behavior of the linearized initial value problem. For this reason a new formulation that investigate the energy amplification that can occur in a transient period has been proposed for the first time in [1] for a simple viscous shear flow. This new approach, called non-modal linear stability analysis reveals that, even in the case of decaying long-term disturbances, there could nevertheless be a significant but transient energy amplification. The transient behavior can be very different from the asymptotic one and this in part explains the discrepancy between the critical Reynolds numbers predicted by modal analysis and the onset of instability observed in experiments.

In the work presented we apply the non modal theory to investigate the linear stability of stratified shear flow in which the viscosity depends on the concentration of some substance (diluted suspension), showing how the stratification of the concentration affects the stability of the flow. We show that, in the absence of diffusion, the system is unconditionally unstable even if the disturbance growth is very slow. On the other hand, when diffusion is incorporated in the model we show that the system is asymptotically stable even if it can exhibit short-time energy amplification.

REFERENCES

[1] S.C. REDDY, D.S. HENNINGSON, *Energy growth in viscous channel flows*, J. Fluid Mech., 252, (1993), pp. 209–238.