University of Leicester

EPSRC DLA Studentship

First Supervisor	Dr Benjamin Bugeat
School/Department	School of Engineering
Email	bb283@le.ac.uk

Second Supervisor	Dr Aldo Rona
School/Department	School of Engineering
Email	aldo.rona@le.ac.uk

Section 2 – *Project Information*

Project Title	Hydrodynamic stability of supercritical fluids with buoyancy

Project Summary

Above certain conditions of temperature and pressure, fluids enter a supercritical state in which the distinction between liquid and gas no longer exists. Growing interest in supercritical fluids is currently observed in industrial applications such as energy production, rocket engines, or chemical processes. The nature of the flow regime, laminar or turbulent, is central in the design of thermo-fluid systems: turbulence promotes high heat transfer, which increases efficiency.

Ren et al. (JFM 2019) discovered a new linear instability specific to supercritical fluids. This has opened exciting perspectives regarding the existence of new fast routes to turbulence, which could be leveraged by engineers to design more efficient systems. Bugeat et al. (JFM 2024) showed that this instability was caused by the large gradients of density and viscosity that occur in supercritical fluids. The authors proposed a physical mechanism based on the concurrent action of baroclinic and shear effects. However, buoyancy (the force resulting from density variations under gravity) was neglected. This assumption is reasonable when inertial effects dominate over buoyant forces. However, many engineering applications, such as heat exchangers, do not satisfy this condition.

The present project aims to provide new mathematical and physical understandings regarding the effect of buoyancy on the stability of supercritical fluids. The standard Taylor-Goldstein equation cannot be employed because it is underpinned by the Boussinesq approximation, which neglects baroclinic effects. An appropriate mathematical model will therefore first be formulated, based on linear stability theory and simple equations of state. This will enable an analysis of how buoyancy modifies the primary instability mechanism. Does buoyancy enhance or inhibit the instability? New quantitative results will be obtained, together with a physical interpretation in terms of vorticity production. Finally, the competition with Rayleigh-Bénard instability, which occurs in the limit of zero shear, will be investigated. The objective is to establish a novel stability diagram identifying the key regimes of instability.

References

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