Instability at Atwood Number \( \sim 1 \)

Eric Nied
With Professor Charles Rosenblatt
Department of Physics, Case Western Reserve University

ABSTRACT

The Rayleigh-Taylor Instability occurs at a fluid interface that is unstable with respect to gravity. Small perturbations at the interface become amplified and grow exponentially with time before entering a non-linear then turbulent stage. The Atwood Number, a reduced density of two fluids in contact at an interface, plays an important role in the Rayleigh-Taylor instability. Experiments are moderately well-developed for low Atwood Number Rayleigh-Taylor instabilities but not for high Atwood Number instabilities, which display self-similar growth and non-symmetric growth of spikes and bubbles. It is important to study the Rayleigh-Taylor instability at Atwood \( \sim 1 \) in order for us to understand phenomena such as a supernova's core exploding into a vacuum. However, no study at Atwood \( \sim 1 \) has been successfully carried out due to experimental limitations and mechanical jitter associated with past techniques. Our group pioneered the use of magnetic levitation to study the Rayleigh-Taylor instability. This research was concerned with using magnetic levitation to obtain unprecedented control of initial conditions for an Atwood Number \( \sim 1 \) scenario. Major accomplishments include a reduction of the magnetic decay time by use of a "flyback diode" and the design of a new data collection system. Future work will include experiment and obtaining a numerical value for the linear growth rate.

THE RAYLEIGH-TAYLOR INSTABILITY

The Rayleigh-Taylor (RT) Instability occurs at the interface of two fluids of varying density, in which the less dense fluid is accelerated into the more dense fluid. An analogous arrangement, which is equally unstable, is a high density fluid resting atop a low density fluid at a flat interface in the presence of a gravitational field. Any perturbations to the interface (caused by thermal fluctuations, mechanical jitters, etc.) will cause the system to rapidly release potential energy; the two fluids switch their positions with respect to gravity and their configuration becomes stable. The characteristic way these fluids switch positions is via the RT Instability. Many modes compete, but only one quickly dominates.

GOALS/PURPOSE

The original purpose of my project was to obtain a numerical value of the linear growth rate, \( \gamma \), of the RT Instability at \( \sim 1 \). However, due to time constraints, the focus of my project has changed to modifying the experimental design in order to prepare for data collection for an At \( \sim 1 \) RT Instability.

PROJECT ACHIEVEMENTS

In previous RT Instability experiments (at \( \sim 0.3 \)), we took data by directly lighting the fluids with a sheet of laser light, then filming the RT instability with a high-speed CCD camera (60 fps). Software was able to analyze the video, frame by frame, and calculate a numerical value for \( \gamma \). Because of a large discontinuity in refractive indices between the two fluids at At \( \sim 1 \), this method was no longer practical. I designed and tested a backlighting set-up for improved data-taking. We also obtained a new, faster camera (260 fps), which currently is being set up.

CONCLUSIONS AND FUTURE WORK

Our group has already proven that magnetic levitation is a superior method for studying the RT Instability because it reduces the presence of mechanical jitters and allows unprecedented control of initial interfacial conditions. My project showed that it is possible to use magnetic levitation to study the RT Instability at At \( \sim 1 \), which has never been successfully done before.

Future work will include experiment and obtaining a numerical value for the linear growth rate.

REFERENCES


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