



# Experimental Analysis of Rayleigh-Bénard Convection in the Weakly Elastic Regime: Insights from Water-Based Liquid Bridges.

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## Introduction

This study investigates experimentally the weakly elastic regime (WER) of Rayleigh-Bénard convection, a domain that remains significantly underexplored in comparison to its extensively studied Newtonian counterpart. Of particular interest is the nature of the primary flow bifurcation from the purely diffusive, motionless state. In the WER, the first bifurcation is known to be stationary, a feature that stands in contrast to certain regimes observed in strongly elastic fluids.

The present research focuses on the so-called "liquid bridge," an axisymmetric column of fluid suspended between two identically sized circular plates or rods aligned along a common central axis. Due to its extended "free lateral surface", this configuration has been widely used in the past to study thermocapillary convection under both microgravity and terrestrial conditions, but it has rarely been employed to investigate buoyancy-driven flow.

This subject is relevant to a wide range of sectors, from materials science to life sciences (assembly of thermoplastic components through melting and solidification methods, coating, biological reactors, microfluidic devices, etc.).

## Aim

To address this gap, this study introduces a novel microscale experimental framework. The problem is investigated for different liquid bridge aspect ratios (length/diameter) and volumes, paying attention to the nature and structure of the emerging flow. The flow is examined from both a lateral and a top-down perspective (transparent top rod).

## Methods

Laser-cut diagnostics are employed to illuminate tracer particles suspended in the fluid uniformly heated from below and cooled from above. Building upon prior investigations that were largely restricted to Newtonian fluids such as pure water [1], controlled quantities of polyethylene oxide (PEO) are incorporated into deionized water to obtain a mixture with viscoelastic characteristics. This modification allows for precise adjustment of the fluid's relaxation behavior and internal resistance to flow, thereby enabling the systematic variation of both the Prandtl number and the Elasticity number.

Aspect ratio:  $A = L / D$   
Volume ratio:  $S = V / V_0$

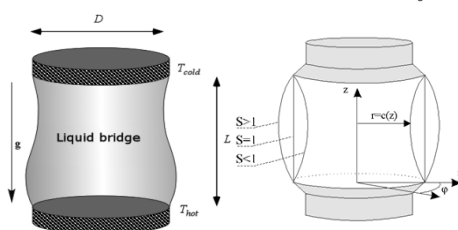
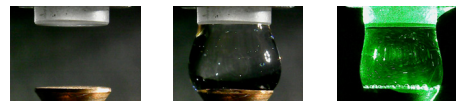


FIG. 1. Sketch of the liquid bridge highlighting relevant variables and related boundary conditions.

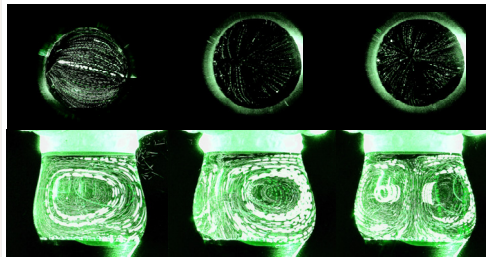
## Results

The introduction of polymer chains into water is found to induce notable deviations from the outcomes anticipated by classical linear stability theory and prior observations involving Newtonian liquids. These discrepancies primarily appear as shifts in the dominant azimuthal mode number characterizing the system's instability patterns.

Liquid Bridge experimental setup:

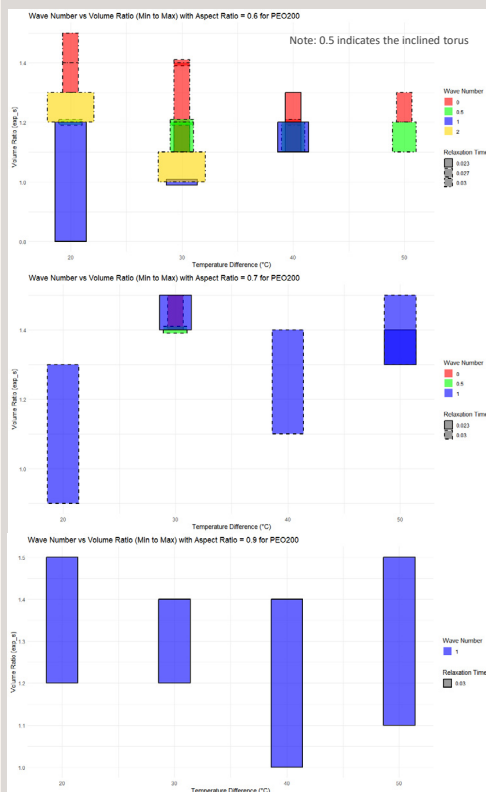


Wave number:  $m = 1$  (roll)     $m = 1$  (inclined torus)     $m = 0$



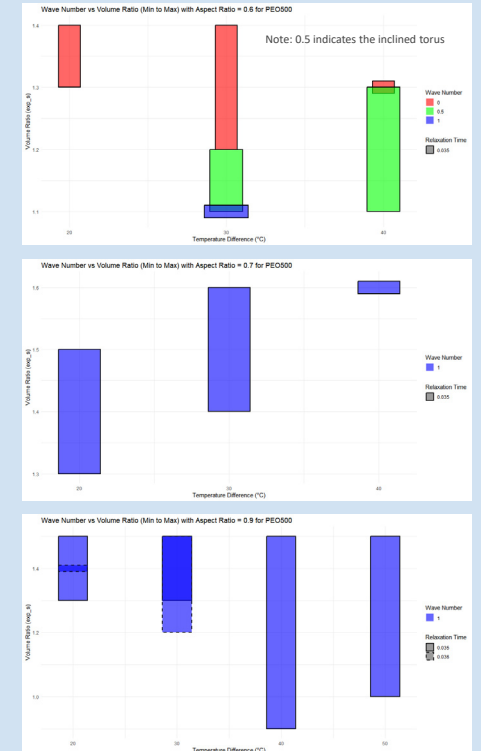
## Results

For water-PEO concentration, PEO200:



## Results

For water-PEO concentration, PEO500:



## Conclusions

The study carried out by Aljanadi et al. [1] using water had not revealed the presence of convection patterns that are strictly symmetric around the axis within the entire range of tested aspect ratios ( $0.5 \leq A \leq 0.9$ ). This finding marks a key distinction from the Weak Elasticity Regime (WER) behavior observed in liquid bridges, where, despite the elasticity number being extremely low, a purely axisymmetric flow structure ( $m = 0$ ) can emerge. By rigorously characterizing the bifurcation structure and flow topology, this work not only extends the existing knowledge but also lays the experimental groundwork necessary for developing new mathematical models and conducting ensuing numerical simulations.

References:

[1] A. Aljanadi, M.S.N. Oliveira, M. Lappa, (2024), "Gravitational modes of convection in water liquid bridges", Physics of Fluids, 36(5), 054113 (22 pages).

## Acknowledgements

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