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Observing Waves in Different Viscosities of Liquid: A Simulation Study Using MATLAB and ANSYS

Introduction

Viscosity possesses an important effect on the speed, amplitude, and energy dissipation of waves in liquids [1], [2]. Highly viscous fluids, like glycerin, show rapid energy loss and smaller wave amplitudes, while thin fluids, like water, permit waves to travel with little damping [3], [6], and [10]. Applications in environmental modeling, chemical processing, and fluid mixing require an understanding of these dynamics.

This study uses simulation-based techniques to examine wave behavior in liquids with different viscosities. Computational fluid dynamics (CFD) modeling will be done using ANSYS Fluent, and data analysis and post-processing will be done using MATLAB. Water (low viscosity), vegetable oil (medium viscosity), and glycerin (high viscosity) are among the fluids taken into consideration.

Research Aims

The research aims to:

- Investigate the effects of viscosity on wave characteristics such as damping, wavelength, amplitude, and speed [6], [10]
- Create and verify CFD simulation models for liquids with low, medium, and high viscosities in ANSYS [7], [9].
- Measure damping rates, analyze energy dissipation, and process simulation data using MATLAB [8].
- Offer findings that may help with real-world uses like fluid mixing, tank design, and industrial process optimization.

Research Questions

1. What effects does viscosity have on wave wavelength, amplitude, and speed [6], [10]?
2. How do viscosity and energy dissipation during wave propagation relate to each other [3], [6]?
3. In comparison to theoretical and experimental predictions [7], [9], how well can ANSYS simulations represent wave behavior?
4. Which computational parameters most affect simulation accuracy, such as time step, solver selection, and mesh refinement [7]?

Literature Review

Viscosity and Wave Dynamics: Viscosity dissipates wave energy and resists fluid motion. While waves in high-viscosity fluids undergo rapid damping, waves in low-viscosity fluids travel farther with less amplitude reduction [6], [10]. Particularly in shallow channels, classical hydrodynamic studies have demonstrated a strong correlation between fluid viscosity and energy loss [10].

Methods of Numerical Simulation: Free-surface flows and wave damping in viscous liquids have been widely modeled using CFD techniques, especially the Volume of Fluid (VOF) approach [7]. These methods offer a trustworthy substitute for difficult physical experiments by enabling precise tracking of wave evolution, surface deformation, and energy dissipation [4], [5].

Research Gaps: Prior work has frequently concentrated on single-viscosity fluids or idealized models [3], [6]. Systematic simulation studies that compare the behavior of waves in various viscosities under uniform conditions are scarce. This project fills this gap by using ANSYS to conduct comparative simulations and MATLAB for post-processing, which yields quantitative insights [7]–[9].

Methodology

ANSYS Simulations:

• Geometry: 2D wave tank with movable parts.

• VOF method for solving transient incompressible Navier-Stokes equations to capture the free surface [7].

• Fluids: glycerin (high viscosity), vegetable oil (medium viscosity), and water (low viscosity) [6], [10].

• Boundary conditions include no-slip walls, an absorbing boundary at one end, and a wave-maker at the other.

• Mesh: To guarantee accuracy, a mesh independence study was carried out after it was refined close to the free surface.

• Time Step: Chosen to ensure numerical stability by satisfying CFL < 1.

MATLAB Post Processing:

- Use ANSYS to import free-surface elevation data [8].
- Determine the decay rates, wavelengths, and amplitudes.
- Determine energy dissipation and damping coefficients.
- To see wave decay and frequency content, use FFT and curve-fitting [8

Simulation Plan:

- Run simulations for two amplitudes, several wave frequencies, and three fluid viscosities.
- Analyze the sensitivity of the tank length, time step, and mesh size.
- Run the simulation long enough to precisely record energy loss and damping trends.

Validation:

- Compare simulation results with theoretical predictions and classical studies on viscous waves [1], [2], [6].
- Conduct error analysis to quantify the accuracy of simulation outcomes [7], [10].

Expected Outcomes

- Determine the quantitative correlations between viscosity and wave characteristics, such as damping, wavelength, amplitude, and speed. [6], [10].
- ANSYS CFD and MATLAB post-processing should be integrated in a validated workflow [7]–[9].
- Provide instructions on how to configure simulation parameters to guarantee accuracy across viscosities.
- Generate knowledge that can be used in scientific research, environmental modeling, and industrial fluid systems.

Timeline (10 Weeks)

Week	Task
1–2	Review of the literature, choice of fluid properties, and design of wave tanks
3–4	Create an ANSYS model and establish boundary conditions.

Week	Task
5–6	Run fluid simulations at low, medium, and high viscosities.
7	Analysis of sensitivity (mesh, time step, tank length)
8	Data export and MATLAB processing
9	Calculate damping metrics and compare results to theory.
10	Create figures, animations, and a report.

Risks and Mitigation

- **Numerical Instability:** Reduce time step, refine mesh [7].
- **High Computational Load:** Begin with 2D simulations, expand to 3D only if necessary [7].
- **Boundary Reflections:** Implement sponge layers or extend tank length [7].

Conclusion

Using a simulation-based methodology, this study will methodically investigate the effects of fluid viscosity on wave propagation and damping. The study will generate quantitative relationships between viscosity and wave behavior by combining ANSYS for CFD modeling with MATLAB for data analysis. This will offer useful insights for environmental studies as well as industrial applications [6]–[10].

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