Hydrodynamic instability and wave formation of a viscous film flowing over a slippery inclined wavy substrate: Effect of odd-viscosity

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1. INTRODUCTION & OBJECTIVE

This study delves into the hydrodynamic instability and wave formation in a viscous film flowing over a slippery, inclined, wavy substrate, with a specific focus on the influence of odd viscosity. The interaction between the surface topography and film flow enhances the complexity of wave formation and instability mechanisms. Furthermore, the non-dissipative odd viscosity component adds a unique feature of complexity to the flow dynamics. In this study, we utilized the Navier slip boundary condition to model the slip effect of the surface. By conducting linear stability analysis using Orr Sommerfeld analysis and considering the governing equations and boundary conditions that incorporate the effects of odd viscosity, bottom topography, and surface slip, we derived a lower-dimensional non-linear model. Notably, our primary results reveal the stabilizing effect of odd viscosity as well as the slip of the surface.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

Thin layer of fluid flowing over differnt surface topography is a interesting topic of research due its applications in various natural and industrial problems. Recently, there has been considerable interest in the role of odd viscosity in quantum Hall fluids in the mechanics of incompressible fluid flow.The viscosity tensor in classical fluids can have a non-vanishing odd part, known as odd-viscosity, when time-reversal symmetry is broken. This phenomenon has significant effects on various systems including swimming strategies, chiral active fluids, and bubble dynamics. This work presents innovative insights into the control of flow instabilities in systems where surface slip and odd viscosity are instrumental, with potential implications for microfluidic applications, coating processes, and the study of active matter systems, offering hope for future advancements in these fields.

REFERENCES

1. BEAVERS, GORDON S. & JOSEPH, DANIEL D. 1967 Boundary conditions at a naturally permeable wall. Journal of Fluid Mechanics 30 (1), 197–207.
2. MUKHOPADHYAY, SANGHASRI & MUKHOPADHYAY, ASIM 2020 Hydrodynamics and instabilities of falling liquid film over a non-uniformly heated inclined wavy bottom. Physics of Fluids 32 (7), 074103.

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3. MUKHOPADHYAY, SANGHASRI & MUKHOPADHYAY, ASIM 2020 Waves and instabilities of viscoelastic fluid film flowing down an inclined wavy bottom. Phys. Rev. E 102 (2), 023117.
4. MUKHOPADHYAY, SANGHASRI & MUKHOPADHYAY, ASIM 2021 Interfacial phase change effect on a viscous falling film having odd viscosity down an inclined plane. International Journal of Multiphase Flow p. 103728.
5. OGDEN, K. A., D'ALESSIO, S. J. D. & PASCAL, J. P. 2011 Gravity-driven flow over heated, porous, wavy surfaces. Physics of Fluids 23 (12), 122102.
6. SADIQ, I. MOHAMMED RIZWAN & USHA, R. 2008 Thin Newtonian film flow down a porous inclined plane: Stability analysis. Physics of Fluids 20 (2), 022105.