Applications in Engineering Science xxx (xxxx) xxx

Contents lists available at ScienceDirect

Applications in Engineering Science

journal homepage: www.sciencedirect.com/journal/applications-in-engineering-science

Editorial on SI "Viscoplasticity: Theory, Modelling and Applications"

The study of viscoplastic fluids continues to be a dynamic and evolving field, bridging fundamental rheology with a diverse array of real-world applications. These complex materials, defined by their characteristic yield stress, exhibit behavior that transitions from solid-like to fluid-like depending on the applied stress. This duality introduces rich scientific challenges and technological opportunities, driving ongoing research across disciplines such as fluid mechanics, materials science, engineering, and geophysics.

This special issue brings together contributions that deepen our understanding of viscoplastic behavior and expand the frontiers of its application. The selected papers reflect current research topics in both theoretical developments and practical implementations, ranging from new constitutive modeling approaches and theoretical characterization techniques to advanced numerical simulations and industrial applications.

Several contributions in this issue explore classical models such as Bingham, and Herschel–Bulkley formulations, offering insights into their limitations and proposing extensions to better account for temperature dependence, density dependence and microstructural effects. Others focus on computational methods for solving the complex flow dynamics of viscoplastic fluids, particularly in domains involving yield surfaces, free boundaries, or non-trivial geometries. These methodological advancements are critical in improving the accuracy and efficiency of simulations in engineering and natural systems alike.

Importantly, the collection also highlights the role of viscoplastic fluids in contemporary industrial and environmental problems—ranging from the pipelining of waxy oils (Andrade and Negrão, 2025) to the modeling of lava flows (Cusack et al., 2024). These applications underscore the interdisciplinary nature of the field and the importance of collaboration between experimentalists, theoreticians, and engineers.

Andrade and Diogo (Andrade and Negrão, 2025) reviewed the effects of composition, sample preparation, and, in particular, experimental history on the rheology of waxy oils, and explored the link between microscopic structure and macroscopic behavior, highlighting common measurement artifacts. Another review is provided by Farooq and Nimbalkar (Farooq and Nimbalkar, 2024), who focus on rheological models used to analyze the behavior of soil structures and assess transport corridor performance, particularly for high-speed rail systems. This includes various types of models—viscoelastic, elastoplastic, viscoplastic, elastoviscoplastic, and viscoelastoplastic—highlighting their relevance to soil-structure interactions. Analytical solutions describing soil behavior, especially in layered systems, are also provided.

Moosavi et al. (Moosavi et al., 2024) employ various experimental techniques, such as camera imaging, laser-induced fluorescence, and particle image velocimetry, in order to capture the flow dynamics in horizontal injection of a heavy Newtonian fluid into a lighter viscoplastic fluid within a large reservoir. More specifically, they analyze the influence of the Froude number and the effective viscosity ratio on the critical jet characteristics like bifurcation length, transition length, deviation length, and jet trajectory, and provide useful correlations and a regime classification based on bifurcation behavior.

Four papers of this special issue concern numerical studies of viscoplastic flows. Lugarini et al. (Lugarini et al., 2024) studied the startup and cessation flows of a Bingham plastic using a lattice Boltzmann scheme, which enabled the accurate calculation of the moving yield surfaces. Cusack et al. (Cusack et al., 2024), investigate numerically how basaltic lava flows in open channels navigate bends on shield volcanoes, focusing on the effects of flow velocity, rheology, and bend geometry. Using the Force Balance Model they calculated the changes in the lava's free surface height across different bend shapes and showed that channel depth, width, and bend radius significantly influence vertical flow displacement, while the bend angle must exceed a minimum threshold for full flow development.

González-Andrade and Méndez Silva (González-Andrade and Méndez Silva, 2024) extend the Herschel–Bulkley model to include density- and shear-rate-dependent viscosity and yield stress, apply Huber regularization and develop an H(div)-conforming discontinuous Galerkin method to solve different flows. They also analyze the stability and existence of discrete solutions. Aghighi et al. (Aghighi et al., 2024) investigate natural convection in a viscoplastic fluid within a triangular enclosure using the finite-element method. Their results reveal two competing effects: wall proximity restricts convective flow, reducing heat transfer, while the proximity of heat sources increases temperature gradients and enhances heat transfer.

The performance of two constitutive equations that can accommodate stresses up to a certain limit and the stability of the associated flows are discussed in (Anand et al., 2024) and (Syrakos et al., 2024). Anand et al. (Anand et al., 2024) investigate the stability of steady, fully-developed flow in a long cylindrical pipe for a shear-thinning fluid that approximates viscoplastic behavior. They use linear stability analysis and the shooting method, to obtain the eigenvalues of the perturbation frequency, and show that the flow is stable. Also, Syrakos et al. (Syrakos et al., 2024) derive an explicit analytical solution for planar Poiseuille flow of a fluid, obeying the De Kee and Turcotte constitutive equation, and show that a solution may not always exist because the flow curve is bounded.

We hope that this special issue serves as both a valuable reference and an inspiration for further research. As the complexity of modern technologies and environmental challenges grows, so does the need for robust, predictive understanding of materials like viscoplastic fluids. We

https://doi.org/10.1016/j.apples.2025.100246

Available online 27 June 2025

Please cite this article as: Lorenzo Fusi, Georgios C. Georgiou, *Applications in Engineering Science,* https://doi.org/10.1016/j.apples.2025.100246

thank all contributors for their high-quality work and dedication, and we invite readers to explore the rich insights presented in these pages.

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