Velocity profiles within thin viscoplastic surges: elucidating the transition layer

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Thin flows of viscoplastic fluids down inclines are characterized by the existence of a pseudo-plug layer, close to the free surface, in which the shear rate is null at leading order in aspect ratio ϵ. Recently, comparisons between asymptotic predictions and highly-resolved experimental measurements of the velocity field within gravity-driven surges of Herschel-Bulkley fluids, showed that first-order corrections in ϵ are essential to capture the evolution of velocity and shear rate close to the tip *[1]*. These correction terms are responsible, in particular, for a strong increase of the shear rate toward the tip, a feature clearly seen in the experimental data. However, regular asymptotic expansions of the velocity profiles at order $O(\epsilon)$ display an unphysical kink at the location of the fake yield surface, which prevents direct comparisons with experimental measurements. To overcome this limitation, a proper matching between the pseudo-plug and the sheared layer needs to be worked out, connecting the two zones over a transition layer in which both viscous and plastic contributions to stress are of the same order. Though the existence of this transition layer was anticipated in previous studies *[2]*, construction of the complete velocity profiles was yet to be performed. We will present the derivation of a uniform velocity approximation, up to order $\epsilon^{\frac{2(n+1)}{n+2}}$, for a Herschel-Bulkley fluid with a power index n. The width of the transition layer scales as $\epsilon^{\frac{2n}{n+2}}$, and thus becomes increasingly prominent as n decreases. The obtained asymptotic velocity profiles will be compared to experimental data for various values of the flow parameters (Froude and Herschel-Bulkley numbers), and the influence of correction terms associated to the transition layer will be discussed. Finally, implications for the formulation of consistent shallow-flow models will be presented.

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References

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