

Coalescence of polymeric droplets

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ABSTRACT

Coalescence is an energy minimization phenomenon in which two equilibrium droplets undergo a transition to attain a final equilibrium state i.e., a coalesced state. Coalescence begins with a point contact between the two drops followed by the liquid bridge of size comparable to the droplet's diameter. This phenomenon is more complex for macromolecular fluids like polymeric solutions than its counterpart Newtonian fluids due to molecular relaxations and chain entanglements. Under experimental conditions, coalescence can be achieved in three different configurations: sessile-pendant, sessile-sessile and pendant-pendant. This study demonstrates the coalescence dynamics of polymeric droplets in sessile-pendant and sessile-sessile configurations. To probe this phenomenon in various configurations, we quantify the growth of liquid neck.

The dynamics of the sessile drop coalescing with the pendant drop is governed by the growth of neck radius R with time t . In this configuration, we unveil the existence of three regimes based on concentration ratio c/c^* , namely, inertio-elastic (IE) $c/c^* < c_e/c^*$, viscoelastic (VE) $c_e/c^* < c/c^* < 20$ and elasticity dominated (ED) regimes $c/c^* > 20$. Our results suggest that the neck radius growth follows a power-law behaviour $R \sim t^b$. The coefficient b is constant in IE, VE and with a monotonic decrease in ED. Based on the variation of b in ED, we propose a new measurement technique named Rheocoalescence, which can possibly predict the relaxation times of the fluids in elasticity dominated regimes. The constant value of b in IE and VE regimes is found to be 0.37 and is distinct from the value of 1, 0.5 in viscous and inertial regime respectively of Newtonian fluids. Here, we reveal the existence of universality in the neck radius evolution following a scale of $R \sim t^{0.36}$. Our findings are substantiated by a theoretical model using the linear Phan-Thein-Tanner (PTT) constitutive equation.

In comparison, coalescence in sessile-sessile configuration is relatively more complex due to the contact line motion and energy interaction between the solid and liquid interface. In such a configuration, coalescence can be triggered by volume filling (VFM) or droplet spreading method (DSM). Coalescence of sessile polymeric fluid drops on a partially wettable substrate via DSM exhibits a transition from inertio-elastic (IE) to viscoelastic (VE) regime at concentration ratio $c/c^* \sim 1$. Our findings unveil that the temporal evolution of the bridge height follows a power-law behaviour t^b , such that the coefficient b continuously decreases from 2/3 in the inertial regime ($c/c^* < 1$) to an asymptotic value of 1/2 in the viscoelastic regime ($c/c^* > 1$). To account for fluid elasticity and characteristic timescale in the viscoelastic regime, a modified thin film equation under lubrication approximation has been proposed using the linear Phan-Thien-Tanner constitutive equation.

Coalescence of two droplets on a solid substrate via volume filling method (VFM) has a contrasting behaviour compared to DSM. Similar to DSM, we identify four different regimes namely, inertial dominated (ID), inertio-elastic (IE), viscoelastic (VE) and elasticity dominated (ED) regimes based on c/c^* . Our results reveal that the temporal evolution of bridge height for VFM follows a power law behaviour, such that b remains constant at 2/3 in ID, IE, VE, followed by a monotonic decrease in ED. Our study unveils that the coalescence dynamics of polymeric drops is not universal and is contingent on the method by which the coalescence is triggered.

ABOUT THE SPEAKER

Sarath Chandra Varma is a Ph.D. student enrolled in the Dept. of Mechanical Engineering, IISc Bangalore. He has a bachelor's degree in Mechanical Engineering from Jawaharlal Nehru Technological University, Hyderabad. He has done his master's degree (M.Tech) in Thermal and Fluids Engineering from NIT Jamshedpur. His research interests include polymeric droplet dynamics (soft matter research).

