Compound Droplet in Extensional and Paraboloidal Flows

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Exact analytical solutions are found for the steady state creeping flow in and around a vapor-liquid compound droplet, consisting of two orthogonally intersecting spheres of arbitrary radii (a and b), submerged in axisymmetric extensional and paraboloidal flows of fluid with viscosity $\mu^{(1)}$. The solutions are presented in singularity form with the images located at three points: the two centers of the spheres and their common inverse point. The important results of physical interest such as drag force and stresslet coefficient are derived and discussed. These flow properties are characterized by two parameters, namely the dimensionless viscosity parameter: $\Lambda = \mu^{(2)}/(\mu^{(1)} + \mu^{(2)})$, and the dimensionless parameter: $\beta = b/a$, where $\mu^{(2)}$ is the viscosity of the liquid in the sphere (part of the compound droplet) with radius b. We find that for some extensional flows, there exists a critical value of $\beta = \beta_c$ for each choice of Λ in the interval $0 \leq \Lambda \leq 1$ such that the drag force is negative, zero or positive depending on whether $\beta < \beta_c, \beta = \beta_c$, or $\beta > \beta_c$ respectively. For other extensional flows, the drag force is always positive. The realization of these various extensional flows by simply changing the choice of the origin in our description of the undisturbed flow field is also discussed. In extensional flows where the drag force is always positive, we notice that this force D_e for vapor-liquid compound droplet is maximum when $\beta \approx 1$ (i.e. two sphere have almost the same radii). Moreover, we find the drag force D_e is a monotonic function of Λ, i.e., the drag force for vapor-liquid compound droplet lies between vapor-vapor and vapor-rigid assembly limits. We also find that the maximum value of the drag in paraboloidal flow depends on the viscosity ratio Λ and significantly on the liquid volume in the dispersed phase.

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