World Academy of Science, Engineering and Technology
International Journal of Computer and Systems Engineering
Vol:13, No:12, 2019

Numerical Investigation of the Boundary Conditions at Liquid-Liquid Interfaces in the Presence of Surfactants

Authors : Bamikole J. Adeyemi, Prashant Jadhawar, Lateef Akanji

Abstract : Liquid-liquid interfacial flow is an important process that has applications across many spheres. One such applications are residual oil mobilization, where crude oil and low salinity water are emulsified due to lowered interfacial tension under the condition of low shear rates. The amphiphilic components (asphaltenes and resins) in crude oil are considered to assemble at the interface between the two immiscible liquids. To justify emulsification, drag and snap-off suppression as the main effects of low salinity water, mobilization of residual oil is visualized as thickening and slip of the wetting phase at the brine/crude oil interface which results in the squeezing and drag of the non-wetting phase to the pressure sinks. Meanwhile, defining the boundary conditions for such a system can be very challenging since the interfacial dynamics do not only depend on interfacial tension but also the flow rate. Hence, understanding the flow boundary condition at the brine/crude oil interface is an important step towards defining the influence of low salinity water composition on residual oil mobilization. This work presents a numerical evaluation of three slip boundary conditions that may apply at liquid-liquid interfaces. A mathematical model was developed to describe the evolution of a viscoelastic interfacial thin liquid film. The base model is developed by the asymptotic expansion of the full Navier-Stokes equations for fluid motion due to gradients of surface tension. This model was upscaled to describe the dynamics of the film surface deformation. Subsequently, Jeffrey's model was integrated into the formulations to account for viscoelastic stress within a long wave approximation of the Navier-Stokes equations. To study the fluid response to a prescribed disturbance, a linear stability analysis (LSA) was performed. The dispersion relation and the corresponding characteristic equation for the growth rate were obtained. Three slip (slip, 1; locking, -1; and no-slip, 0) boundary conditions were examined using the resulted characteristic equation. Also, the dynamics of the evolved interfacial thin liquid film were numerically evaluated by considering the influence of the boundary conditions. The linear stability analysis shows that the boundary conditions of such systems are greatly impacted by the presence of amphiphilic molecules when three different values of interfacial tension were tested. The results for slip and locking conditions are consistent with the fundamental solution representation of the diffusion equation where there is film decay. The interfacial films at both boundary conditions respond to exposure time in a similar manner with increasing growth rate which resulted in the formation of more droplets with time. Contrarily, no-slip boundary condition yielded an unbounded growth and it is not affected by interfacial tension.

Keywords : boundary conditions, liquid-liquid interfaces, low salinity water, residual oil mobilization
Conference Title : ICCFD 2019 : International Conference on Computational Fluid Dynamics
Conference Location : London, United Kingdom
Conference Dates : December 09-10, 2019