Linear Stability Analysis of a Regularized Two-Fluid Model for Unstable Gas-Liquid Flows in Long Hilly Terrain Pipelines

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Abstract : In the petroleum industry, multiphase flow occurs when oil, gas, and water are transported in the same pipe through large pipeline systems. The flow can take different patterns depending on parameters like fluid velocities, pipe diameter, pipe inclination, and fluid properties. Mainly, intermittent flow is produced by the natural propagation of short and long waves, according to the Kelvin-Helmholtz Stability Theory. To model stratified flow and the onset of intermittent flow, it is crucial to have knowledge of short and long waves behavior. The two-fluid model, frequently employed for characterizing multiphase systems, becomes ill-posed for high liquid and gas velocities and large inclination angles, for short waves can develop infinite growth rates. We are interested in focusing attention on long-wave instability, which leads to the production of roll waves that may grow and result in the transition from stratified flow to intermittent flow. In this study, global and local linear stability analyses for dynamic and kinematic stability criteria predict the regions of stability of the flow for different pipe inclinations and fluid velocities in regularized and non-regularized systems, concurrently. It was possible to distinguish when: wave growth rates are absolutely bounded (stable stratified smooth flow), waves have finite growth rates (unstable stratified wavy flow), and when the equation system becomes elliptic and hyperbolization is needed. In order to bound short wave growth rates and regularize the equation system, we incorporated some lower and higher-order terms like interfacial drag and surface tension, respectively.

Keywords : linear stability analysis, multiphase flow, onset of slugging, two-fluid model regularization
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