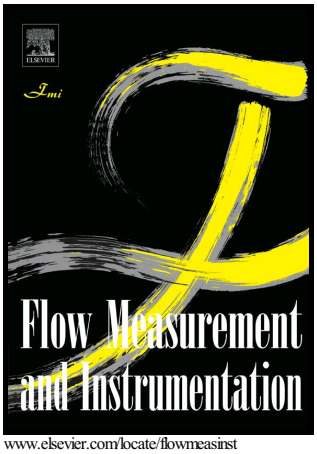

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Analysis of Vertical Upward Oil-gas-water Three-phase Flow based on Multi-scale Time Irreversibility

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Abstract

Based on the measurement signals obtained from oil-gas-water three-phase flow experiments, multi-scale time irreversibility is investigated to characterize the dynamic behavior of different flow patterns. Firstly, the conductance fluctuation signals of oil-gas-water three-phase flow in the vertical upward pipe are collected. Subsequently, three typical flow patterns, i.e., oil in water-type bubble flow, oil in water-type transition flow and oil in water-type slug flow, are defined and analyzed. Using multi-scale time irreversibility index and the surrogate data approach, multi-scale time irreversibility can be detected from the collected signals with different flow patterns. Furthermore, in order to quantitatively characterize the time irreversibility of oil-gas-water three-phase flow, a novel criterion, i.e., Average value of Asymmetric Distance (AAD), is proposed in this paper. The proposed criterion is validated by the experiments. The experiment results show that the conductance signals acquired from different typical flow patterns of oil-gas-water three-phase flow have different time irreversibility. The AAD value obtained for the oil in water-type slug flow is larger than the AAD value obtained for the oil in water-type transition flow, and the AAD value obtained for the oil in water-type transition flow is larger than the AAD value obtained for the oil in water-type bubble flow. In addition, the mechanism leading to the formation of time irreversibility was further explored in terms of adaptive optimal kernel time-frequency representation. It is proved that AAD can be used to reveal the characteristics of asymmetry in the evolution of oil-gas-water three-phase flow pattern. The utilization of AAD will provide an important reference for characterization and analysis of the non-linear dynamic characteristics of oil-gas-water three-phase flow regime evolution in real applications.