Comparison of Different Passive Oil-Water Mixing Schemes in a Flow Loop

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Abstract

Oil and water are immiscible fluids and they tend to separate very easily when introduced into a flow stream from two different sources in a flow loop. In order to properly study the behavior of oil-water mixtures, it is therefore necessary to include a mixing device in the flow loop. Dynamic mixers have been shown to be very effective in mixing, but they require additional electrical power, are expensive and need operator supervision. Static mixing elements that work mainly by introducing obstructions in the flow path and altering the flow pattern are easy to install and operate, but their effectiveness depends on a lot of parameters like flow velocity. In this study, we present 3 passive mixing strategies (blind-T, check valve, and static mixer) and compare their efficiencies. The two fluids considered were water (1000 kg/m3) and crude oil (870 kg/m3).

The fluid flow and interaction between two liquid components within a flow loop was modeled using the Multiphase Flow physics within the COMSOL Multiphysics® software with CFD Module. Since the Reynolds numbers are expected to be low, the Two-Phase Laminar Flow Level Set (tpf) interface was chosen to solve for the time-dependent development of the flow profile along the loop and capture the mixing dynamics. In order to model different final mixture compositions, the inlet velocities of the fluids were varied within the model. COMSOL solves the Navier-Stokes equations for the conservation of momentum and a continuity equation for the conservation of mass while satisfying the inlet velocity conditions, and the results obtained show the distribution of the WLR (water-liquid ratio) at different time steps (Figure 1, Figure 2).

Simulations of the oil-water flows show that the homogeneity of the mixture varies with different schemes. For example, if the mean and standard deviation of the WLR is calculated at multiple locations (Figure 3) within the flow loop, then we see that the mean values are similar (based on injected flow velocities of the individual phases) but the variation in WLR across a cross-section is much lower downstream of the passive mixing device. For example, in the case of a check valve shown in Figure 4, the standard deviations of local WLR distributions across the pipe diameter is nearly 0.3 before the valve, 0.1 immediately after the valve and 0.15 further downstream form the valve; hence, the flow is better mixed right after the valve location.

The results of this study will be useful to operators of two-phase flow loops and researchers studying such mixtures because it shows the following: (i) simply injecting two immiscible fluids

into a single pipeline does not result in the formation of a homogeneous mixture and there can be huge variations in local properties, and (ii) introduction of passive mixing schemes improves homogeneity of the mixture but their effectiveness can vary with physical configuration.

Figures used in the abstract

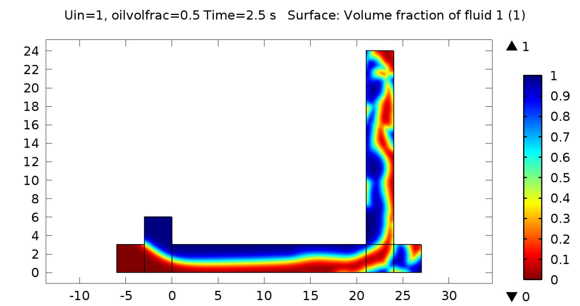

Figure 1: Snapshot of oil-water flow with blind-T as mixing element.

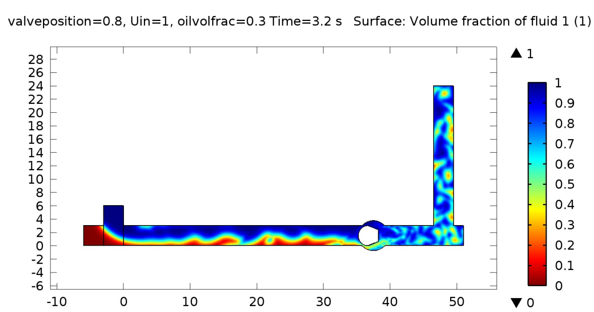

Figure 2: Snapshot of oil-water flow with a check valve as mixing element.

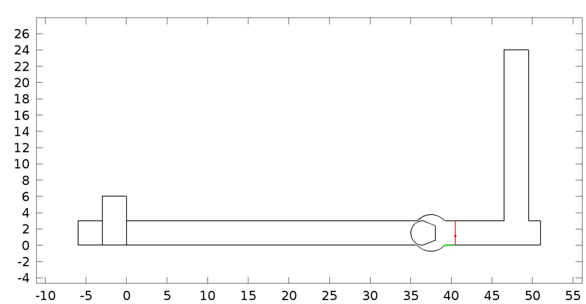

Figure 3: Geometry for flow loop simulation. Shows example flow loop location #2 (in red) for calculating mean and standard deviation of local WLR.

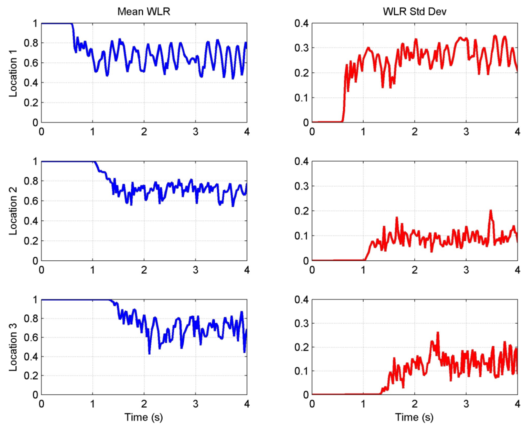

Figure 4: Mean and standard deviation of WLR at 3 different locations in the flow loop (check valve case); 1: before check valve, 2: immediately after check valve, 3: downstream of check valve (in vertical section).