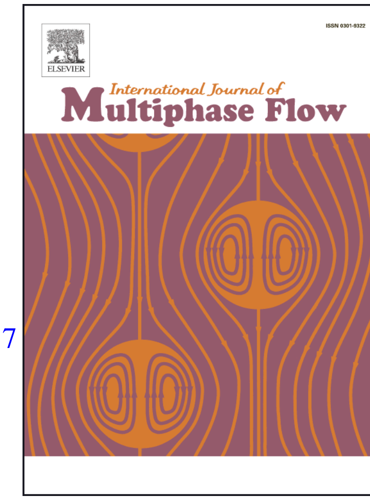

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Laterally stratified fully developed flow in a curved channel is investigated, in this work. Motivated by applications in microchannels, we focus on the limit of small Reynolds numbers. The method of domain perturbation is used to obtain an analytical solution, by considering the curvature ratio of the channel (ratio of the channel's width to its radius of curvature) to be a small parameter. Centrifugal forces give rise to multiple pairs of Dean vortices in the two fluids. Depending on the properties of the fluids and their holdups (volume fractions), one of the fluids dominates the flow and influences the flow pattern within the other fluid. The multi-dimensional parameter space is divided into five different regions, each characterized by a distinct vortex pattern. Centrifugal forces are shown to deform the interface; it bulges outward, in the direction of centrifugal force, to an extent that increases with the Weber number (ratio of centrifugal forces to interfacial tension forces). The deformation also depends on the flow pattern. Redistribution of the axial velocity profile is analyzed and attributed to geometric and inertial effects. The perturbation solution is compared with numerical simulations and found to be accurate for the range of Reynolds numbers and curvature ratios typically encountered in microchannel applications.

Keywords: two-phase, laterally stratified, curved channels, Dean vortices, microchannels

I. INTRODUCTION

Laterally stratified two-phase flows have recently acquired new significance in microfluidics. Stable stratified flow has been achieved in microchannels, by several workers, by bringing the two phases into contact via a Y-junction. In these studies, laterally stratified flow was used to carry out liquid-liquid extraction[1–5] and phase transfer catalysis[6] over a range of flow rates. In a typical extraction process, an aqueous phase bearing a solute is purified by bringing it into contact with an organic solvent. The inter-phase mass transfer is facilitated by the high surface area to volume ratio attainable in microchannels. Laterally stratified flow provides an additional benefit of ease of separation of the phases at the outlet. Extraction of biomolecules has also been carried out in microchannels using stratified flow of aqueous two-phase systems[7]. The efficiency of phase transfer catalysis also depends on the rate of mass transfer between the fluids[6].

In these microdevices, the microchannels are often designed in a hairpin serpentine structure, which has short bends interspersed between long straight sections. This allows one to