Thesis Title: Liquid-liquid flow in small diameter conduits - Hydrodynamics and Mass transfer

Abstract

The present study deals with hydrodynamics and mass transfer characteristics of liquid-liquid flow in millimeter size conduits. In this work process intensification is achieved for mass transfer dominant flows by enhancing the range of slug flow and decreasing the range of annular flow. It is observed from experiments that mass transfer co-efficient is highest in slug flow and minimum in annular flow for the same operating parameters. Experiments have shown that reduction in channel diameter enhances the range of slug flow and consequently, the mass transfer rates. Further mass transfer rates are affected by conduit orientation - the highest rates are observed during downflow for the same flow conditions and the effect of orientation is most significant in case of the slug flow pattern. A detailed image based diagnostic to evaluate the various slug characteristics reveals the highest in-situ toluene holdup in downflow - thus explaining the orientation effect.

Mass transfer enhancement is also achieved by introduction of a 90° bend in the straight conduit. The introduction of bend has a two fold effect as it enhances the slug flow range and inhibits the range of annular flow. The effect of bend on frictional pressure drop is quantified by amplification factor and bend loss co-efficient and it is seen that both these parameters are independent of flow patterns and exhibit an inverse relation with mixture Reynolds number. Based on the previous results, a compact multi bend device is proposed for process intensification in mass transfer dominant systems and its performance is compared with a helical coil. The effectiveness has been quantified by considering the a) overall volumetric mass transfer coefficient, b) extraction efficiency and c) solute transferred per unit frictional pressure gradient. The multi bend device gives the best results in terms of mass transfer rates while the single bend device is better when the coupled effect of both mass transfer and pressure drop is considered, however both the devices perform better than the helix.