409c Dynamic Behavior of Stretching and Folding of Fluid Interface Induced by Reciprocating a Disk in a Cylindrical Vessel

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The most common apparatus used for mixing applications in industry is the rotating impeller. However, reciprocal mixing or recipro-mixing is a more efficient way of mixing fluids than the traditional rotating impeller methods, particularly for low viscosity liquids. Three types of fluid flow have been observed during recipro-mixing with a disk in a cylindrical vessel: laminar creeping flow, laminar flow with vortex generation, and turbulent flow. The generation of vortices is the largest contributor to mixing in recipro-mixing. In this study, the interface between two miscible fluids undergoing reciprocal mixing is visualized by using a laser-induced fluorescence (LIF) reaction in order to better understand the stretching and folding of fluid elements and the generation of vortices. Since this interface increases with time due to the continual stretching and folding of the fluid element, it is helpful to think of the fluid as being completely mixed when all of the fluid particles comprise the fluid interface. Experiments were conducted at Reynolds numbers of approximately 15, 50, 75, 100, and 125 with disks of diameters 4.45, 5.45, and 6.21 cm and a cylindrical vessel of diameter 7.6 cm. The length of the fluid interface was measured during the first reciprocation cycle. The fraction of fluid mixed was measured for up to 10 reciprocation cycles. This information was derived from digitized data taken from video recordings of the experiments. Laminar creeping flow was observed at the lowest Reynolds number and laminar flow with vortex generation was seen in all others. Vortex size increased with increasing Reynolds number and disk size. This is supported by the change in length of the fluid interface with respect to time. The length of the interface during the first reciprocation cycle increased with increasing disk diameter and Reynolds number. Mixing effectiveness also increased with increasing disk diameter; it was relatively insensitive to Reynolds numbers (in the range 75 to 125) for the two larger disks but depended on Reynolds number (in the range 49 to 74) for the smaller disk. The fraction mixed could be fitted to a simple function in order to determine a characteristic number of cycles for mixing, which was relatively independent of Reynolds number for the 5.45-cm and 6.21-cm disks and dependent on Reynolds number for the 4.45-cm disk for the Reynolds numbers tested.