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Mixing in oscillating columns: Experimental and numerical studies

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The influence of free surface's stability on mixing in a vibrating column was studied through experiments and numerical simulations. The oscillation provided at the bottom of the column creates waves at the air/solution interface. As the strength of the oscillation is increased, the top surface becomes unstable. These instabilities and waves propagate through the solution down the column. Hence, these are responsible for the hydrodynamics formed within the vibrating column. We believe that, for each frequency and amplitude, the hydrodynamics within the solution is unique until the free surface disintegrates and becomes chaotic. To understand the hydrodynamics in a reactor, mixing within the reactor should be examined. Mixing is often correlated with the applied power. Hence, we believe that the mixing in an oscillating column will be highly non-linear function of applied power. The applied power can be correlated as A2ω3 (amplitude2 x frequency3). In this study, the frequency of the oscillation was varied from 1 Hz to 20 Hz whilst the amplitude was kept constant at 0.25 cm. The mixing experiments were performed using phenolphthalein and NaOH solution and the mixing time was computed using an in-house MATLAB code. Numerically, the air-solution interface was tracked using VOF model and the solution was vertically disturbed by oscillating the base of the column. The bottom boundary was treated as a rigid body and a compiled user-defined function (UDF) was applied to the boundary to sinusoidal displace it. The interior of the column was assumed to be a deforming body and the dynamic mesh was employed to improve the mesh quality. It was found that the mixing time is highly nonlinear with respect to the applied power. The mixing time as a function of frequency of the applied oscillation is presented in the figure below. The stability chart mapped in Benjamin and Ursell (1954) by solving a series of Mathieu equations was applied to our system and the nonlinear behavior of mixing in a vibrating column was explained. Pseudo steady states were observed, however they lasted only for few minutes and then switched back to 'real' steady states.

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