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Mixing induced by an homogeneous bubbly flow

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Abstract :

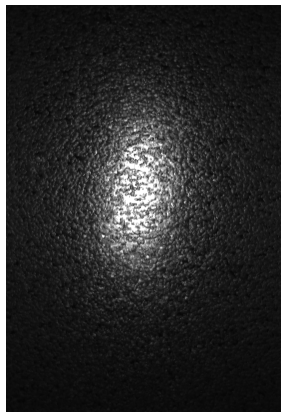
The present work investigates experimentally the mixing of a passive scalar at high Schmidt number in a homogeneous bubbly flow for gas volume fraction ranging from 1 to 13%. The mixing experiment consists of injecting a given amount of a fluorescent dye within the bubble swarm and measuring the dye propagation. The Reynolds number based on the bubble diameter and velocity varies from 700 to 850 in such a way that the turbulence induced by bubbles is fully developed. However the flow remains stable with no liquid recirculation and no turbulence induced by shear-stress. In this kind of flow, two main mixing mechanisms can be expected: the mixing induced by dye capture in the wakes [1] and mixing induced by wake interactions. However the first mechanism has been found to be negligible in this configuration [2].

The field of the dye concentration is measured by the fluorescence of fluorescein sodium induced by 12 UV neons arranged vertically all around the tank which allows to have a uniform illumination. In one side of the tank, a camera (sCMOS PCO) records only the fluoresced light thanks to the presence of two different filters disposed in front of the camera lens (a low-pass filter 650 nm and a high-pass filter 450 nm). A typical image filmed by this experimental technique is shown on figure a. Two types of disturbance are noticeable in this raw image. The fluoresced light is occulted by bubbles situated between the dye patch and the camera and there are reflexions and refractions of the fluoresced light on the bubbles interfaces. In order to prevent these optical distortions, an image processing has been developed and it allows to measure the dye concentration field during 15 seconds.

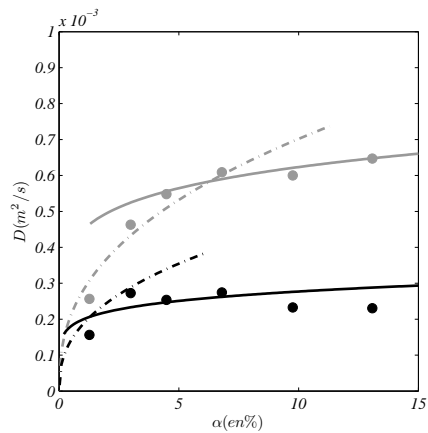
The spread of the experimental concentration field is estimated by fitting it with the solution of the diffusive equation in a confined field. A good agreement between this fits and the experimental concentration fields is found and a linear evolution of the variance of the concentration distribution versus time is also observed in the horizontal and vertical directions. Both informations lead to the conclusion that mixing in a homogeneous bubbly flow is a diffusive process and an effective diffusivity can be determined. Figure b presents the effective diffusivity as a function of the gas volume fraction for the vertical

(in gray) and horizontal (in black) directions. Two main properties of the effective diffusivity are noticeable. First the mixing is anisotropic. Secondly the effective diffusivity saturates when the gas volume fraction increases. Both properties can be interpreted thanks to a model based on Taylor's theory. The proposed model involves two regims depending on the gas volume fraction. At low gas volume fraction, the effective diffusivity can be written as the product of the standard deviation of the velocity fluctuations in the liquid and the integral Lagrangian length scale (dashed line). At large volume fraction, the effective diffusivity can be estimated by the product of the variance of the velocity fluctuation and the mean time between two bubble passages (solid line). This modelling including two regims allows to estimate both the anisotropy of the mixing and the saturation properties of the effective diffusivity.

Key-words : Bubbly flows, Mixing, LIF, Diffusivity



(a) Mixing of a fluorescent dye in a homogeneous bubbly flow (Row image)



(b) Effective diffusivity measured in a homogeneous bubbly flow.

Références

[1] E. Bouche, S. Cazin, V. Roig, F. Risso, Mixing in a swarm of bubbles rising in a confined cell measured by mean of PLIF with two different dyes, *Exp Fluids* (2013) 54:1552

[2] E. Alméras, Etude des propriétés de transport et de mélange dans les écoulement à bulles, Phd thesis, Université de Toulouse (2014)