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TEMPLATE FOR ABSTRACT SUBMISSION

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IMPACT OF CONFINEMENT ON MASS TRANSFER AND TRANSPORT OF OXYGEN AROUND INERTIAL BUBBLES

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New experimental results are reported for oxygen reactive mass transfer at the interface of an isolated bubble rising in liquid at rest at large Reynolds number, the bubble being confined in a vertical thin-gap cell of thickness w smaller than the capillarity length. Considered bubbles have a diameter d greater than w and therefore look like 'pancakes' separated from the walls by thin liquid films. The flow regime is inertial, and there exists a strong coupling between the bubble motion and its wake dynamics (Filella et al., 2015). The interfacial mass transfer leads to the transport of oxygen in the flow perturbation generated by the bubble motion. Understanding the transport in bubble wakes is our goal as it is crucial for discussing yield and selectivity of reactive mass transfer (Khinast, 2001).

Experiments were performed to measure the oxygen concentration transferred to the liquid. An imaging system based on shadowgraph technique was used to follow the path of the bubble, its in-plane shape oscillations and the gap-averaged oxygen concentration released around it. Indeed, as liquid phase, a reactive solution was used that consisted in an aqueous solution of resazurin dye (Yang et al., 2016). In oxygen-free atmosphere, this solution was transparent, and when it was in contact with oxygen a pale

pink color appeared due to the fast chemical reaction between oxygen and the dye. This reaction was reversible (the back reaction was very slow, i.e. few minutes). With an adequate calibration of the grey levels delivered by the camera and knowing the stoichiometry of the reaction, it was possible to describe the field of 'equivalent' oxygen concentration averaged through the gap of the cell. A 4D Lagrangian Particle Tracking Velocimetry (PTV) experimental technique was also used to explore the structure of the liquid velocity field so as to decipher the complexity of the mass transfer and the transport of concentration. Particle tracks (positions) and individual velocities were calculated using the Shake-The-Box (STB) method as in Pavlov et al. (2021).

This study reveals the presence of horseshoe vortices generated at the nose of the bubble (fig. 1.a). They are filled with oxygen that is transported towards the rear of the bubble (fig. 1.c). Behind the bubble, two contrasted regions are fed by mass transfer, either from the thin liquid films or from around the free periphery of the bubble that does not face the walls (fig. 1.b or 1.c). Their combination leads, for oscillating bubbles (fig. 1.c), to a double periodic deposit of oxygen at the rear of these confined bubbles: (i) one in the vicinity of the walls and the other (ii) in the wake generated by the interaction of the horseshoe vortices and of the vortices periodically released from the separated shear layer at the bubble equator, this wake being dampened by shear stress exerted at the walls.

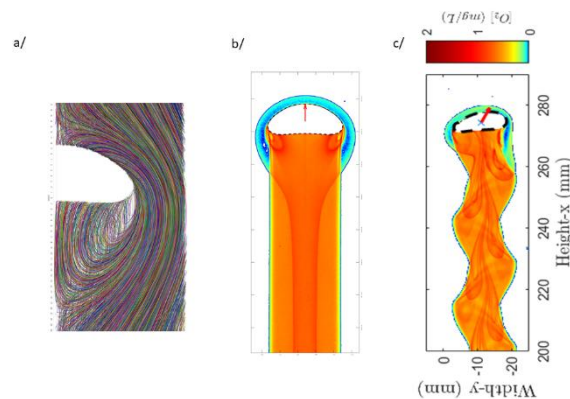


Figure 1: a/ Tracks of liquid particles indicating the presence of a horseshoe vortex at the tip of the bubble ($Ar = 4630$, $Bo = 30$) ; b/ and c/ Gap-averaged concentration of oxygen around: (b/) a large bubble ($Ar = 4670$, $Bo = 26$) or (c/) around an oscillating bubble ($Ar = 2660$, $Bo = 12.1$)

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