



Air trumpets

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Abstract : It is very common to observe air bubbles when we pour water into a glass. However, the mechanism of air entrainment by plunging jets is still a widely open question. This study will be dedicated to study the viscous version of the problem wherein a viscous plunging jet entrains a thin film of air into a pool containing the same liquid. By controlling the viscosity of the liquid, and both the jet speed and diameter, we want to characterize experimentally the thickness and the shape of the entrained air film. Such an investigation will provide the foundation to the study the criteria of film rupture which leads to air bubble formation in viscous air entrainment flows.

Project description :

Figure 1 displays photographs from a article from Physical Review Letters about 20 years ago by Lorenceau, Qu er e and Eggers (2004) [1]. They used a viscous silicon oil of viscosity approximately 1000 times more than that of water. The jet diameter before impact is 3 mm. As the jet speed is increased from a little over 0,1 m/s up to 2 m/s, the jet first curves the free-surface and an intriguing trumpet shaped object is clearly visible below the air-liquid interface.

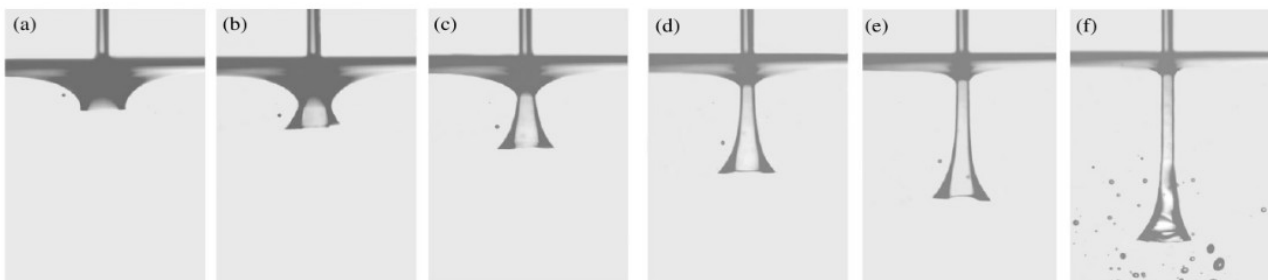


Figure 1: Air trumpets by Lorenceau & Qu er e (PRL 2004) [1] .

The dark edges of the jet indicate that the plunging jet does not mix with the pool liquid until the very end of the trumpet. This is possible if and only if a thin air film lubricates the plunging viscous jet. Lorenceau (2003) [2] illustrated the presence of the air film by demonstrating that the flow rate remains constant in the trumpet. Furthermore, she also demonstrated that such an air film is occurs beyond some threshold velocity which depends uniquely on silicon oil viscosity. Her stunning

experimental results confirmed the theoretical predictions of Eggers (2001) [2] for the rupture of a viscous cusp. However, the physical origin of the length of the air trumpet around the plunging liquid jet before the subsequent air-film rupture into bubbles is very complex. In this context, the break-up of an air film into bubbles is crucial to understand bubble formation by plunging jets and waves is crucial in many industrial and geophysical flows.

During the internship, we propose to investigate the air trumpet formation and its dynamics by properly varying liquid viscosity, jet speed and diameter. We will use high-resolution and high-speed imaging to quantify the temporal evolution of the air-trumpet. Once the steady state trumpet is established, its length, and the air film thickness will be measure using Chromatic Confocal Sensing (CCS) using an optical pen. In addition, the critical conditions for the air trumpet rupture, leading to bubble formation will be systematically measured over various experimental conditions. Bubble size distribution will be conducted via conventional image processing techniques.

References:

- [1] Lorenceau, É., Quéré, D., & Eggers, J. (2004). Air entrainment by a viscous jet plunging into a bath. *Physical Review Letters*, 93(25), 254501.
- [2] Lorenceau, É. Interfaces en grande déformation: oscillations, impacts, singularités. 2003. Thèse de doctorat. Université Pierre et Marie Curie-Paris VI.
- [3] Eggers, J. (2001). Air entrainment through free-surface cusps. *Physical Review Letters*, 86(19), 4290.