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Visualization of the contact line during water entry and water exit experiments by LED edge-lighting

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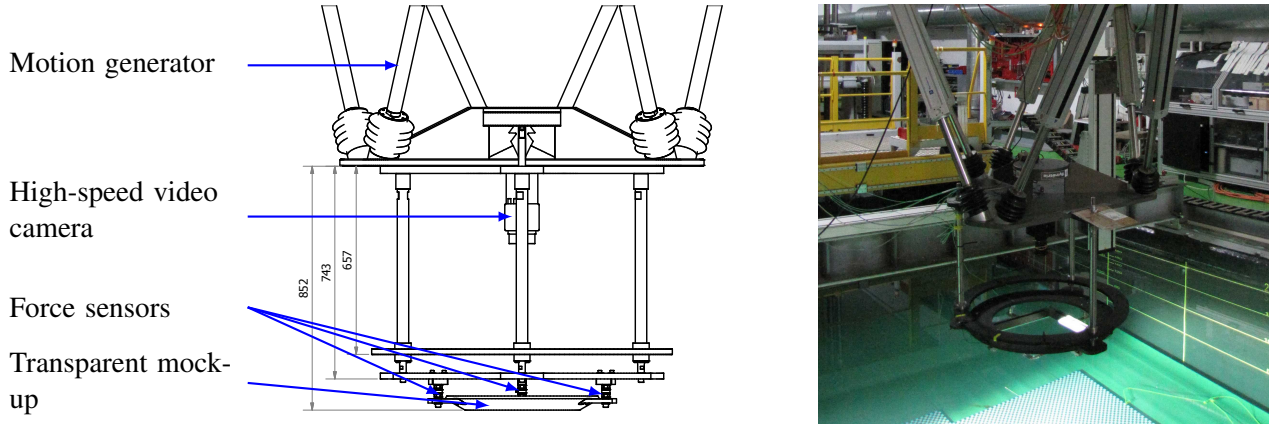
Abstract We present an original technique for the visualization of the contact line during water entry and/or water exit experiments. In the water entry experiments, the body enters vertically (downwards) the water with an initial velocity and then decelerates until it starts going up again, and finally it fully exits the water. In the pure water exit experiments, the body is initially resting at the surface of the water and is then lifted upward until it fully exits the water. This technique is based on the use of transparent mock-ups made of a plexiglas (PMMA) shell. A LED light array is fixed along the periphery of the mock-up in order to diffuse light in the material and a high-speed video camera records a top view of the scene. We show that this technique makes it possible to illuminate the contact line which delimits the surface of contact between the water and the mock-up. The accuracy of the technique is demonstrated through comparisons with experiments during which a draughtboard was placed at the bottom of the tank. The different shapes which have been studied so far include a circular disc, an elliptic disc, a square plate, a cone and a hemisphere. The three-dimensional mock-ups required to manufacture a calibration part which was placed under the mock-up in order to compensate for perspective distorsions. Moreover, we show that the illumination technique works for both the entry and exit stages and that it is possible to visualize simultaneously the jet front and the contact line during the entry stage. Preliminary results were published in [1] where we showed the feasability of the technique at small scale and for flat plates. We now demonstrate the performance of the visualization technique with three-dimensional mock-ups (cone, hemisphere) of larger scale (up to 50 cm diameter).
Keywords: water exit, water impact, high-speed video, hydrodynamics, free-surface flows, contact line

Experimental set-up

The experimental set-up depicted in Fig. 1a comprises a motion generator which is used to move the mock-up vertically. A high-speed video camera records the scene from above at 1000 fps. Note that the distance between the camera and the mock-up is fixed, as the camera moves together with the mock-up. Force sensors are also used to measure the hydrodynamic force. A picture of the set-up is presented in Fig. 1b where the reader may see the draughtboard located at the bottom of the tank. This draughtboard was used for the validation of the LED edge-lighting technique. In order to use the LED edge-lighting technique, we manufactured dedicated transparent mock-ups which are described in Fig.2. Note the sloped sides of the circular disc mock-up in order to be able to incorporate the LED arrays along the edge of the mock-up without touching the water. A series of images obtained during the water exit of a cone is presented in Fig. 3. Figs. 3a and 3b were obtained with the LED edge lighting technique whereas Figs. 3c and 3d were obtained with the draughtboard technique. In the images obtained with the draughtboard technique, the surface in contact with the water corresponds to the portion of the image where the draughtboard is undistorted. The contact line extracted from Figs. 3a and 3b is superimposed to Figs. 3a and 3b to show the close correspondance between the illuminated contact line and the surface of contact observed with the draughtboard technique for the same values of the elevation, $h(t)$, of the cone. Different examples of images obtained in different configurations are presented in Fig. 4. One may observe in Fig. 4a that it is possible to track both the contact line and the jet front during the water entry of a cone. In Fig. 4b we can see how the shape of the contact line is very complex during the water exit of a square plate. In the case of an elliptic plate (Fig. 4c), the contact surface becomes very thin. In Fig. 4d, one can see the contact line during the impact of a wave (propagating from left to right) on a (stationary) sphere

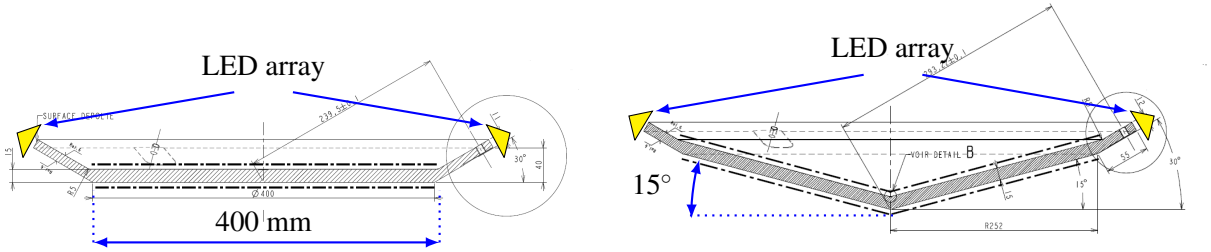
References

[1] Tassin A, Breton T, Forest B, Ohana J, Chalony S, Le Roux D and Tancray A (2017) Visualization of the contact line during the water exit of flat plates. *Experiments in Fluids,*, vol. 73, pp 776-788.



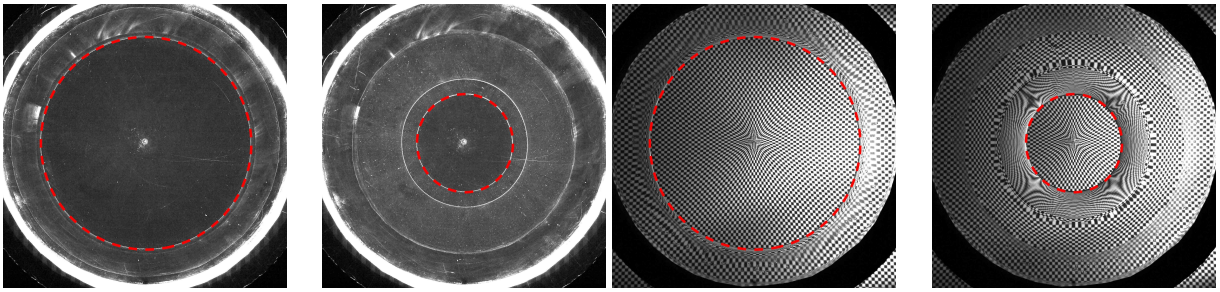
(a) Sketch of the set-up (dimensions in mm) (b) Picture of the set-up

Fig. 1 Experimental set-up



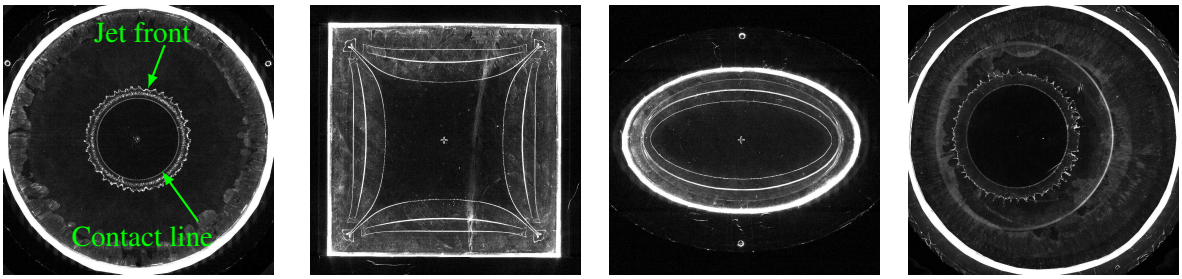
(a) Circular disc (b) Conical mock-up

Fig. 2 Description of some transparent mock-ups used for the LED edge-lighting technique



(a) h(t)=2.36mm (b) h(t)=60.8mm (c) h(t)=2.36mm (d) h(t)=60.8mm

Fig. 3 Sequence of images obtained with the LED edge-lighting technique (a,b) and the draughtboard technique (c,d) during the water exit of 15° deadrise angle cone with an initial contact surface of radius $c_0 = 0.25m$ for different values of the elevation h(t). The position of the illuminated contact line is depicted by the red dashed line in Figs. 3c-d



(a) (b) (c) (d)

Fig. 4 Images obtained during (a) the water entry of the cone, (b) the water exit of a square plate, (c) the water exit of an ellipse and (d) the impact of a wave on a sphere