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MECHANICS OF BIDIMENSIONAL LIQUID FOAMS

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Summary An experimental study of foam flow is presented. A 2D foam is confined between a soap solution and a glass plate. It flows through a channel around an obstacle. This device enables to perform simultaneously external sollicitation, measurement of the response force and image analysis. We perform a systematic study of the drag exerted by the foam on the obstacle, *versus* the experimental control parameters: flow rate, bubble size and fluid fraction. Simultaneously, local velocity and stress fields are measured; we also measure a statistical strain field. The comparison of both types of measurements enables to study the link between local events and the global mechanical behaviour of the foam.

MOTIVATIONS

Liquid foams, made of two fluids, sometimes behave as solids. Actually, they can exhibit elastic, plastic or fluid response depending on external sollicitations. In bidimensional foams, one can easily obtain from images of the deformed structure the pressure, capillary stress and velocity fields. Liquid foams are thus complex fluids which are convenient to study.

EXPERIMENTAL GOALS AND DEVICES

When shearing a foam, one does not know *a priori* how stress and strain vary within it. Hence, a local analysis is needed to find an accurate description of the local mechanical behaviour of the foam. This description can then be used to predict the global behaviour of the foam, and must be validated by a global measurement. The local analysis is provided by acquisition and processing of the images of the deformed foam, and the global measurement is either a force or a torque exerted between the foam and an external sensor. We present different experimental set up (2D Stokes experiments) built in order to do both image analysis and mechanical measurement simultaneously: a Langmuir foam sheared by an optical fiber [1], a soap foam in a Hele-Shaw cell [2], and a current experiment combining the advantages of both [4].

BUBBLE DEFORMATION – LOCAL DESCRIPTION

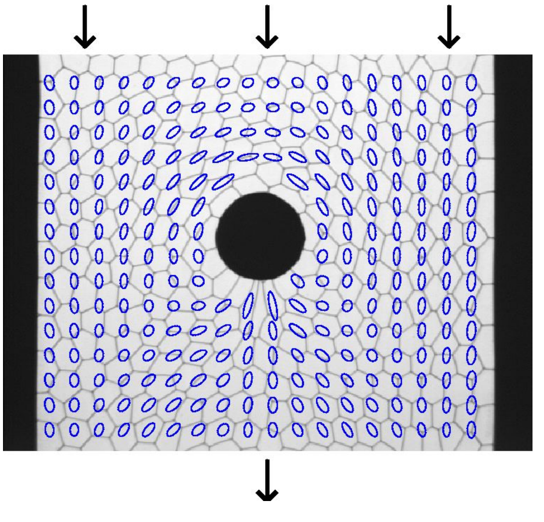

Figure 1. Analysed image from the experiment. The foam flows from top to bottom at a velocity of order 1 cm/s. The width of the channel if 10 cm and the typical size of bubbles is 5 mm. The ellipses represent bubble deformation, averaged over time at each point. With this representation one can visualise the deformation experienced by bubbles at the vicinity of the obstacle, compression uphill and stretching downhill [2] (picture M. Asipauskas).

In 2D foams, one has a geometrical intuition of the bubble deformation from an image (fig. 1). We quantify this intuition by the texture tensor $\bar{\bar{M}} = \langle \vec{\ell} \otimes \vec{\ell} \rangle$, where $\vec{\ell}$ represents a bubble edge and the spatial and/or tempoal average is taken at a mesoscopic scale to have sufficient statistics. We define a statistical strain as $\bar{\bar{U}} = (\log \bar{\bar{M}} - \log \overline{\overline{M_0}})/2$, where $\overline{\overline{M_0}}$

corresponds to a reference state [3]. This tensor coincides with the classical strain $\bar{\bar{u}}$ as long as no bubble rearrangement (neighbour swapping) occurs, and is always defined. The comparison between measured stress and statistical strain yields a linear relation, hence enables to measure the shear modulus of the foam, which agrees with an independent mechanical measurement [1].

FORCE MEASUREMENTS AND RESULTS

By blowing nitrogen in a soap solution, we prepare one layer of bubbles confined between the top glass plate of the channel and the soap solution. An obstacle stands in the channel and modifies the foam flow. Depending on the flow rate, this flow is quasistatic or not. We measure the drag exerted by the foam on this obstacle, as well as the stress, statistical strain and velocity fields induced within the foam by the presence of the obstacle. The control parameters of this experiment are numerous and easily tunable: flow rate, bubble size, fluid fraction, obstacle size and shape, viscosity and surface tension. We present a systematic study of the variation of the drag determining the elastic and viscous contributions. Furthermore, we emphasize the main features of the stress, strain and velocity fields. The effect of bubble rearrangements is studied to take into account the specific mechanical behaviour of the foam. We also compare these two kinds of measurements, drag versus local data, to study the effect of local events at the global foam scale.

References

[1] Courty S., Dollet B., Elias F., Heinig P., Graner F., *Europhys. Lett.* **64** (5): 709–715, 2003.
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[3] Aubouy M., Jiang Y., Glazier J. A., Graner F., *Granular Matter* **5**: 67–70, 2003.
[4] Dollet B., Graner F., Quilliet C., Aubouy M., Elias F., work in progress.