Non-pairwise interactions between bubbles in wet foams

G. Ginot [1], R. Höhler[2], S. Mariot[3], A. Kraynik[3], W. Drenckhan[1]

[1] Institut Charles Sadron, University of Strasbourg – CNRS, France

[2]Institut des nanosciences de Paris, Sorbonne Université - CNRS, France

[3] Laboratoire de Physique des Solides, Université Paris-Saclay - CNRS, France

E-mail: gael.ginot@ics-cnrs.unistra.fr

ABSTRACT

In wet 3D foams, bubble shapes and packing configuration (Figure 1a) are determined by interfacial tension and contact forces between neighbours. In "bubble model" simulations, bubbles are commonly represented as perfect spheres that can overlap and whose interaction energy is proportional to their overlap distance. rgy is proportional to their overlap distance [1,2]. The interaction energies associated with different contacts of the same bubble are assumed to be independent. However, a contact force squeezing a real bubble in a foam causes it to expand laterally, because of volume conservation. This in turn enhances contact forces exerted on lateral neighbours, resulting in a contact force-deformation relation which is intrinsically non-pairwise[3]. This argument holds in the same way for drops, i.e. for emulsions. A theoretical model of the bubble energy change induced by contact forces accounting for this many-body interaction in wet foams has been derived from first principles by Morse and Witten[4]. Höhler *et al.* have deduced from it a relation between contact forces and displacements which predicts elastic bulk behavior of foams near the jamming transition which is qualitatively different from bubble model predictions[5]. Weaire *et al.* obtained similar results in 2D [3]. We report the first experimental confirmation of the bubble interaction model based on Morse Witten theory [2] in a simple experimental setup which creates a controlled confinement of trains of equal-volume bubbles in square capillaries (Figure 1b). These results are compared to numerical simulations using first-principle finite elements calculations using Surface Evolver [6]as shown in Figure 1c. The Morse Witten interaction model can also be adapted to account for gravity, and therefore to describe bubble behavior on the scale of a foam. It also holds for the description of emulsions.

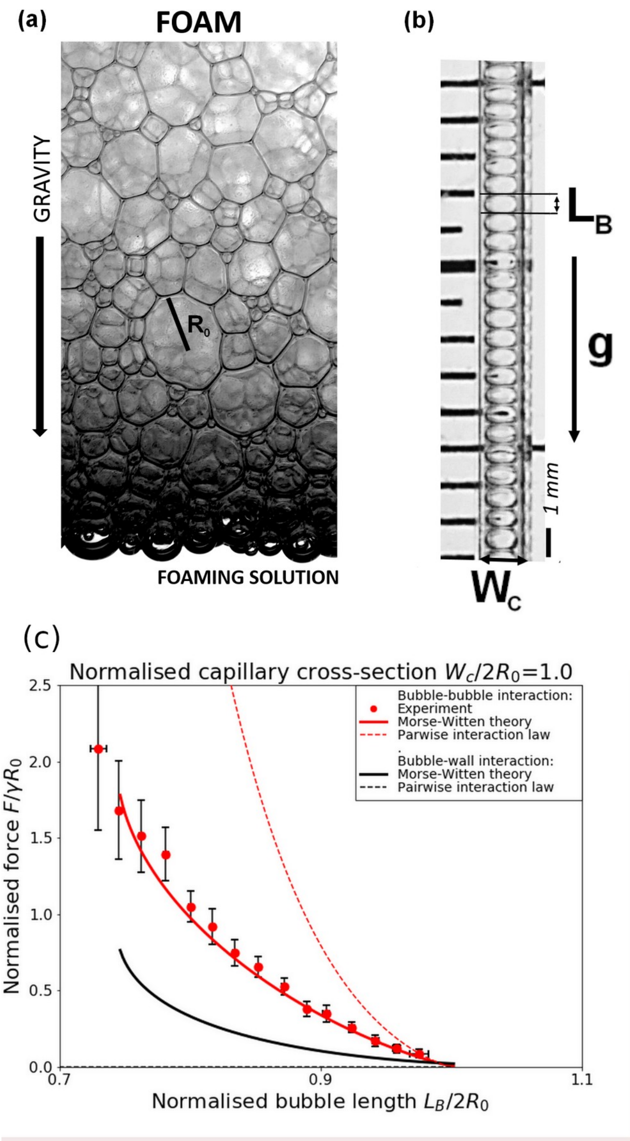

Figure 1: (a) 3D foam under gravity (b) Equal-volume bubbles trapped inside a capillary. The square cross-section imposes four contact points with walls, and two with neighboring bubbles. Buoyancy force exerted on upper neighbors causes the bubbles to gradually deform when going up the capillary. (c) Force-deformation relation for a cubic geometry. Theory, simulations and experiments are represented. In addition, a previously used effective two-body interaction model is represented as a dotted line for comparison [7].

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