Experimental study of flow behavior in a bubble raft

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Overview

• Experimental study of flow in a two-dimensional foam.
• Ability to measure bubble motions and stress/strain relations.
• Comparison with various two-dimensional models.
Bubble Raft Experiment

Bubble Sizes: 1.92 mm, 2.81 mm, 5.31 mm
Number of bubbles: 900
Area fraction: 0.9
Schematic of Apparatus

Inner radius: 3.84 cm        Outer radius: 7.43 cm
Torsion constant: 2450 dyne cm/rad
Typical rotation rate ($\Omega$): 0.005 to 0.01 rad/s
Typical angular motion of pendulum: 22° to 40°.
Results

• Average stress versus shear rate
• Stress versus strain ("avalanche" type behavior)
• Distribution of stress drops
• Duration of stress drops (distribution)
• Rate of stress drops per bubble per strain: $S$
Stress versus Shear Rate

![Graph showing Stress versus Shear Rate with Max Stress and Ave Stress markers. The x-axis represents Shear Rate (sec^{-1}), ranging from $10^{-3}$ to $10^{-1}$, and the y-axis represents Stress (dyne/cm), ranging from $10^1$. The graph includes markers for Max Stress and Ave Stress.]
Stress versus Strain for $d\gamma/dt = 10^{-3} \text{ s}^{-1}$

Steady Strain ($\Omega = 0.0005 \text{ rad/s}$)
Steady Strain ($\Omega=0.01$ \text{rad/s})

Stress versus Strain for $d\gamma/dt = 2.6 \times 10^{-2}$ \text{s}^{-1}
Distribution of Stress Drops

Line has slope: -0.78
Average stress drop versus shear rate

\[ \langle \Delta \sigma \rangle \text{ (dyne/cm)} \]

vs.

\[ \frac{d\gamma}{dt} \text{ (s}^{-1}) \]
Duration of Stress Drops

\[ \Omega = 0.05 \text{ rad/s} \]
\[ \frac{d\gamma}{dt} = 0.13 \text{ s}^{-1} \]
Stress drops per bubble per strain

\[ S = \frac{\gamma}{dt} \]
Summary

- Results strongly support a quasi-static limit
- “Typical” size to stress release
- Results in excellent agreement with simulations of Bubble Model (Durian, PRL 1995, Tewari, et al., PRE 1999)
- Results consistent with monolayer foam.

MOVIES AND REPRINTS: http://www.physics.uci.edu/~dennin