BREAKAGE, COALESCENCE AND SIZE DISTRIBUTION OF SURFACTANT-LADEN DROPLETS

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Figure 1: Snapshot of the droplets shape (iso-level $\phi=0$) for We=3.00 and β_s=4.00.

INTRODUCTION

The breakage and coalescence of surfactant-laden droplets and the resulting size distribution play a key role in a wide range of environmental and industrial applications, from raindrop formation in the atmosphere [1] up to fragmentation and evaporation process in combustion chambers [2].

METHODOLOGY

We consider a turbulent flow in which a swarm of surfactant-laden dropletsis dispersed. The system is described coupling direct numerical simulation of the Navier-Stokes equations with a phase-field method [3,4]. Two dimensionless parameters characterize the system:

- Weber number (We); ratio between inertial and surface tension forces. This parameter determines the interface deformability.
- Elasticity number (β_s); parameter that defines the surfactant strength. Larger values identify stronger surfactants (i.e. large surface tension reduction for a fixed concentration).

EQUATIONS

$$\nabla \cdot \mathbf{u} = 0$$

$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} = -\nabla p + \frac{1}{Re_\tau} \nabla^2 \mathbf{u} + \frac{3}{\sqrt{8}} \frac{Ch}{We} \nabla \cdot [f_\sigma(\psi) \tau_c]$$

← INTERFACIAL FORCES

← SURFACTANT ACTION

PHASE FIELD →
$$\frac{\partial \phi}{\partial t} + \mathbf{u} \cdot \nabla \phi = \frac{1}{Pe_\phi} \nabla \cdot (\mathcal{M}_\phi \nabla \mu_\phi)$$

SURFACTANT →
$$\frac{\partial \psi}{\partial t} + \mathbf{u} \cdot \nabla \psi = \frac{1}{Pe_\psi} \nabla \cdot (\mathcal{M}_\psi \nabla \mu_\psi)$$

BREAKAGE & COALESCENCE

The droplets, interacting with turbulence and surrounding droplets, can break or coalesce.

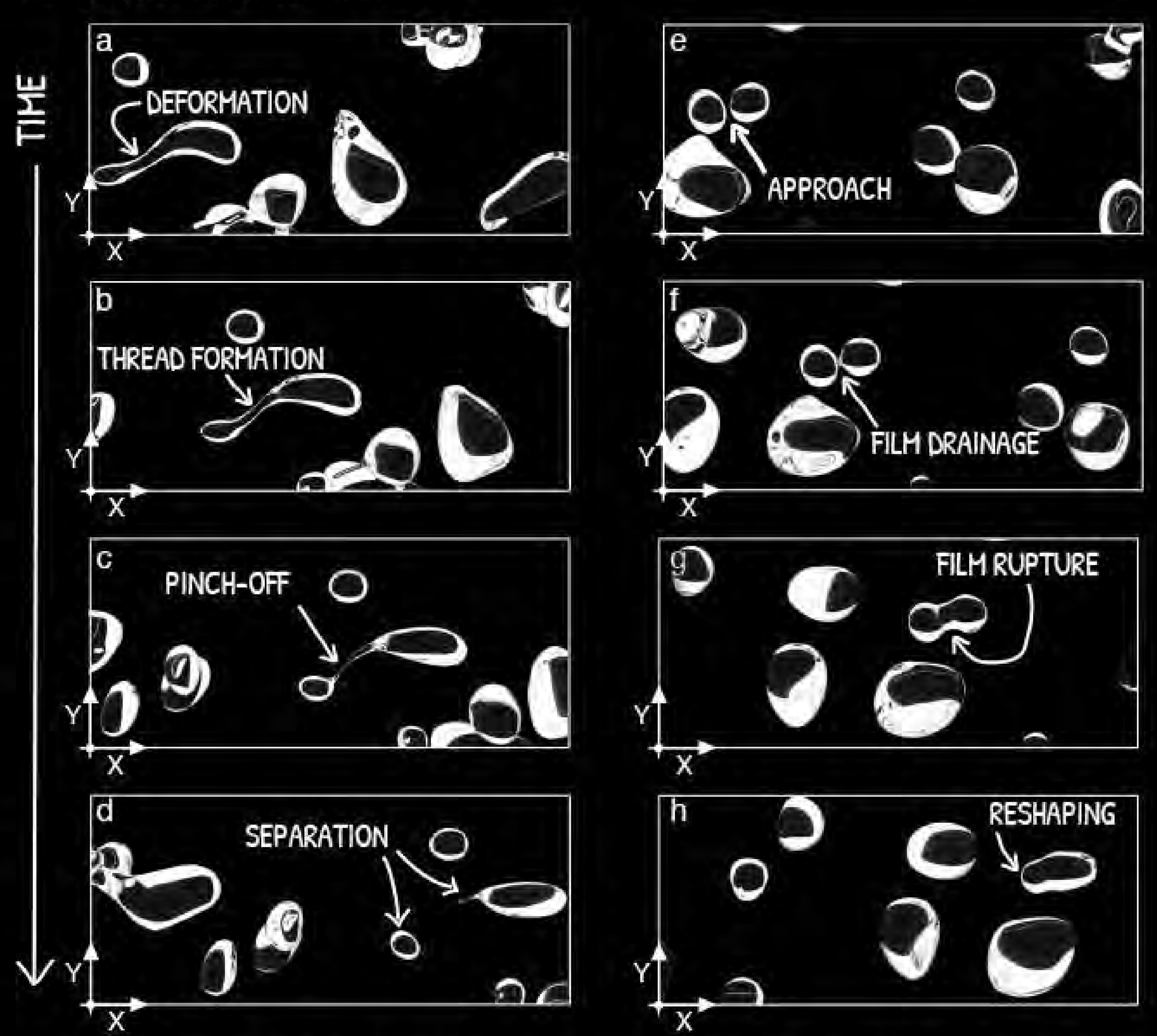

Figure 2: Time sequeance of a breakage event: Deformation (a), Thread formation (b), Pinch-off (c) and Separatio (d) and of a coalescence event: Approach (e), Film drainage (f), Film rupture (g), Reshaping (h).

RESULTS

The droplet size distribution (DSD), which is the result of the competition between breakage and coalescence events, is a fundamental tool that can be used to characterize the dispersed phase morphology.

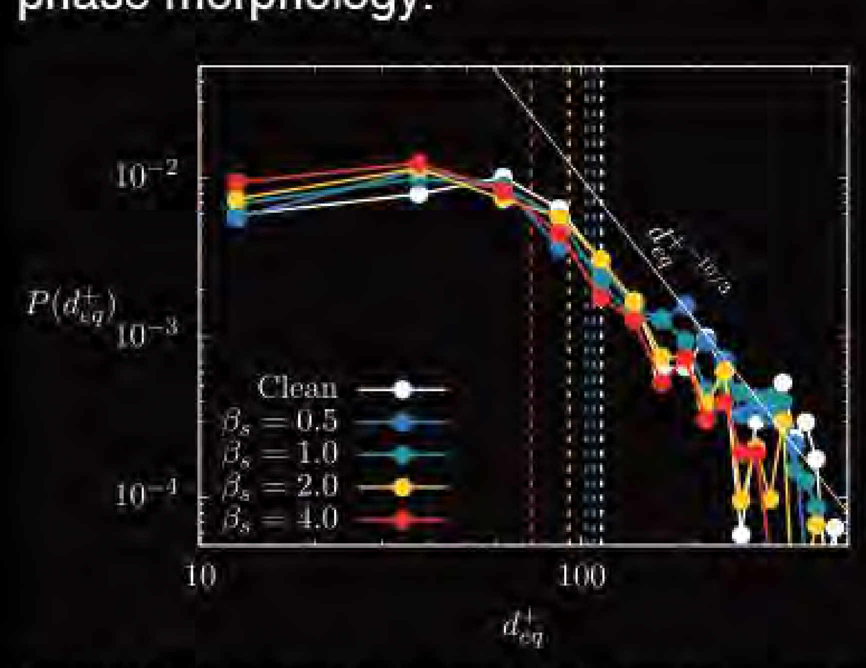

Figure 3: Droplet size distributions (DSD) reported in log-log scale. The results refer to We = 3.00 and the different cases are identified with different colors: black (clean), β_s = 0.50 (blue), β_s = 1.00 (green), β_s = 2.00 (yellow) and β_s = 4.00 (red). The theoretical scaling d**exp(-10/3) is reported with a thin continuous white line. The Hinze inviscid scale for each case is reported with vertical dashed lines (same color code as the droplet size distributions).

As can be observed from figure 3, the resulting DSDs are in good agreement with the scaling proposed by Garrett *et al.* (2000) [5] and previous experimental results [6]. The quality of the agreement increases for larger elasticity numbers (larger number of samples/droplets).

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