SUPPLEMENTARY MATERIAL FOR: Emulsions in microfluidic channels with asymmetric boundary conditions and directional surface roughness: stress and rheology

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I. FURTHER ANALYSIS ON VELOCITY PROFILES, LOCAL MICROSTRUCTURE AND DROPLET CONCENTRATION PROFILE

We report on additional analysis to better understand the difference in stress profiles for the concentrated emulsion with $\Phi = 0.629$, shown in Fig.4d of the main manuscript. We addressed this point by performing a Lagrangian tracking analysis on the droplet motion close to the rough wall and by investigating the change in the microstructure in the same channel region. For completeness, we also analyzed the droplet concentration profile across the channel.

Lagrangian tracking: To highlight the difference in the slip velocity between FWD and BWD direction, we randomly select droplets in the two configurations moving close to the rough wall. We show in Fig. 1 the trajectories along the z-direction of these droplets' center-of-mass z_{cm}. The solid black line indicates a droplet moving in the FWD direction, while the red one refers to a droplet moving in the BWD direction. It is clear how the first one "jumps" very often beyond the triangular posts since it is thrown into a stepping stone, while the second hits against a vertical obstacle, resulting in a rare "jumping" beyond the obstacle. We also included animation maps for FWD and BWD direction simulations (see `movie_F.avi` and `movie_B.avi`).

Analysis of the microstructure: we analyzed the droplet microstructure via the Delaunay triangulation [1, 2]. The Delaunay triangulation has been constructed starting from the centers of mass of the droplets, wherein each droplet is associated with a set of neighboring droplets connected with links. Links between droplets can break due to plastic rearrangements, and novel links can form (see Fig. 2). Fig. 2(b) shows the number of plastic events N_p across the microfluidic channel, normalized to the total number of detected plast events $N_{p,tot}$. It emerges that the plastic activity in the FWD simulation is more prominent than the BWD one close to the rough wall, thus producing better fluidization.

Droplet concentration profile: To further check the impact of the presence of an asymmetric boundary condition, we analyzed the droplet concentration profile across the channel section $\Phi(z)$. From data reported in the supplementary material of Ref. [3] (Fig. S10), we expect no impact of the presence of the roughness on the spatial behavior of $\Phi(z)$. Our analysis performed for $\Phi = 0.629$ data confirms this expectation. Fig. 3 shows profiles $\Phi(z)$ for FWD and BWD flow direction at fixed pressure gradient. Both profiles are almost flat, but the concentration profile in the BWD direction shows a larger value close to the rough wall and a slight depletion in correspondence to the second layer of droplets, as expected since droplets are blocked when entering into contact with the vertical posts in the BWD direction only.

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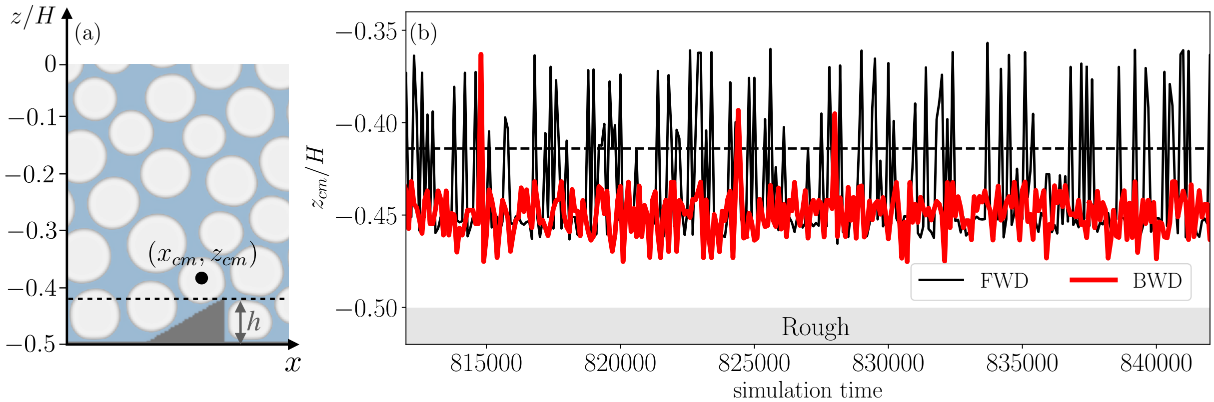

FIG. 1. Panel (a): A sketch of the position of a representative droplet moving close to the rough wall. It helps in understanding the occurrence or not of a "jump" beyond the obstacle with respect to the flow direction. Panel (b): Trajectories of the center-of-mass along the z- direction (z_{cm}) of representative droplets moving close to the rough wall, randomly selected over the x-direction. The solid black line indicates the time evolution of z_{cm} of a droplet moving in the FWD flow direction, while the red one refers to the time evolution of z_{cm} of a droplet moving in the BWD flow direction. in both panels, the dashed black line highlights the height h of the roughness posts.

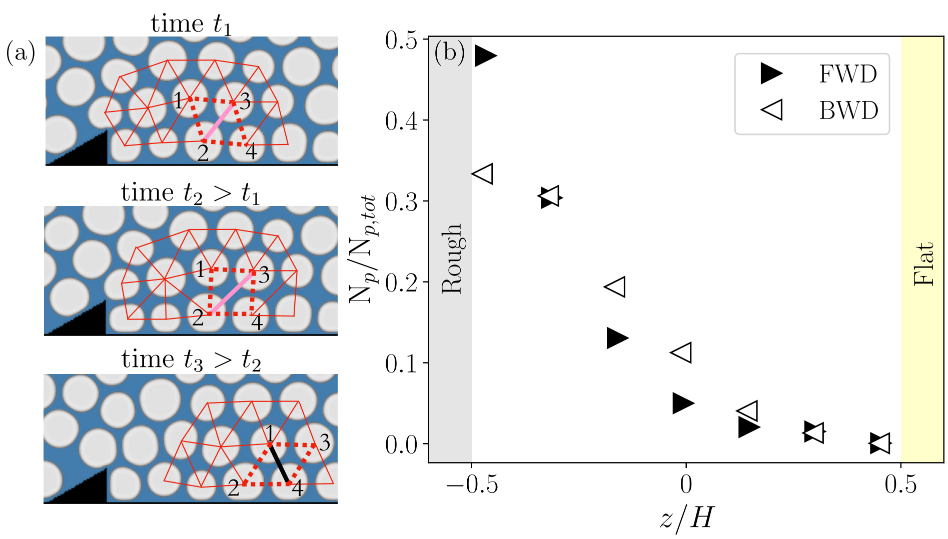

FIG. 2. Panel (a): a sketch describing the detection of a plastic rearrangement. By considering the Delaunay triangulation constructed with the centers-of-mass of the droplets labeled from 1 to 4, we detect a plastic event any time an existing link between two droplets (the pink solid link between droplets 2 and 3) disappears, and a new one is created (the black solid link between droplets 1 and 4). Panel (b): the number of plastic events N_p across the microfluidic channel, normalized to the total number of detected plastic events $N_{p,tot}$. The vertical z coordinate is normalized with the microfluidic channel height H. We show data for FWD (▶) and BWD (◁) flow directions.

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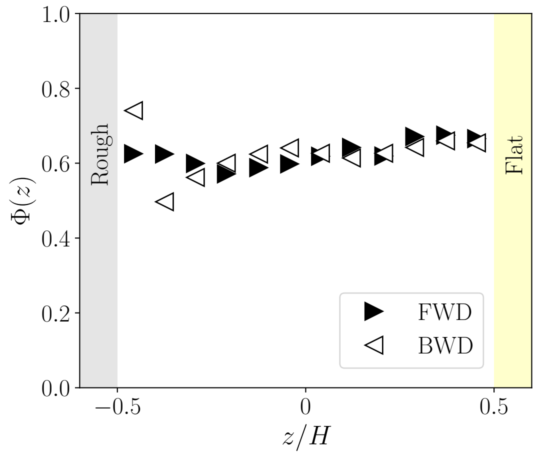

FIG. 3. Droplet concentration profile $\Phi(z)$ as a function of the z-coordinate normalized with wall-to-wall distance H for the concentrated emulsion with $\Phi = 0.629$. We show data for FWD (▶) and BWD (◁) flow directions.