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Droplet snap-off in fluids with nematic liquid crystalline ordering

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New Journal of Physics **14** (2012) 023010 (12pp)


Received 21 October 2011

Published 3 February 2012

Online at <http://www.njp.org/>

doi:10.1088/1367-2630/14/2/023010

Abstract. We studied the snap-off of nematic liquid crystalline droplets originating from the Rayleigh–Taylor instability at the isotropic–nematic interface in suspensions of charged gibbsite in water and sterically stabilized gibbsite in bromotoluene. We found that droplet snap-off strongly depends on the director field structure inside the thinning neck, which is determined by the ratio of the splay elastic constant and the anchoring strength of the nematic phase to the droplet interface relative to the thickness of the thinning neck. If anchoring is weak, which is the case for aqueous gibbsite, this ratio is comparable to the thickness of the breaking thread. As a result, the thinning neck and pending drop have a uniform director field and droplet snap-off is determined by the viscous properties of the liquid crystal as well as by thermal fluctuations of the interface. On the other hand, in sterically stabilized gibbsite where anchoring is strong, this ratio is significantly smaller than the neck thickness. In this case, the neck has an escaped radial director field and the neck thinning is retarded close to snap-off due to a topological energy barrier involved in the separation of the droplet from the thread.

 Online supplementary data available from stacks.iop.org/NJP/14/023010/mmedia

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1. Introduction

The breakup of liquid threads into droplets is a familiar phenomenon in everyday life that has been studied for a long time, and has been comprehensively reviewed by Eggers [1, 2]. The subject is of scientific interest because of the singularity that occurs at breakup when the small amount of fluid left in the pinch region is driven by increasingly strong forces and at the same time the radius of curvature goes to zero [1]. However, research on this intriguing phenomenon is also driven by practical interest. The stability and control of a liquid thread is a crucial factor in a variety of applications, such as diesel engine technology, ink-jet printing [3] and the manufacture of electronic and optoelectronic devices [4].

The singular behaviour close to the snap-off event allows in the case of Newtonian fluids a description of the geometry of the thinning neck as a function of time by universal scaling functions independent of initial conditions [2]. On the other hand, in the case of non-Newtonian fluids, the strain rate-dependent viscosity is at the origin of exotic phenomena during the breakup process and is still not completely understood. For example, the breakup of viscoelastic fluids under certain conditions involves beads-on-a-string structures [5], and the elastic stress built up during the breakup of filaments of worm-like micelles can cause the falling drop to stall before pinch-off [6]. In general, the breakup of a liquid thread is driven by the interfacial tension and counteracted by either the viscosity or inertia of the liquid [1].

A special case of breakup is when the fluid thread possesses liquid crystalline order. Control over breakup in these types of systems is important for the production of liquid crystalline polymer composites [7–9], as well as the formation of micro- and nano-fibres by electrospinning of elongated particles, such as long rod-like viruses [10]. Another application is the breakup of liquid crystalline threads in a microfluidic device in order to produce liquid crystalline droplets [11]. Theoretical calculations by Cheong and Rey [12] showed that the anchoring properties and the texture of nematic liquid crystalline threads strongly influence the breakup and in most cases will stabilize the thread. Fel and Zimmels [13] showed that liquid crystalline fluids with *planar* anchoring exhibit enhanced stability in comparison to ordinary liquids, by an increase of the threshold wavelength and a decrease of the disturbance growth rate. Similar results were obtained recently from computer simulations by Zhou *et al* [14], who showed that both the interfacial anchoring and the bulk elasticity of the liquid crystalline fluid dampen

the growth of capillary waves. They argue that these effects are only quantitative, and that nematic threads break up in essentially the same way as Newtonian ones. In contrast, computer simulations of the breakup of a nematic thread with *homeotropic* anchoring revealed that the breakup in this case requires a morphological transition with an accompanying free energy barrier [15].

A decade ago, it was shown by computer simulations and theory that in isotropic fluids the breakup and drop formation of the so-called nano-jets follow a fundamentally different mechanism than at larger scales [16, 17]. When the jet diameter approaches the molecular scale, thermal fluctuations start playing a role and dominate the breakup process, changing both the snap-off geometry and its dynamics. Interfaces in phase separated colloidal suspensions have an ultralow interfacial tension, which implies that they reach the regime where thermal noise influences breakup already at the micrometre scale. The thermal roughness, defined as $L_T = \sqrt{k_B T / \gamma}$ with k_B being the Boltzmann constant, T the absolute temperature and γ the interfacial tension, is of the order of micrometres in such systems and can be directly observed with confocal microscopy [18]. Exploiting this feature, the effect of thermal noise on droplet snap-off was studied in detail in colloid–polymer mixtures that phase separate into a colloid-rich phase and a polymer-rich phase [19].

Here, we investigate droplet snap-off in suspensions of colloidal gibbsite platelets that exhibit nematic liquid crystalline ordering, where several of the aforementioned effects come together, leading to new and interesting behaviour. Apart from the nematic order, these systems have a very low interfacial tension so that thermal fluctuations of the isotropic–nematic interface can possibly play a role as well. With polarized light microscopy, nematic droplets are studied snapping off from Rayleigh–Taylor fingering instabilities at the isotropic–nematic interface, which arise when a heavier nematic phase is located on top of a lighter isotropic interface. Two different gibbsite suspensions are used, namely charge-stabilized gibbsite in water and sterically stabilized gibbsite in bromotoluene. We show that the anisotropy of the liquid crystal indeed significantly influences the breakup and pinch-off process, and also that the differences between the two systems in terms of the splay elastic constant and anchoring strength give rise to quantitatively but also qualitatively different behaviour. In particular, the neck geometry and thinning rate and the occurrence of satellite drops appear to depend on the nematic director structure of the thread and pending drop.

2. Experimental system and methods

Two gibbsite systems were used in this study, namely charged gibbsite in aqueous dispersion and sterically stabilized gibbsite dispersed in bromotoluene. These systems have different values for the ratio of the splay elastic constant and the anchoring strength, which will appear to be a crucial difference for droplet snap-off.

2.1. Particle synthesis

Both systems were synthesized by hydrothermal treatment of aluminium alkoxides (aluminium-sec-butoxide and aluminium-iso-propoxide) in an acidic environment, according to the procedure developed in the Van 't Hoff laboratory [20].

Subsequently, the obtained particles were treated either to enhance the stability in aqueous dispersions or to enable dispersion in apolar solvents. For enhanced stability

in aqueous dispersions, 0.5% (w/w) aluminium chlorohydrate (Locron P, Hoechst AG, Germany) was added to the dispersion. At $\text{pH} \approx 4$ aluminium polycations (Al_{13} Keggin ions, $[\text{Al}_{13}\text{O}_4(\text{OH})_{24}(\text{H}_2\text{O})_{12}]^{7+}$) are formed [21] that adsorb on the surface of the gibbsite particles, giving rise to a steep repulsive particle interaction which prevents the platelets from aggregating [22]. After three days, the dispersion was centrifuged to remove excess aluminium chlorohydrate and the particles were subsequently redispersed in a 10^{-2} M NaCl solution.

To enable dispersion of the gibbsite platelets in apolar solvent, the particles were sterically stabilized with an amino-modified poly-iso-butylene (SAP 230 TP, Infineum, UK) through a gradual substitution of the solvent upon addition of the stabilizing polymer, as described in [23]. The particles obtained through this method were dispersed in 2-bromotoluene (Acros, 99%).

Finally, the dispersions were concentrated by centrifugation and subsequent redispersion to reach the desired particle concentration. For aqueous gibbsite this was a volume fraction of 30% (v/v) and for sterically stabilized gibbsite at 21% (v/v). Samples of aqueous gibbsite were prepared in flat optical capillaries (VitroCom, NJ, USA), with internal dimensions of $0.2 \times 4 \times 50 \text{ mm}^3$. Samples of sterically stabilized gibbsite were prepared in a rectangular Hellma cell of 2 mm path length (Hellma, Müllheim, Germany). All samples were stored in upright position at room temperature.

2.2. Polarized light microscopy

Both systems were studied with a Nikon LV100 Pol polarized light microscope equipped with a full wave retardation plate ($\lambda = 530 \text{ nm}$) and $10\times$ and $20\times$ Nikon CFI Plan Fluor ELWD objectives. The microscope was in a tilted position with the focal plane along gravity in order to allow investigation of the samples in the upright position. Images were captured with a MicroPublisher 5 megapixel CCD camera (MP5, QImaging). Image analysis of the aqueous gibbsite samples was performed with IDL-based routines² [24]. The sterically stabilized system was analysed manually with the microscopy software iTEM³.

2.3. Rayleigh–Taylor instability

We study the droplet snap-off resulting from the Rayleigh–Taylor instability that arises when a nematic phase with a higher mass density is located on top of an isotropic phase. The way we achieve this is different for the two systems.

The aqueous system consists of gibbsite platelets with a bimodal distribution of the platelet aspect ratio (diameter/thickness). This system exhibits a remarkable three-phase equilibrium, with a bottom columnar phase, a top nematic phase and an isotropic phase sandwiched between the two [25]. When such a three-phase sample is left in upright position over a long period of time (months to years), a sedimentation equilibrium develops, resulting in a four-phase coexistence as an isotropic phase appears on top of the nematic phase, as sketched in figure 1(a). This is accompanied by a density gradient in the nematic phase. The lower part of the nematic phase, which was originally homeotropically aligned in the relatively thin ($200 \mu\text{m}$) capillary, buckles under the pressure of the suspension above it, forming beautiful stripe patterns shown in figure 1(b). Furthermore, near the lower isotropic–nematic interface the mass-density of

² Interactive data language, ITT visual information solutions (<http://www.itvis.com/>).

³ iTEM, Olympus Soft Imaging Solutions GmbH (<http://soft-imaging.net/>).

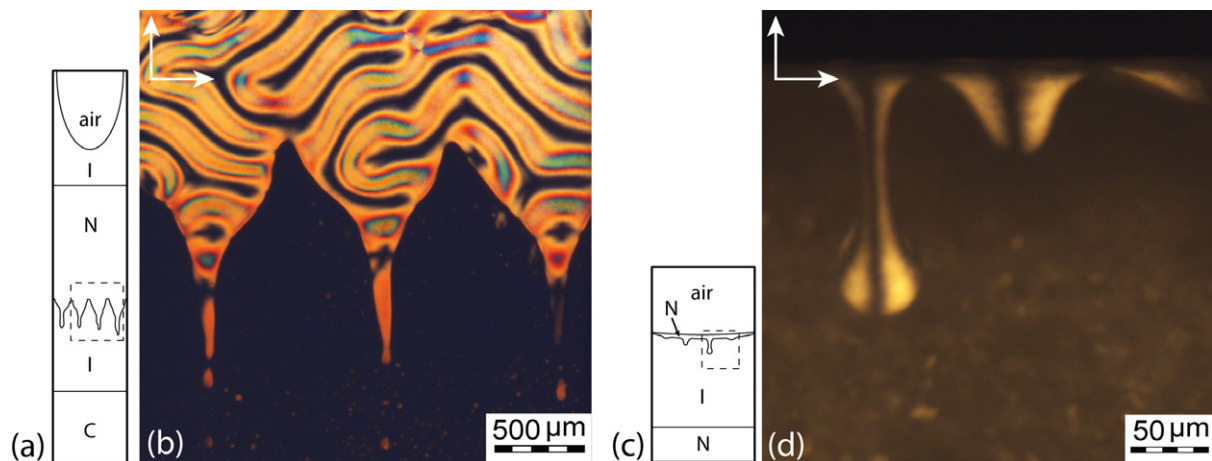


Figure 1. Rayleigh–Taylor instabilities develop over time in both systems. (a) The initial three-phase sample (NIC) of bimodal aqueous gibbsite develops in half a year to a four-phase (INIC) coexistence, with Rayleigh instabilities at the lower nematic–isotropic interface. The dashed box indicates the area pictured in (b). (c) The solvent of the sterically stabilized gibbsite sample is allowed to evaporate slowly, giving rise to Rayleigh–Taylor instabilities of nematic phase at the air–suspension interface. The dashed box indicates the area pictured in (d) (not to scale). Arrows indicate the orientation of the polarizers.

the nematic phase eventually becomes larger than that of the isotropic phase below, and Rayleigh–Taylor instabilities develop from which nematic droplets start dripping.

The sterically stabilized gibbsite system, on the other hand, has a monomodal platelet distribution, and forms the usual isotropic–nematic phase coexistence with the isotropic phase on top of the nematic phase. The sample is contained in a rectangular cell of 2 mm path length closed with a stopper. This stopper does not close the cell air-tight and the solvent evaporates slowly, leading to a higher particle concentration near the air–suspension interface. After a few weeks, a thin layer of nematic phase forms in the top layer, heavier than the isotropic phase, and also here Rayleigh–Taylor instabilities develop with nematic droplets snapping off and sedimenting towards the nematic phase (figures 1(c) and (d)).

3. Droplet snap-off

The formation of Rayleigh–Taylor instabilities and the subsequent snap-off of nematic droplets is extremely slow in both systems. For one drop to snap off it takes hours in the sterically stabilized system and even days in aqueous gibbsite. This is not surprising, taking into account the material properties of the systems (see table 1): the density difference $\Delta\rho$, inducing the Rayleigh–Taylor instability, is in both cases small. Moreover, for the subsequent droplet snap-off, the interfacial tension γ , the driving force, is very small, and the viscosity of the nematic phase η , the counteracting force, is large.

We found in previous work that the two systems represent different regimes with regard to anchoring of the platelets to the isotropic–nematic interface [27]. Both prefer homeotropic alignment, but the aqueous gibbsite sample represents the weak anchoring regime with a

Table 1. Relevant system properties and scaling lengths for the two gibbsite suspensions; see also the main text.

	Charge stabilized gibbsite	Sterically stabilized gibbsite
γ (10^{-9} N m $^{-1}$)	70	130
η (Pa s) ^a	10	0.1
$\Delta\rho$ (kg m $^{-3}$) ^b	1.3	2.7
ω ($\equiv w/\gamma$)	0.5	2
K_1/w (μ m)	>10	0.3
L_T (μ m)	0.24	0.18
L_c (μ m)	74	70
L_η (m)	10^6	10^2

^aAverage viscosity of the nematic phase, estimated on the basis of rheological measurements by the authors of [20, 26].

^bEstimated from the sedimentation velocity of the droplet after snap-off.

dimensionless anchoring strength ω ($\equiv w/\gamma$) = 0.6, while the sterically stabilized system with $\omega = 2$ exhibits rather strong anchoring. Because the splay elastic constant (K_1) of the two systems is comparable, the ratio K_1/w of aqueous gibbsite is considerably larger than that of sterically stabilized gibbsite, which leads to a different director configuration during the breakup process. In order to investigate how these different director field structures influence the breakup of the nematic thread, we will now analyse and compare the snap-off process for both systems, first qualitatively, in terms of neck geometry, breakup position and the occurrence of satellite drops, and also quantitatively when we measure the minimal neck thickness as a function of time.

3.1. Aqueous gibbsite

In the aqueous gibbsite system (figures 1(a) and (b)) both the thinning neck and the pending drop are, depending on the orientation of the polarizers, either completely birefringent or completely non-birefringent, which implies that they have a uniform director field. The use of a retardation plate (figure 2(b)) reveals that the particle director points in the horizontal direction, as schematically depicted in figure 2(a). The fact that not only the thinning neck, but also the pending drop with a size of $60 \times 100 \mu\text{m}$ has a uniform director field implies that the value of K_1/w is considerably higher than we found for this system in previous experiments ($5\text{--}6 \mu\text{m}$) [27]. Using the relation $R > 3K_1/w$ for the transition from a uniform to a non-uniform director field [27], we deduce from the size of the falling droplet that K_1/w in the present case must be larger than $10 \mu\text{m}$.

This rather large difference can be understood when we take into account the difference between the experimental conditions. The previous values for K_1/w were determined from the properties of nematic droplets during the phase separation process, whereas the present sample has been standing for over a year. In the meantime a sedimentation equilibrium has developed, which is evidenced by the appearance of the isotropic phase on top of the nematic phase and a gradient in the scattering intensity that is clearly visible on a macroscopic scale. When we also

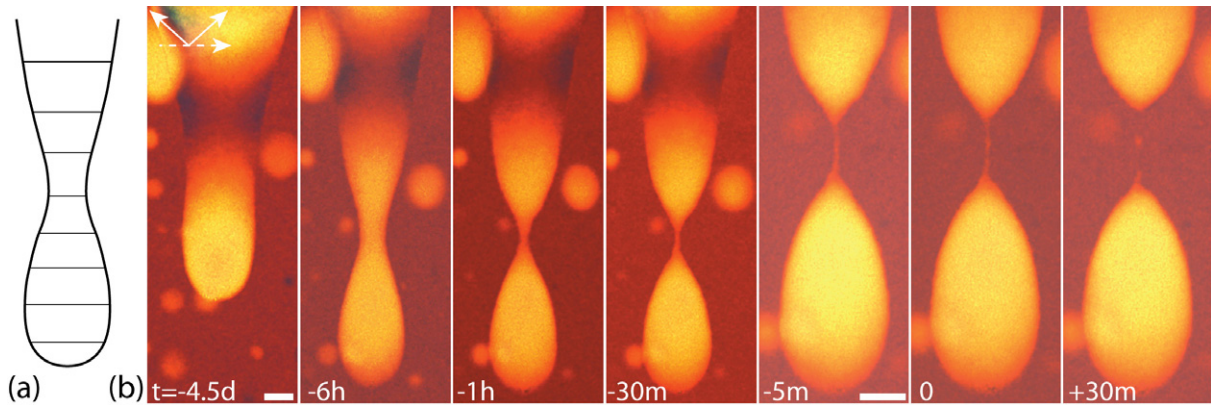


Figure 2. Droplet snap-off in an aqueous gibbsite suspension. (a) Uniform director field in both the thinning neck and the pending drop. (b) Time series of a droplet pinch-off event in aqueous gibbsite. Time is set to zero at pinch-off. Solid arrows indicate the orientation of the polarizers and the dashed arrow that of the retardation plate. The scale bar represents $25\ \mu\text{m}$. See also movie 2 in the supplementary data (available from stacks.iop.org/NJP/14/023010/mmedia).

take into account the fact that the mass density of the nematic phase has now become larger than that of the isotropic phase below, it is clear that the platelet concentration in the lower part of the nematic phase is significantly higher than in the nematic phase of a freshly phase separated sample. As elastic constants are proportional to the square of the concentration and the anchoring strength has a linear dependence, a higher particle concentration would indeed lead to a larger value for K_1/w [28].

3.1.1. Neck and drop geometry. The thinning neck has a symmetric shape with a prolate pending drop. A symmetric neck is typical for breakup under the influence of thermal noise, although it should probably be more cone-shaped [16]. Fluctuations of the interface can be observed, in an early stage and even more clearly close to pinching when the thinning neck is less than $10\ \mu\text{m}$ thick (see movie 1, available from stacks.iop.org/NJP/14/023010/mmedia). This suggests that thermal noise indeed plays an important role in the snap-off process.

The neck and prolate pending drop shape also resemble strongly the shape observed in yield-stress fluids [29]. It is not unlikely that the highly concentrated nematic phase actually exhibits a yield stress. The observed buckling distortions also point in this direction.

Because anchoring is weak in aqueous gibbsite, we do not expect it to have a large effect on the snap-off process, which is supported by the fact that the pending droplet is prolate instead of oblate, the shape that would provide optimal anchoring for the majority of the particles at the interface.

We should also probably consider the role of anisotropic viscosity, as the viscosity of the nematic phase strongly depends on the flow geometry [28, 30]. However, if we take into account the symmetry of the uniform director field inside the drop compared to the shape of the drop, we find that the symmetry axis of the director field points in the horizontal direction, whereas for the droplet shape the symmetry axis is along the vertical axis. This suggests that the anisotropy of the viscosity plays a negligible role, at least for the observed elongated drop shape. This is supported by Zhou *et al* [14], who reported only quantitative effects of the viscous anisotropy.

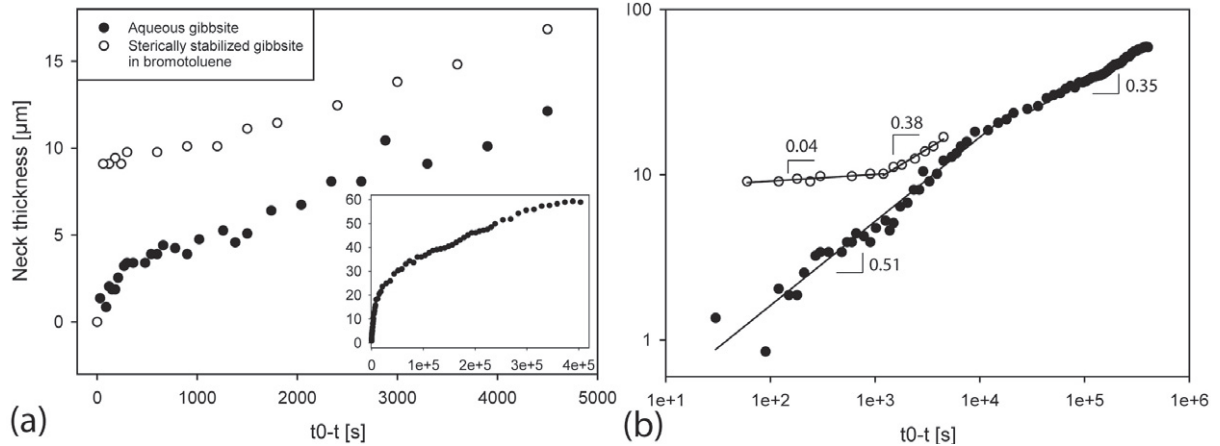


Figure 3. Minimal neck thickness as a function of the time to snap-off of both systems represented in (a) a linear plot (the inset shows the complete dataset of aqueous gibbsite) and (b) a logarithmic plot. Indicated are the fitted power-law exponents α (see also the main text).

The formed drop has a width and length of about 60 and 100 μm , respectively, which is of the order of the capillary length, L_c , defined as $L_c = \sqrt{\gamma/g\Delta\rho}$, with g being the gravitational acceleration (see table 1).

3.1.2. Snap-off position. The first breakup appears to always take place at the top of the thread. The literature reports that the viscous droplet snap-off usually breaks up near the end of the thread (end-pinching), except in the case of very high viscosity, where the thread tends to break at random positions [1, 31]. When thermal noise determines the snap-off process, the breakup position is also random [16, 19]. It is therefore remarkable that the thread in this case, where snap-off seems to be influenced by thermal noise, tends to break at the upper end of the neck.

3.1.3. Satellite drops. We observe one or two satellite drops of about 1–3 μm in diameter, comparable to the minimal neck thickness just before breakup. This might be attributed to the influence of thermal roughness on the snap-off process, because theory predicts many satellite drops for viscous drops, as against only a few if thermal noise drives the breakup [1, 16].

3.1.4. Neck thickness. In order to analyse the droplet snap-off process quantitatively, we measured the minimum neck thickness as a function of time for one snap-off event. Figure 3 depicts the results in a linear (figure 3(a)) and a logarithmic (figure 3(b)) representation.

According to Zhou *et al* [14], liquid crystalline threads, at least with a uniform director field, should break up as a Newtonian liquid, be it with a different critical wavelength and breakup time. In Newtonian fluids, the minimum neck thickness h as a function of time obeys $h(t) \propto (t_0 - t)^\alpha$, with $t_0 - t$ the time to snap-off and the exponent α depending on the nature of the breakup process [1]. If inertia is dominant, α has a value of 2/3. However, the viscous length L_η , which sets the hydrodynamic inertial regime and is defined as $\eta^2/\rho\gamma$ with η being the viscosity of the nematic phase and ρ the mass density, is several orders of magnitude larger than the system size, which implies that inertia is completely negligible here. For viscous breakup a

value for the exponent α of 1 has been reported [2]. Furthermore, if the viscosity of the outer fluid plays a significant role, α should also be 1 [32], but if thermal noise controls snap-off, α is expected to be 0.42 [17]. For the breakup of a *thermotropic* nematic thread (8CB), however, a significantly larger exponent of 1.5 has been measured [33].

When we fit our data with a power law, we find for aqueous gibbsite an exponent α of 0.35 (± 0.007) far away from snap-off and 0.51 (± 0.01) closer to breakup. Far away from breakup there is probably some restructuring of the nematic phase, because the defect that initially was located close to the thinnest part of the neck moves upwards, away from the neck minimum, during 4–3 days before breakup (compare figure 2 at 4.5 days and 6 h before breakup). This may influence the value of α . The value $\alpha = 0.51$ close to snap-off suggests that thermal fluctuations play a role here. Indeed, as we pointed out above, thermal fluctuations of the interface can be observed and will probably affect the droplet snap-off.

3.2. Sterically stabilized gibbsite in bromotoluene

In previous experiments, we determined the value of K_1/w from the droplet shape and director field as a function of its size, as well as from the deformation of the droplets in a magnetic field [27, 34]. For the sterically stabilized gibbsite system dispersed in bromotoluene we obtained through the first method only an upper bound for the value of K_1/w , namely $2 \mu\text{m}$. However, from the deformation of the droplets in a magnetic field we obtained a precise value, namely $0.3 \mu\text{m}$.

So, the value for K_1/w in sterically stabilized gibbsite dispersed in bromotoluene is much lower than that of aqueous gibbsite. $K_1/w = 0.3 \mu\text{m}$ implies that at length scales larger than about $1 \mu\text{m}$ a non-uniform director field is energetically more favourable. More precisely, Goyal and Denn [15] predicted that if one assumes that the values of the splay, bend and saddle-splay elastic constants are equal ($K_1 = K_3 = K_{24}$, although that is not exactly true for plate-like particles [35]), a cylinder with radius R for values $wR/K_1 > 8.65$ would have an escaped radial (ER) director field. In this configuration the platelets are homeotropically aligned to the interface, forming a two-dimensional (2D) radial director field with the director escaping along the third dimension. The sterically stabilized system has a value for wR/K_1 of about 20 and indeed when we deduce the director field from the polarized micrographs in figures 1(d) and 4(b), we find in the neck this ER configuration, with the escape in the upward direction, as schematically drawn in figure 4(a). The pending drop has a distorted 3D radial director field. A movie of the snap-off process is available at stacks.iop.org/NJP/14/023010/mmedia (movie 2).

3.2.1. Neck and drop geometry. The thinning neck is asymmetric and the pending drop has a spherical shape, comparable to the shape reported for snap-off in Newtonian fluids [1]. The drop shape and its birefringent pattern closely resemble the observations of Goyal and Denn [15], where simulations of the breakup of a nematic thread with an ER director field lead to exactly the same distorted radial director field in the drop. The formed drop has a diameter of 50–60 μm , which is of the order of the capillary length, L_c (see table 1), and comparable to the drop size in aqueous gibbsite.

3.2.2. Snap-off position. In contrast to the aqueous gibbsite system, the neck in the sterically stabilized system breaks up near the droplet (end-pinching), in line with predictions for viscous breakup in isotropic fluids.

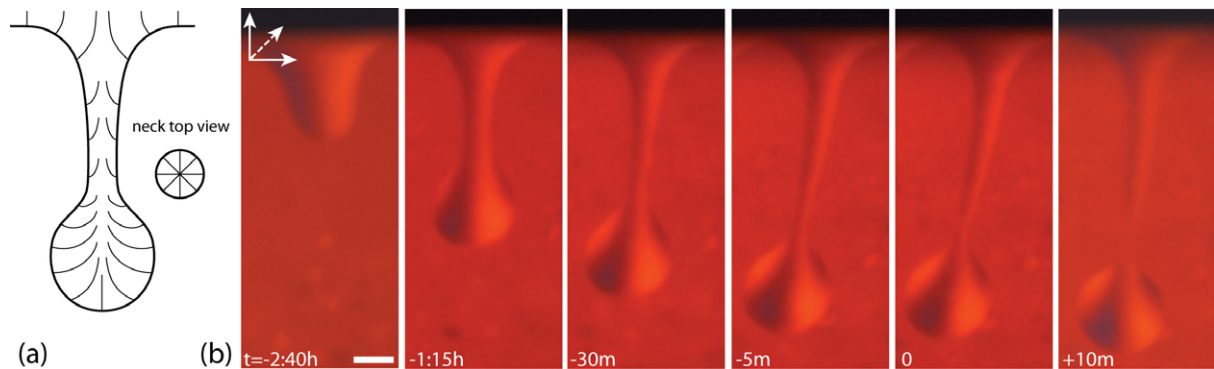


Figure 4. Droplet snap-off in a suspension of sterically stabilized gibbsite in bromotoluene. (a) An ER director field in the thinning neck and a distorted 3D radial field in the pending drop. (b) Time series of a droplet pinch off event. Time is set to zero at pinch-off. Solid arrows indicate the orientation of the polarizers and the dashed arrow that of the retardation plate. The scale bar represents $25\ \mu\text{m}$. See also movie 2 in the supplementary data (available from stacks.iop.org/NJP/14/023010/mmedia).

3.2.3. Satellite drops. Contrary to the observations for aqueous gibbsite, in the sterically stabilized system no satellite drops are observed at all. This may be related to the energy barrier that is involved in the breakup of a thread with an ER director field [15]. This energy barrier arises because the formation of a droplet requires the introduction of a point defect, which presumably suppresses drop formation. This effect is obviously absent in the case of a uniform director field in the neck and snapping drop.

3.2.4. Neck thickness. The neck thickness as a function of time is depicted in figure 3 in a linear (figure 3(a)) and logarithmic (figure 3(b)) representation. From this figure it is immediately clear that the sterically stabilized system differs both quantitatively and qualitatively from the aqueous gibbsite system.

Far away from snap-off the neck thins with a velocity comparable to that in aqueous gibbsite, but at a thickness of about $10\ \mu\text{m}$, the neck thinning slows down dramatically and then the neck breaks suddenly. If we perform a power-law fit (which is somewhat questionable because the data comprise hardly two decades), we find an exponent α of $0.38 (\pm 0.02)$ far away from breakup and $\alpha = 0.04 (\pm 0.008)$ close to breakup. To understand this extremely small value for the exponent α close to snap-off, we consider what sort of mechanisms play a role in the breakup here. For the case of a thread with radial director field, Cheong and Rey [12] distinguish two competing mechanisms. The first is the surface tilting mechanism, where in the case of strong surface anchoring tilting of the surface leads to bend distortions in the thread. Frank elasticity in this case tends to stabilize the thread. The second effect is the so-called surface displacement mechanism, which is destabilizing in the case of a radial thread. However, if we calculate these two contributions for sterically stabilized gibbsite, we find that both effects contribute roughly equally, so we do not expect this to play a significant role.

An effect that probably plays a major role is the morphological change accompanying the breakup of the thread with ER director field, which we mentioned above [15]. At snap-off, a point (or a small ring) defect has to be created in the separating droplet, which may

form a considerable energy barrier and retard the breakup. Also, the neck thinning might be delayed because as the neck becomes thinner, at a certain point the ER director configuration will become unfavourable, although at the thickness just before snap-off, $R = 4.5 \mu\text{m}$, the value of wR/K_1 is still 14, well above the critical value 8.65 [15].

4. Conclusion

We have studied the droplet snap-off of nematic liquid crystalline threads in suspensions of charged gibbsite platelets in water and sterically stabilized gibbsite in bromotoluene. The major difference between these two systems is the ratio of the elastic constant and the anchoring strength, which leads to hugely different snap-off behaviour. In aqueous gibbsite with relatively weak anchoring (large K_1/w), the thinning neck has a uniform director field, while strong homeotropic anchoring in the case of sterically stabilized gibbsite leads to an ER director field. This difference in director field configuration results in considerably different breakup mechanisms, both quantitatively and qualitatively. The uniform thread forms a prolate drop with a uniform director field, possibly due to the fact that the highly concentrated nematic phase exhibits a yield stress, whereas the neck thinning rate and satellite drop occurrence show the influence of thermal noise. On the other hand, in the sterically stabilized system the pending drop has a spherical shape with a distorted radial director field and no satellite drops are formed during snap-off. Moreover, the neck thinning rate in this case decreases dramatically close to snap-off, probably due to an energy barrier related to the creation of a point defect in the separating drop.

Acknowledgments

Dirk Aarts is acknowledged for allowing us to use his IDL routine for image analysis. Emile Bakelaar is thanked for his IDL routine for edge detection. We thank David van der Beek for particle synthesis (gibbsite in bromotoluene) and Paul van der Schoot for useful discussions. The authors acknowledge the Royal Netherlands Academy of Sciences (KNAW) for financial support.

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