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Citation for published version (APA):

Document status and date:
Published: 01/01/2017

Document Version:
Author’s version before peer-review

Please check the document version of this publication:
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Instability of thin liquid films compressed between soft solids

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Keywords: thin liquid films, dewetting, soft matter, elastohydrodynamics

The instability of thin liquid films located between soft solids is relevant to coating and printing processes involving elastomeric rollers. Other applications concern the traction of car tires on wet asphalt, the adhesion of labels on wet surfaces, or bioadhesion of animals in wet and underwater environments. Brochard-Wyart et al. [1,2,3] squeezed a fluorinated silicone oil between a spherical-cap-shaped rubber lens and a flat glass slide using a displacement-controlled mechanical setup. The latter contained a micron-sized indentation or a sub-micron elevation, which acted as dry-spot nucleation centers, once the film thickness became small enough. They studied the dynamics of axisymmetric dewetting as a function of time, liquid viscosity, and the spreading parameter. Persson et al. [2] extended their theoretical analysis towards non-uniform pressure distributions inside the contact spot.

We performed similar experiments of liquid films squeezed between spherical-cap-shaped and flat elastomer layers using a force-controlled mechanical setup. Figure 1(a) shows a cross-sectional sketch of the contact area. Film thickness is observed real-time using reflection interference contrast microscopy. Figure 1(b) shows an example of a dry-spot that nucleated close to the perimeter of the contact spot and grows in time. Depending on the dimension of the contact spot, the film thickness and the density of nucleation centers, the dewetting process can lead to an entirely dry contact spot or the occurrence of (temporarily) trapped droplets. Often the dewetting initiated close to the perimeter of the contact spot, where the local film thickness is smallest. We observed that the dewetting speed under these circumstances is strongly anisotropic and proceeds much faster along the perimeter of the contact spot. Trapped liquid occurs primarily for high speed-anisotropies, large contact spot diameters and high defect densities. The trapped droplets tend to be expelled from the contact spot by the radial contact pressure gradient. We studied the expulsion dynamics as a function of drop volume, radial position and applied force. We also developed a numerical finite-element-based model that qualitatively reproduces many features observed in the experiments.

Fig. 1: (a) Sketch of experimental setup. (b) Optical interference micrograph of an experiment.

References