Title

Pattern Formation in Floating Sheets

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Abstract

This thesis presents a study of two basic modes of deformation of a thin sheet: wrinkling and crumpling, viewed primarily in the context of an elastic sheet confined by capillary forces on a drop of liquid.

First, it provides a brief conceptual background in the relevant physics of thin sheet mechanics and capillarity and introduces the general principles of wrinkling and crumpling.

The problem of confining a circular sheet on an increasingly curved spherical drop is presented as a vehicle to explore these principles. At finite curvature, the sheet is seen to wrinkle around its outer edge. At large confinement, characteristic features of crumpling gradually dominate the pattern. The experimental observations in both regimes are analyzed separately.

Analysis of images of the sheet in the wrinkled regime yield data for the number and length of the wrinkled zone, as a function of the experimental control parameter, the pressure. The length of the wrinkles is correctly described by a far-from-threshold theory, which describes a limiting regime in thin-sheet mechanics, distinguished by high 'bendability'. The validity of this theory is verified by the data for highly bendable, ultrathin sheets for the first time. The theory is based on the assumption that the wrinkles completely relax compressive stresses and therefore preserve the cylindrical symmetry of the stress field.

The emergence of crumpling from the wrinkled shape is explored via evolution of visible features in the sheet as well as gaussian curvature measurements obtained by analyzing height maps from optical profilometry. The emergence of several length scales, increasing asymmetry in curvature distribution, the failure of wrinkle extent prediction and formation of d-cones associated with crumpling are all measured to locate the transition to a crumpled state. The value of gaussian curvature at the center of the sheet appears to follow the cylindrically symmetric prediction over the whole range of the experiment, suggesting that the onset of crumpling events does not affect the global shape of the sheet.

Finally, analogous wrinkling and crumpling behavior of particle-laden interfaces is discussed. The spontaneous formation of conical defects in a curved 2D crystal is compared to the crumpling of a sheet on a drop, and insight from thin sheet mechanics is applied to the mysterious wrinkling of particle rafts. Some future directions for measuring wrinkling of sheets on negative curvature surfaces and deformations of fluid interfaces are proposed.

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