SHape Morphing Of Drying Foods By Symmetry Breaking Principles

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Abstract

As an alternative to the poor scalability of 3D printing, we are investigating the prospects of 4D printing, where a multimaterial object with simple flat geometry is printed, and subsequently dried. Due to differences in elastic moduli of the multiple materials, which shrink at different ratios, core-shell geometries gets mechanically frustrated, and undergo shape morphing induced by a buckling instability. Via inserting extra ellipsoidal stiff domains, one can steer the symmetrical properties of the buckled shape, and thus drive the shape morphing into desired directions.

The resulting shape morphing is calculated with a COMSOL model, derived from our earlier study on buckling of cylindrical core-shell geometry (van der Sman et al,2025). There we solve the momentum balance, energy and mass balances in the Lagrangian frame via the weak formulation. We assume large deformation, with food materials behaving as gels, following NeoHookean law and Flory-Huggins theory for moisture sorption. Large deformations and moisture transport are strongly coupled, as the pressure appears in both of their driving forces: the stress and chemical potential. The pressure field is solved via the incompressibility condition, which is also solved as a weak formulation.

The basic core-shell disc will buckle into a saddle-like hyperbolic paraboloid shape (a Pringle-like shape). For various designs, with examples shown in the figure, we show that the paraboloid shape can be modulated with the inserted stiff ellipsoidal domains, or ellipsoidal cut-outs. The buckled shape have a very organic appearance via their bilaterial symmetries.

Same symmetry breaking principles can be used to design shape morphing for other means of postprocessing for 4D printing, like boiling, baking or frying. We anticipate that with the design of the morphed shape, one can have good degree of control of crunchiness of snacks produced via 4D printing.

Reference

van der Sman, R. G. M. et al. "Buckling during drying of edible soft matter with cylindrical core–shell geometry." Current Research in Food Science (2025).

Figures used in the abstract

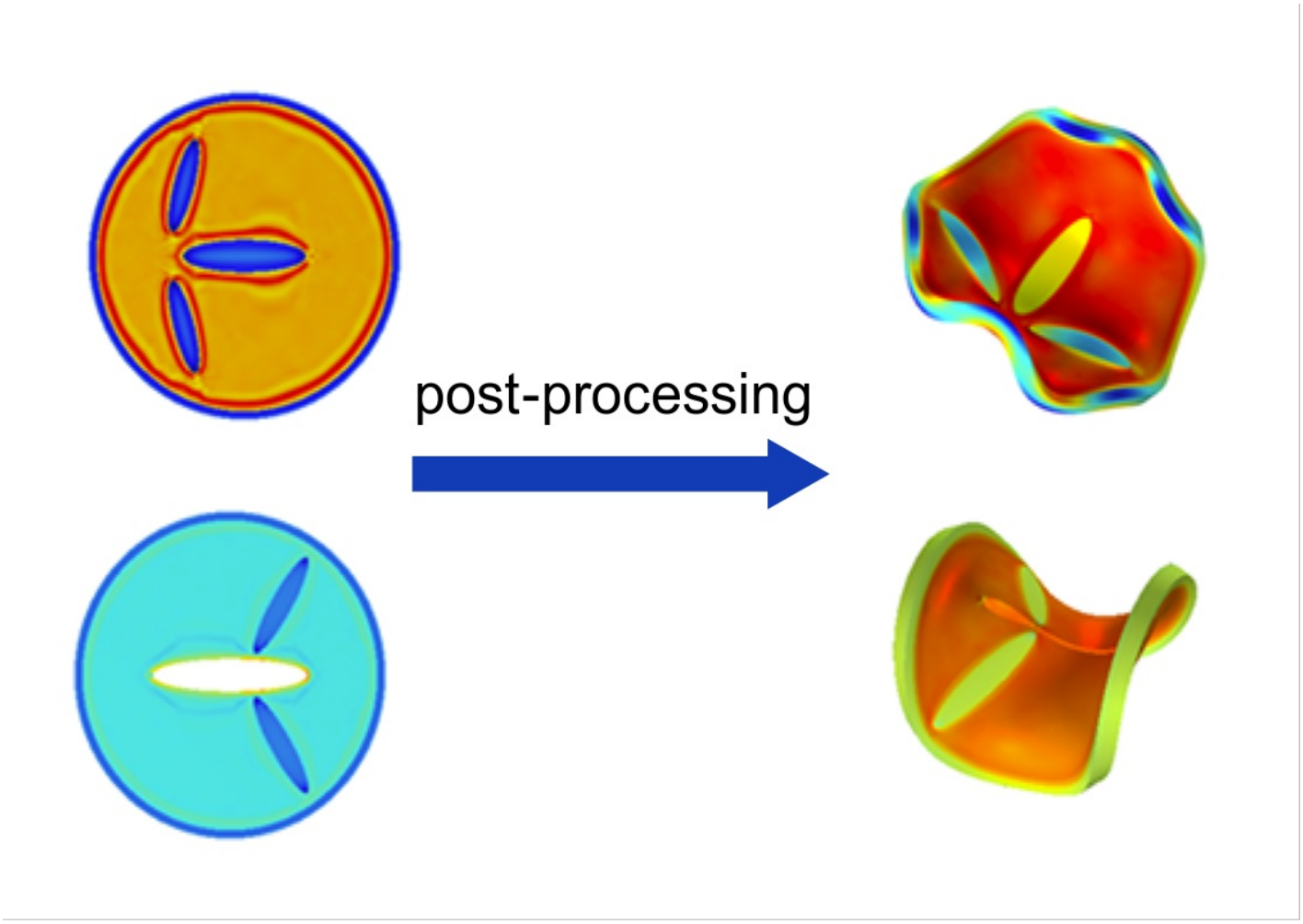

Figure 1 : Our figure shows two examples of the initial basic shape with inserted domains, and the final buckled shapes.