The Race against Instabilities: Gravity vs. Carbopol - Who Will Win?

Balanchandar, Sidhika

3D printing is the emerging technology for making complex objects directly without assembling parts. Ink-jet printers at home allows one to print delicate 2D structures on paper and the vision for 3D printing is to be able to make delicate 3D structures, such as blood vessels, bronchi, flexible electronics or thin nested shells. Researchers have developed an innovative granular gel that by jamming and unjamming transitions serves as an excellent scaffolding material for controlled 3D printing. The key challenge that remains is preventing instabilities from altering/destroying the delicate printed structures. The objectives of the project are to understand the physics of post-injection instabilities of the printed objects and to extend the limits of 3D printing capabilities. Two types of experiments were performed in a solution of Carbopol, a granular gel. In Type-I experiments, spherical balls of different material and size were inserted into the gel and results were classified as "Stable", "Creep", or "Fall", depending on whether the ball stayed in place or not. In the type-II experiments horizontal stacks of a marker material was laid, and as the falling ball approached the stack, the deformation of the stack was measured. My four conclusions are: a) With the increasing weight of the ball there exists a maximum beyond which gravitational instability will start. b) By increasing the yield strength of the granular gel scaffolding the maximum weight that can be supported without gravitational instability can be increased. c) A simple theory based on mechanics of condensed matter correlates the data very well and allows accurate prediction of the limits of stable printing. d) The yield radius of Carbopol around the ball is about twice the radius of the ball.

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