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Experimental investigation of the Rayleigh-Taylor instability using a magnetorheological fluid

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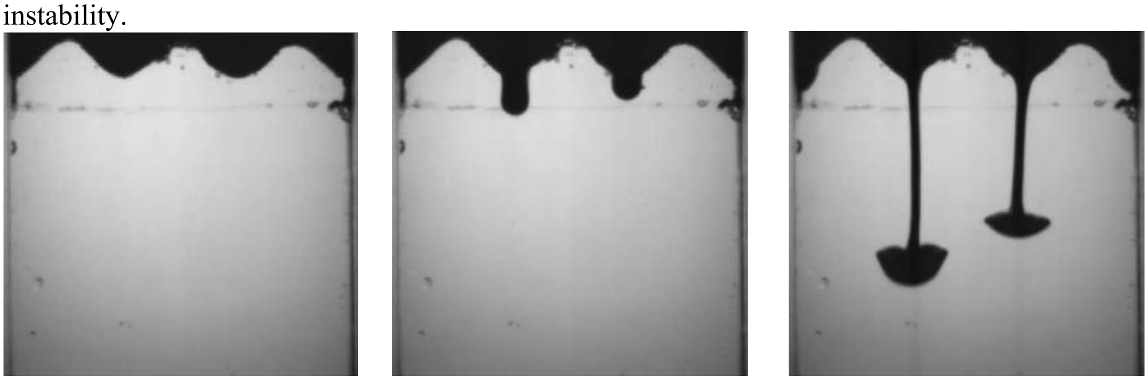
A new experiment has been developed for the study of the Rayleigh-Taylor (RT) instability. It is centered on the use of a magnetorheological (MR) fluid as one of the two fluids at a perturbed interface. The property of the MR fluid that makes it ideal for a RT experiment is that the fluid can be “frozen" into any shape by applying a sufficiently large magnetic field; the fluid’s behavior is very nearly Newtonian in the absence of a magnetic field. One can therefore impose an arbitrary shape on the free surface of a MR fluid, then apply an external magnetic field thus forcing the MR fluid to retain the imposed shape; the “frozen" MR fluid can now be coupled with a different fluid (*e.g.* water) thus forming a pair of fluids of different densities separated by a perturbed interface; when the magnetic field is removed, gravity drives the RT instability. Use of an MR fluid thus allows for the preparation of interfaces of any desired shape (in particular, with any superposition of sinusoidal modes) and ensures that the experiment begins with both fluids at rest.

The new experiment uses a Plexiglas test section, 6.3 cm wide, 1.3 cm thick, 13 cm tall. The MR fluid in use is a dispersion of Fe particles (average diameter 4.5 μm) in mineral oil (75 % weight of Fe), with a small addiction of a surfactant (oleic acid) to prevent coalescence of the Fe particles. The “shaped" MR fluid sits on top of water (the interface Atwood number is 0.48) and it is held in place by two sets of five permanent magnets each mounted in two Plexiglas holders. The magnets each have a strength of 1.2 T, large enough to freeze the MR fluid into shape from a distance of about 15 cm. To start the experiment, the magnet holders are retracted away from the test section by two pneumatic cylinders. The interface is illuminated with diffuse, white light and it is imaged using a 512 × 512 pixel CCD camera, operating at 230 fps. Sample images from an experiment with a single mode interface (initial conditions: η = 2.7 mm; λ = 21.5 mm) are shown below. We will present results from experiments with both single-mode and multi-mode initial conditions and compare them to some of the proposed non-linear theories for the RT instability.



(a) (b) (c)

Figure 1:Rayleigh-Taylor instability at a magnetorheological fluid/water interface. (a) 0^- ms, (b) 150 ms, (c) 300 ms.