Melting, erosion and dissolution of blunt objects in turbulent flows

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Description

Melting, dissolving and eroding are similar processes that are frequently found in nature, where they can result in some very interesting geometries. Formation of ice scallops, stone forests, and river sedimentation and shaping are some examples that can be found. In the figures below several examples of naturally occurring phenomena and studies can be found. Our aim is to study these effects in a controlled lab environment such that we can increase our understanding of these phenomena and their relevance (e.g. how to model the effect of scallops in melting rate of ice, relevant to effects of global warming).

Figure 1: Natural pinnacles and stone forests. (A–C) Photographs showing limestone structures of different scales in the Tsingy de Bemaraha National Park in Madagascar. A–C: Image credit: Stephen Alvarez (photographer). (D) Similar limestone formations in the Gunung Mulu National Park of Malaysia. D: Image credit: Grant Dixon (photographer) [1]

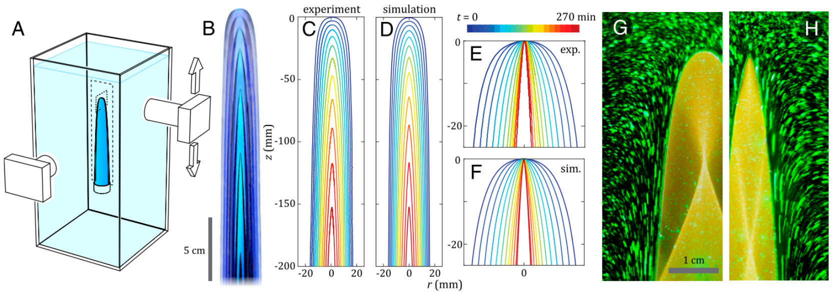

Figure 2: Emergence of pinnacles in experiment and simulation. (A) Laboratory experiments. An upright object cast from solidified sugars dissolves in a large tank of water. One camera captures full-view images of the solid as it develops in time, and a second is zoomed in and follows the apex region. (B) Overlaid full-view images spaced at an interval of 50 min. (C) Solid–liquid boundary profile extracted from full-view images and displayed every 25 min. (D) Corresponding boundary profiles as computed by the simulation. (E and F) Development of the apex region in experiment (exp.) and simulation (sim.). These profiles are shown in the moving frame of the apex, revealing a trend toward sharper structures. (G and H) Flow visualization via pathline photography of microparticles illuminated by a laser sheet. Flows descend along the surface and entrain fluid from the sides at both early and later times. [1]

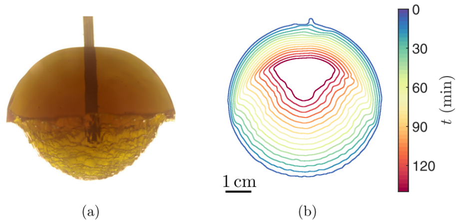

Figure 5: Shape evolution of a dissolving body. (a) Side-view photograph of candy body (initially a sphere)after dissolution in water for 70 min. (b) Measured profile shape displayed every 10 min. The upper surface remains smooth while the lower surface becomes pitted and dissolves several times faster [4]

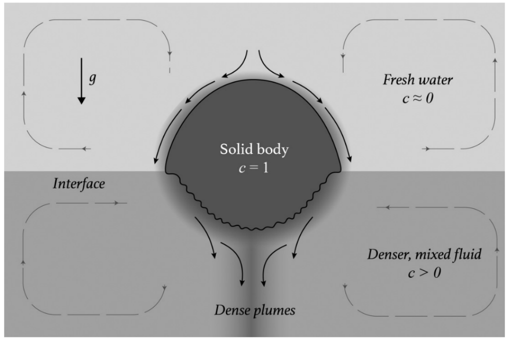

Figure 6: Interpretation of the buoyancy-driven flow around a dissolving body. Dense solute-laden fluid descends as an attached boundary-layer flow on the upper surface and a highly separated flow over the lower surface. Accumulation of dense mixed fluid in the lower portion yields a sharp stratification. The downward flows induced near the body are matched by broader, slower return flows [4]

Figure 3: Natural patterning. (a) Water-driven mineral scallops (Image credit: Johannes Lundberg). (b) and (c) Water-driven iceberg scallops, exposed by turnover (Image credit: Phillip Colla) [2]

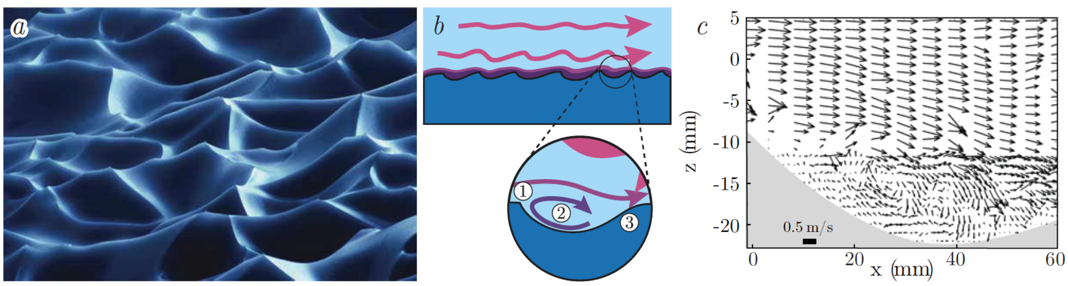

Figure 4: a: Roof of an ice cavern in Bavaria [from National Geographic] showing clear scallops. b: Fluid along a melting boundary showing scallops. Zoom: one of the scallops, O1 : crest of the scallop, O2 : recirculation zone, O3 : and the flow reattachment zone. c: 2D velocity measurement in the middle part (O2 in b) of a scallop, showing a recirculation zone, taken from [3].

Assignments

We have a variety of different projects available to choose from. Some of the assignments are suitable for either BSc. or MSc. assignments, where the MSc. version will be more elaborate and detailed than the BSc. version. The Physics of Fluids turbulence labs contain several setups that can be utilised for the assignments. Schematics of these can be found in figure 7. Note that for the assignments described in this document the Taylor-Couette facilities are less likely to be used, but assignments utilising these are possible.

BSc.

The following topics are available for BSc. Assignments:

- Melting of a sphere in the dodecahedron, with turbulence
- Erosion of a blunt object in a bubble column
- Melting of a cylinder/spike in varying angles of inclination
- Dissolution of a cylinder in varying angles of inclination

During the assignment you will learn to prepare and perform experiments, under supervision of a PhD student. Most experiments will use high-speed imaging techniques to record data. You will learn how to use the cameras that we choose to use for the experiment. You will learn image analysis techniques to extract information from the images that are taking during the experiments.

MSc.

The following topics are available for MSc. Assignments:

- Dissolution of a cylinder in varying angles of inclination
- Melting of a submerged (gallium) sphere
- Towed erosion or dissolution
- Melting, erosion, and/or dissolution in bubble induced turbulence
- Melting, eroding, and/or dissolving of of multi-material blunt objects (e.g. block of ice with a piece of metal on top)
- Extension of any of the previous subjects by adding initial patterning on the objects

As mentioned before, it is also possible to pick one of the BSc. assignments and extend these projects where you would not study just the shape and rate of change, but also the surrounding flow that carries away material. It is also possible to extend a project, in scope, by applying a pattern on the initial geometry, possibly influencing the outcome in a specific way.
During the assignment you will learn to prepare and perform experiments, first with guidance of a PhD researcher, and later individually. Most experiments will use high-speed imaging techniques to record data. You will learn how to use the cameras that we choose to use for the experiment. You will learn image analysis techniques to extract information from the images that are taking during the experiments.

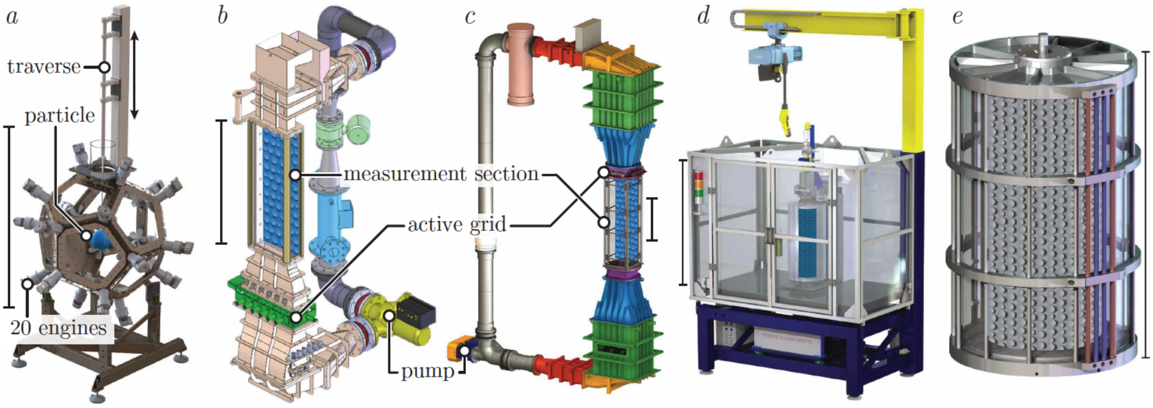

Figure 7: All setups that can possibly be used for assignments. a: Homogeneous isotropic turbulence facility with 20 engines. b; c: Twente Water Tunnels [5, 6] with large test sections and active grids to enhance and control the turbulence. d; e: Turbulent Taylor-Couette facilities [7, 8], the flow between concentric, coaxial rotating cylinders. Ice (alternatively sugar) particle/surfaces are drawn in Fig. a-d, Fig. e has a replica surface. Each facility is brine proof and has a scale bar of 1 m.

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