Chair: Physics of Fluids group

Melting of Ice Balls in Homogeneous Isotropic Turbulence

Description

The interest that the problem of melting is receiving in the recent times is fully justified. This research can impact several other branches of physics, starting from the melting of icebergs in the oceans, a mechanisms that is poorly understood, and has implication on our climate predictions. The improvement of climate models passes through a better understanding of the fundamental physics.

Classically, the problem was investigated from a theoretical point of view, partly due to the mathematical interest of the equations involved. But we believe that the most effective approach to tackle this problem is by performing an experiment, and consider a melting spherical object (an ice ball) that is hit by isotropic turbulence.

The group's brand-new Dodecahedron setup has been created to generate strong, turbulent flows. More specifically, its aim is to create Homogeneous Isotropic Turbulence (HIT). The latest addition to the setup is a vertical rail, which allows us to slide in large objects, such as ice or acrylic balls. A brief description of the setup is to be found in the caption of Figure 1.

It is very easy to see that the Dodecahedron has been designed with this experiment in mind. Other groups have already worked on the melting in turbulent environments (see for example [2], [1], [3], [4],...) but few have approached it from an experimental point of view, and none has a facility with the same capabilities of the Dodecahedron.

Summarising, this is the perfect project for a student that is interested in experimental geophysical fluid dynamics, and is looking for a challenging and ultimately rewarding thesis project.

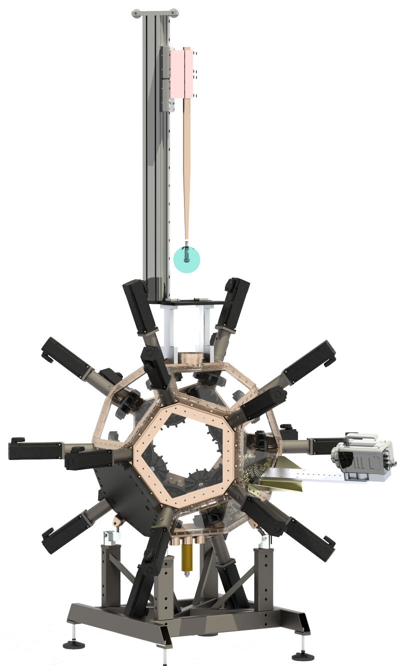
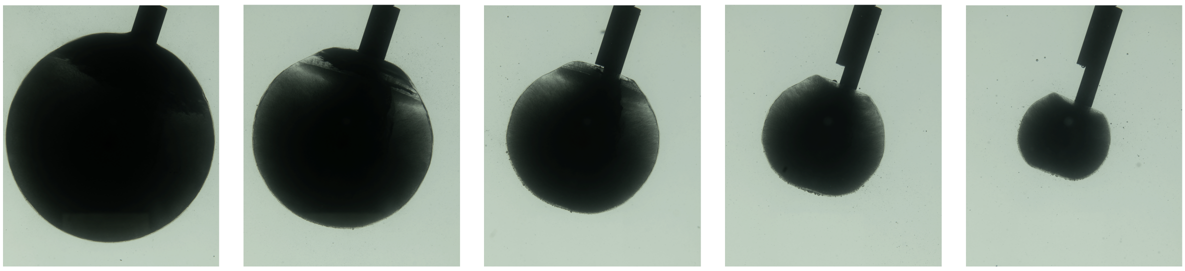


Figure 1: Graphical rendering of the Dodecahedron. The tank contains about 210 liters of water. Each of the vertices of the tank hosts a 1 kW electric motor (they are visible as "spikes" in the tank). The motors are controlled through a computer, and each can run independently of the others. Two of the windows are used as heat-exchange plates, the other ten are free for lighting and imaging (a high-speed camera is visible mounted on the right hand side). A cart mounted on a vertical rail allows to slide in (and fix in place) large particles, like the ice ball rendered in the image.



(a) $t = 0s$ (b) $t = 60s$ (c) $t = 120s$ (d) $t = 180s$ (e) $t = 240s$

Figure 2: Images of an ice ball during the melting process. The subfigures are labeled with the time from the beginning of the experiment. As a reference, this iceball would melt in around half an hour without turbulence.

Assignment

This project touches several aspects of the experimental investigation of melting in turbulence. Hereafter we sketch a possible plan, but we are open to discuss with you and adapt the assignment to your personal preference.

The first part of the project will focus on understanding how the presence of an object disturbs the turbulent flow, and what are the characteristics of the flow in the close vicinity of the surface. For this task, instead of a melting ice ball, we will use an acrylic one, and will image the flow with PIV[1].

Having acquired some information on the interaction of the flow with a fixed object, we will move to studying a melting one. An additional level of complexity will be added to the problem, namely the one of having the boundary of the object that changes in time. We will track the shape of the ice ball in time using at least one (the more, the better) digital camera, which will track the contours of it while it melts. An example of raw images is shown in Figure 2.

The relevant nondimensional number for the melting is the Nusselt number[2]. The one for the turbulent flow is the Reynolds number[3]. The data analysis will relate the change of one to the other, to explain how a turbulent flow and a melting object interact.

A good project will likely produce results that will be shared with climate researchers.

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[1] Particle Image Velocimetry
[2] https://en.wikipedia.org/wiki/Nusselt_number
[3] https://en.wikipedia.org/wiki/Reynolds_number

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