COHESIVE PROPERTIES OF FRESH DEPOSITS ANALOGUES ON ENCELADUS AND EUROPA.

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Introduction: Most planetary bodies in the outer solar system are composed largely of water ice, which can behave like granular materials at the surface conditions. These materials present a particle size distribution typically ranging between 10 and 100µm, which is the characteristic size of powders, a class of granular materials [1] that are subjects to potentially very high cohesion forces. This implies mechanical behavior different from those of more classical granular materials. In the particular case of Saturn's moon Enceladus, jet activity resulting in the deposition of very fine ice grains (~10-100µm) at low temperature (~60-80K) suggests the formation of relatively stable powdery deposits [2]. Analogous processes could also be active on Europa [3, 4]. Characterizing the properties of these ice powders is essential for understanding the evolution of surface morphologies and anticipating the technical issues for future missions during landing and/or sampling of surface materials.

This study aims at characterizing the mechanical behavior of micrometric ice powders, on a wide range of temperatures, from Jupiter to Saturn's moon conditions. The main goal is to quantify the evolution of internal parameters controlling the mechanical properties of ice powder, such as grain cohesion, with temperature, through various experiments.

Methods: We produce ice powder analogues by using a spray nozzle to create a fog consisting of water droplets, frozen in a liquid nitrogen bath (~77K), producing spherical grains of controlled size. By using different injection pressure configurations, we are able to produce two different grain populations: the ice powder A, with a median grain size of around 40µm (d20=21.5µm, d80=66.5µm) and the ice powder B, with a median grain size around 60µm (d20=38.0µm, d80=101.0µm). These grain size distributions are shown on fig. 1.

The shape and size distribution of synthesized samples are analyzed using a numerical microscope, coupled with a cryostat to maintain our grains in controlled atmosphere (~80K and 10^{-1}mbar). We then use a liquid-nitrogen cooled rotating drum to perform dynamical measurements (Fig. 2). The goal is to quantify the cohesion by analyzing the angle and irregularities of the flowing surface [5] on a wide range of temperatures (~80-250K). The more cohesive a powder is, the higher is the angle of the surface inside the drum, and the more irregular this surface is. We take several images of the ice powder inside the rotating drum, at multiple rotation speeds, and extract the angle of the surface for each image. We deduce a mean angle, and calculate a standard deviation around this angle, corresponding to a first level of irregularities as illustrated on fig. 2.

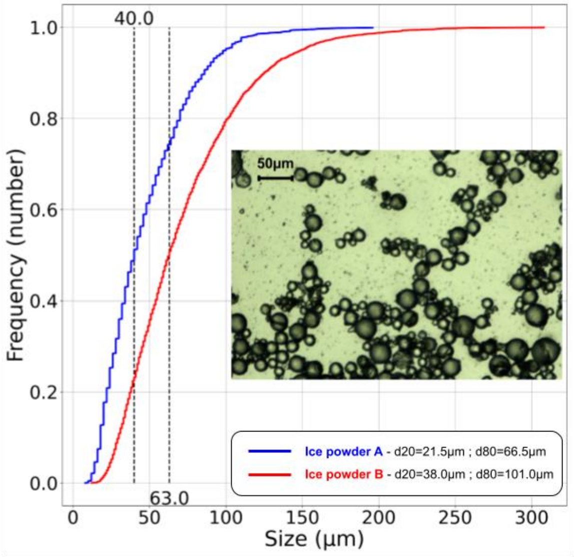

Figure 1: Grain size distribution for the two ice powder samples and example of ice grains produced by spraying

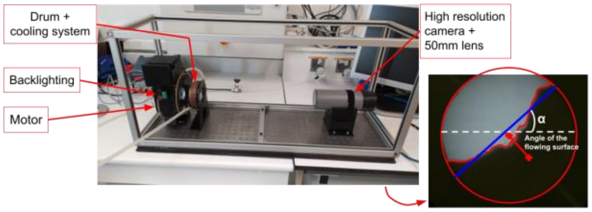

Figure 2: Rotating Drum experimental setup and image analysis example

Results: The two samples measurements performed with the rotating drum on spherical grains ice powders (powder A and B) show an increase of the mean angle of the flowing surface within the temperature range of 90 to 150K (Fig. 3). This indicates that the cohesion significantly increases with temperature over this range for ice powders, a behavior that is not observed for the non-ice powder samples we tested. At around 90-100K, ice powders behave as non-cohesive glass beads samples, while at 130-150K, they behave as cohesive limestone powder. This process appears to be reversible, going from low to high temperatures or from high to low temperatures leads to the same evolution of the powder inside the rotating drum. This is a surprising result on first look, but in agreement with other studies conducted at higher temperatures (>170K) [6, 7]. In addition, ice powder A appears to be more cohesive than ice powder B, because of the finer particle size. Tests performed on a sample with a smaller grain size distribution (median grain size around 20µm) show that this powder is so cohesive that no surface flow can be analyzed with our method.

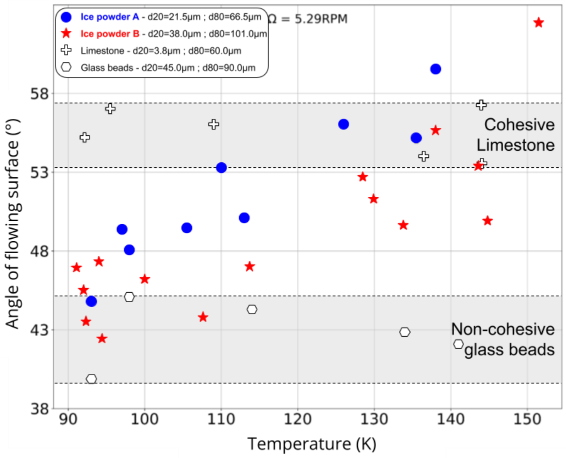

Figure 3: Evolution of the angle of the flowing surface inside the drum with the temperature, at a rotation speed of 5.29RPM. The lines indicate the range of angles for non-ice powders.

Conclusion and Perspectives: We have developed a new experimental device to determine the cohesive properties of cold icy powders. These first rotating drum experiments on spherical grains samples of pure water ice indicate a clear dependence of grain cohesion on temperature. These results indicate that over the range of temperature expected on Europa's surface and at the vicinity of the tiger stripes on Enceladus, the cohesion of fresh water ice deposits can significantly vary. This change of cohesion strength can have important implications for surface flow features and for surface stability or sampling by future landing missions. Similar experiments on other types of powdered samples (grinded icy grains, salt-ice powder, organics-ice powder) are currently under development.

These drum experiments will be completed by shear tests using a powder rheometer and by numerical simulations, which will allow us to provide a full model of the surface energy (cohesion) of icy grains, taking into account the temperature dependence.

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