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### EXPERIMENTAL DETERMINATION OF ADHESION FORCE OF LUNAR DUST SIMULANTS USING CENTRIFUGAL FORCE

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**Introduction:** Lunar exploration have been impacted by the dust contamination occurring on scientific equipment ([1]–[2]). The next space missions will be initiated by robots, with no human intervention and are no longer confined to the Moon: planets, comets and asteroids are also targeted. It appears that dust contamination can also occur in tokamak chambers. Indeed, dust particles are produced by repetitive interactions between the plasma and the wall of the tokamak chamber and can be electrically charged due to tritium adsorption. Such dusts can be responsible for tritium inventory issues and safety concerns in case of a loss of confinement. In both cases, it becomes more and more crucial to anticipate and bring under control the overall dust adhesion problem and more specifically to quantify adhesion forces.

**Objectives:** Adhesion of dust to exploration unit surfaces is mainly due to two forces: the Van der Waals force, which is a distance-dependent cohesive force, and the electrostatic forces [3]. The latter are a direct result of the complex interaction between dusts and the space environment. The intensity of these forces remains poorly quantified within the regolith. The objectives of this work are to describe the method developed to characterize and to quantify dust adhesion forces applied on dusts of various composition and size.

**Experimental setup:** The test setup is composed of an external motor driving an internal rotor going up to

1500 RPM. Samples made of dust deposits on substrates are placed on the rotor. The particles detach from the substrates when the applied centrifugal force is exactly the opposite of the adhesion force minus the gravity force. The centrifugal force is  $F_c = m\omega^2R$ , with  $m$  the mass particle,  $\omega$  the angular velocity varied from 100 to 1500 rpm and  $R$  the radius of the rotor (5.3 cm in this experiment). Ex-situ high resolution images are taken with a binocular magnifier and a microscope before and after the centrifugal tests. In-situ images are also taken during the tests as a mean to detect dust detachment in live.

**Results:** Figure 1 presents an example of dust detachment as a function of rotation speed. The dust in question are DNA-1 lunar dust simulant with a size smaller than 50  $\mu\text{m}$ . They are placed on partially painted aluminum substrates which are tightly taped to the rotor using carbon scotch. The system is placed under vacuum. Each centrifugation step lasts one minute. On each image, white circles highlight the grains removed during the next step. At 1475 RPM, a large fraction of the dust was removed from the substrate.

The quantitative results of this experiment are presented in Figure 2 showing adhesion forces as a function of the particle diameter. Red dots represent the present work [4]. They are compared with results from the literature obtained in different conditions. Blue squares and yellow triangles were obtained using AFM (Atomic Force Microscope) method at atmospheric

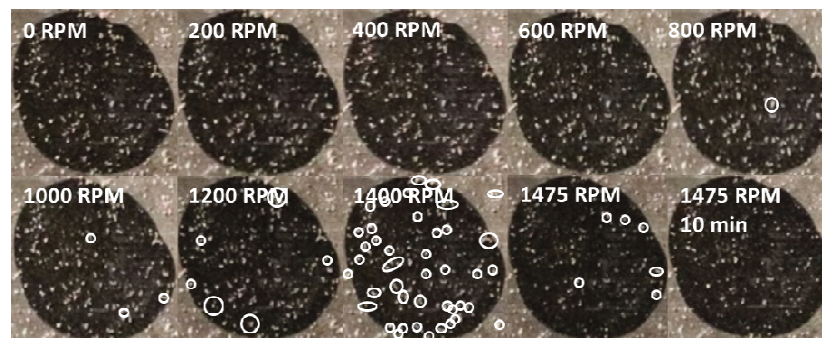


Figure 1 – Evolution of particle detachment as a function of the angular speed of the rotor. Samples used are sieved DNA-1 samples particles  $< 50 \mu\text{m}$  on aluminum substrate with 2.7 mm black paint dot. White circles highlight particles detached during the next step.

pressure. Values present the adhesion force between a smooth tungsten sphere and a rough and a smooth tungsten substrate, respectively [5]. The tungsten sphere radius are between 3.5 and 10.5  $\mu\text{m}$ . It appears that adhesion force highly depend on the substrates roughness [6]. Numerical estimation of the adhesion force of tungsten spheres on tokamak surfaces are done (purple squares) and are the same order of magnitude of adhesion force between a sphere and a smooth substrate [7].

Using the same centrifugal principle, [8] determined adhesion force of JSC-1 simulant on three samples (black Kapton, silicon and quartz). Values (turquoise and orange dots) are several orders of magnitude lower and need further investigation.

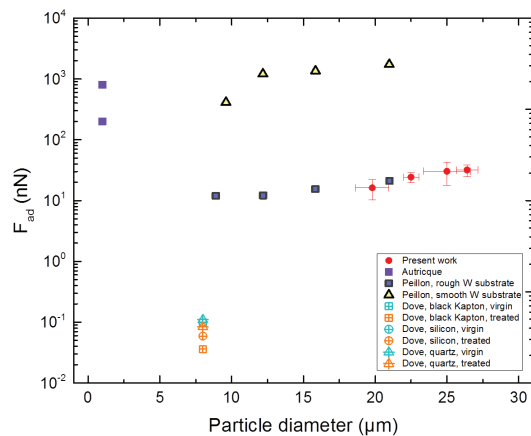


Figure 2 – Comparison of adhesion forces determined using centrifugal force (red, turquoise and orange values) and AFM force (yellow and blue). Numerical determinations are represented by the purple values.

More specific force values obtained with this experimental setup will be presented using different samples and substrates.

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