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# Experimental study on low velocity impact onto granular media:Dependence on gravity acceleration and ambient pressure

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Because gravitational acceleration at an asteroid surface is very small, it is not known which scaling should determine the size of an impact crater, gravitational scaling or strength scaling. In order to estimate the evolutional processes of asteroid surfaces it is important to understand the gravity dependence of crater diameter. However, not many impact cratering experiments under low gravity conditions have been conducted. Some hypervelocity impact experiments were conducted under increased gravities (*Schmidt and Housen, 1987*) and under low gravities (*Gault and Wedekind, 1977; Takagi et al., 2007*). These studies show different gravity dependences and further study is required to understand why the results look inconsistent.

We developed a drop mechanism which can simulate gravities smaller than 1 G: a target container was suspended by springs of constant force. We conducted experiments under a gravity range of 0.25-1 G. We used silica sand of diameter 140 $\mu$m and glass beads of diameter 500 $\mu$m as the target material. Stainless steel sphere of 8 mm diameter was dropped and impacted onto the target. The impact velocity was between 1 and 4 m $s^{-1}$. As a result, the crater diameter formed under the gravity range between 0.5-1 G was proportional to -0.188$\pm$0.008 power of the gravity acceleration for the silica sand and -0.183$\pm$0.007 for the glass beads. These values are roughly in agreement with previous studies at hypervelocity (*Schmidt and Housen, 1987; Gault and Wedekind, 1977*).

We conducted new experiments in which the container was fallen freely and simulated gravity was about 0.01 G. In this case the crater diameter was smaller than the expected value by the above gravity dependence. We estimated the adhesion of the target material based on a theoretical model (*Rumpf, 1970*), and we found that the effect of the target strength on the crater size is not negligible. On the other hand, when we conducted similar experiments in an evacuated chamber the crater diameter was larger than the one under 1 atm. There is a possibility that the smallness of the crater under 0.01 G is due to atmospheric effects.

In order to evaluate the above effects, it is important to understand the atmospheric effects on crater formation. *Schultz (1992)* conducted hypervelocity impacts under the ambient pressure range between $10^3$-$10^5$ Pa and the crater volume was found to become larger as the ambient pressure becomes lower. Mostly impact experiments in the past were conducted under the ambient pressure range approximately between 1-$10^3$ Pa and it is unknown whether or not these results could apply to the ultra-high vacuum condition.

We conducted impact experiments under the ambient pressure range between 1-$10^5$ Pa. Target was silica sand and projectile was stainless steel sphere which were the same ones used in our study on the dependence of gravity. Impact velocity was 2.5 m $s^{-1}$. As a result the crater diameter was found to become larger as the ambient pressure becomes lower and this result has the similar tendency to the previous study conducted at hypervelocity. It may be due to the change of the air drag which affects the motion of particles or of the internal friction of target material. It is known that crater diameter formed in the particles with smaller internal frictional angle tends to become larger. We measured the angle of repose (which is approximately similar to internal frictional angle) of silica sand and found that the one under 20 Pa was smaller than the one under 1 atm. Conversely, it is shown that the internal frictional angle under ultra-high vacuum was larger than the one under 1 atm (*Perko et al., 2001*). The mechanism for the change of internal frictional angle is not understood, however it is suggested that the change of ambient pressure may affect the crater size through the change of the internal frictional angle. We will further investigate the effect of ambient pressure on crater diameter and will present the results.

Keywords: Asteroids, Impact craters, Laboratory experiments, Microgravity, Ambient pressure