Impact cratering on a silica dust layer with high porosity and the effect of porosity on the crater size scaling law

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Recent planetary exploration revealed that small bodies in the solar system could have a large porosity as large as 80% for comet nuclei and less than 75% for asteroids. Impact craters found on such highly porous bodies were recognized to be quite different from that found on rocky bodies without porosity, that is, there were several craters on their surface which sizes were beyond their radius. These large craters were supposed to be formed by pore collapse during the impact compression and so it was recently classified into a compressive type crater. Classically, the impact crater is classified into two types depending on the physical mechanism controlling the final crater size: they are a crater formed in a gravity dominated regime and a crater formed in a strength dominated regime. These classical type crates have been studied to construct the crater size scaling law, and now the p scaling law was widely accepted to use for the planetary impact phenomena. However, the effect of porosity on this p scaling law for the crater size was not clarified yet although limited studies have been conducted by Housen and Holsapple (2003) and others. The π scaling law applicable for the porous asteroids is necessary for the impact experiment on small asteroid Ryugu by Hayabusa-2 small carry-on impactor because one candidate for the surface condition on Ryugu is fine-grained layer with a high porosity.

In this study, commercial amorphous silica dusts with the average particle size of 0.5mm and the density of 2.2gcm^{-3} (ρ) were used to prepare the target with the bulk porosity from 50% to 78%, and the target was simply consolidated by the cohesion force of Van Der Waals force with the tensile strength from 100 Pa to 10^4 Pa. We made impact cratering experiments using this porous target to study the effect of the porosity on the crater morphology including the crater size. Impact experiments were conducted by using a horizontal type two-stage light gas gun set at Kobe University and a glass bead projectile with the diameter of 2mm and the mass of 10 mg (m_p) was launched at the impact velocity at 3.60 kms^{-1}. The projectile was impacted on the target surface normally set in a large vacuum chamber less than 20 Pa. The crater morphology was found to change with the increase of the porosity, that is, the shallow dish type crater was observed on the target with the porosity of 50% having the tensile strength of 10^4 Pa, and as the porosity increased the impact spherical cavity was formed to grow and expanded below the shallow dish crater. The recovered target was hardened by epoxy resin and cut at the center of the crater to observe the cross section to measure the cavity diameter (D), the depth of the crater (d) and the diameter of the shallow dish crater. The relationship between the distension ($a=\rho/\rho_{bulk}$) and the normalized cavity diameter, $\pi_D=(\rho_{bulk} D/m_p)^{1/3}$, was found to follow the empirical equation of $\pi_D=3.8a^{0.7}$, where r_{bulk} is bulk density of the target, and the relationship between the distension and the normalized depth, $\pi_D=(\rho_{bulk} d/m_p)^{1/3}$, was found to follow the empirical equation of $\pi_D=3.0a^{1.0}$. While the crater diameter of the shallow dish crater found at the entrance of the cavity was recognized to be constant irrespective of the porosity. These empirical equations could be used to incorporate the effect of porosity on the crater size scaling law.

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