EPSC Abstracts
Vol. 13, EPSC-DPS2019-1560-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

On the Strength of the Aba Panu (L3) Meteorite: Implications for Hazard Mitigation

Desireé Cotto-Figueroa (1), Md Fazle Rabbi (2), Ashwin Rai (2), Aditi Chattopadhyay (2), Laurence A.J. Garvie (3) and Erik Asphaug (4). (1) Department of Physics and Electronics, University of Puerto Rico at Humacao, Humacao, P.R., USA (desiree.cotto@upr.edu) (2) Adaptive Intelligent Materials & Systems Center, Arizona State University, Tempe, AZ, USA (3) Center for Meteorite Studies, Arizona State University, Tempe, AZ, USA (4) Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA.

1.Introduction

Measuring the strengths of asteroidal materials is important for developing mitigation strategies for potential Earth impactors and for understanding properties of in situ materials on asteroids during human and robotic exploration. Few measurements of meteorite strength have been undertaken, as the samples have to be crushed [1]. As such, catastrophic disruption modeling [2, 3] parameters have largely been obtained from studies of terrestrial analogs (e.g., basalt and concrete), or from studies limited to single specimens of meteorites [4, 5, 6]. The few strength measurements performed [7] leave open the question of statistical variation of meteorite strength, and the scale variation relevant to asteroid materials.

In order to provide the data necessary to understand or predict the physical and rheological properties up to hundreds-of-meter scales, we are undertaking repeated destructive measurements of representative meteorites typical of primitive materials and the common asteroids in near Earth orbit. In our previous effort [1], we developed the first Weibull failure distribution analysis of meteorites based on uniaxial failure studies of centimeter-sized cubes of Allende, a carbonaceous chondrite (CV3), and Tamdakht, an ordinary chondrite (H5). We showed that the derived Weibull distribution projected to meter scales, overlaps the strengths determined from asteroidal airbursts and can be used to predict properties up to the 100-m scale.

Here, we present the results for the Aba Panu meteorite, which is an L3 ordinary chondrite fall. It fell in 2018 over the Nigerian state of Oyo. The meteorite was recovered immediately after the fall and curated. The interior of the stones is greyish green and show scattered rounded to angular light-colored clasts. Cut surfaces are dominated by a gray matrix, studded with well-developed chondrules and chondrule fragments. The stones are very hard and difficult to cut and lack visible fractures and shock veins.

Figure 1: Shown here are nineteen 1-cm cubes that were obtained from a slice of a 1,269 g Aba Panu meteorite.

2.Methods

Elastic wave velocity measurements are performed using a manually controlled Olympus 5077 PR electric pulse generator/receiver and uniaxial compression tests are performed on an Instron 5985 frame with a 250 kN load cell and compression fixtures comprising of 145 mm diameter radial platens with a maximum rated load of 100 kN. Measurement of displacement and strain fields were undertaken with a non-contact GOM ARAMIS 5M 3D Digital Image Correlation system.

We consider the stochastic variation in strength and what it implies for weakest-link failure of larger random specimens (meteoroids and boulders) of the same material, using a Weibull approach [8] common to theoretical studies of asteroid disruption. The characteristic statistical variation of strength is given by the failure probability where the volume dependence goes away with identical samples and the Weibull parameters are obtained in order to derive the strength scale-dependence of the material.

3. Preliminary Results

Preliminary results of a 1-cm Aba Panu cube of 3.574 g provide a longitudinal and shear wave velocity of 4,689.33 m/s and 2,918.00 m/s, respectively. From these measurements, we estimate an Elastic modulus (E) of 61.2 ± 1.8 GPa. For comparison, the Elastic moduli for Allende and Tamdakht are 16.66 ± 4.72 GPa and 21.01 ± 6.57 GPa, respectively [1].

The compression strength (σ) obtained from the destructive test of the Aba Panu cube was 365.34 MPa. This is significantly higher than the Allende and Tamdakht cubes, whose maximum measured strengths were 58.4 MPa and 247.4 MPa, respectively [1]. During disruption, the Aba Panu meteorite showed axial crack initiation at the macro-scale at high strains and close to the ultimate strength, with rapid propagation into instant final failure by axial splitting. In contrast, the Allende cubes developed several competing cracks at low deformations well before ultimate strength, which coalesced to a single major crack and often led to material failure at ultimate strength. For comparison, the Tamdakht cubes retained several major cracks even at final failure, leading to finer scale fragmentation.

The implication is that Aba Panu meteorites are more homogeneous than the Allende and Tamdakht meteorites. Exhibiting therefore higher strengths at meter-scales. Knowledge of in situ strength behavior, at a variety of scales and rates, is important to sample return missions [9, 10], resource utilization, robotic manipulation, and hazardous asteroid mitigation. This study will improve our understanding of the typical asteroid material environment and is a step towards placing fundamental constraints on disruption limits of asteroids.

Acknowledgements

This material is based upon work supported by the National Aeronautics and Space Administration under Grant/Contract/Agreement No. 80NSSC18K1444 issued through the SSO Near Earth Object Observations Program.

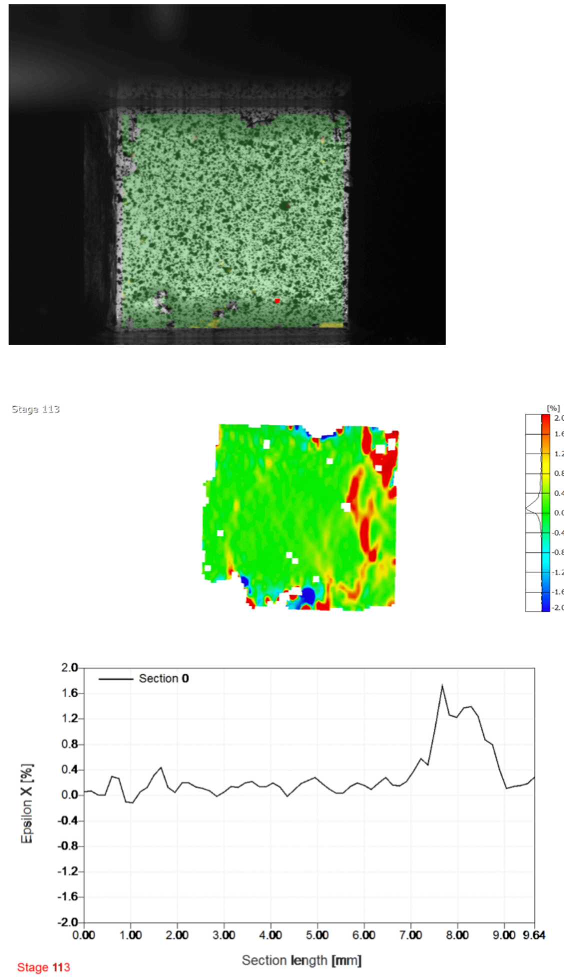

Figure 2: Shown here is the crack initiation stage where a crack starts at the top right corner of the 1-cm Aba Panu cube with (top) DIC image, (middle) strain distribution in the x-direction, and (bottom) strain in the x-direction with the section length.

References

[1] Cotto-Figueroa et al., 2016, Icarus, Vol. 277, pp. 73-77. [2] Melosh et al., 1992, J. Geophys. Res. 97 (E9), 14735. [3] Benz and Asphaug, 1999, Icarus 142, 5–20. [4] Durda and Flynn, 1999, Icarus, 142, 46–55. [5] Flynn et al., 2005, Planet. Space Sci. 52, 1129–1140. [6] Durda et al., 2011, Icarus, 211, 849–855. [7] Kimberly and Ramesh, 2011, Meteorit. Planet. Sci., 46, 1653–1669. [8] Weibull, 1951, J. Appl. Mech., 18, 293–297. [9] Berry et al., 2013, 36th Annual AAS Guidance and Control Conference. [10] Brophy and Muirhead, 2013, 33rd International Electric Propulsion Conference, IEPC-2013–82.