Modeling impact-induced porosity and fracturing on Fe-Ni bodies

A. M. Alexander[1,2], S. Marchi[1], S. Chocron[3], J. Walker[3]
[1]Southwest Research Institute, 1050 Walnut St, Ste 300, Boulder, CO, 80302, alexander@boulder.swri.edu
[2] University of Colorado Boulder, Boulder, CO, 80309, USA
[3]Southwest Research Institute, San Antonio, TX 78238, USA

Introduction:

The significance of cratering processes in metal-rich targets has been underscored by the upcoming launch of the *Psyche* mission in 2022. The target of the *Psyche* mission, 225-km asteroid (16) Psyche, is thought to be a metal-rich asteroid [1-2], possibly the collisionally-exposed core of a large, differentiated planetesimal [3-4]. Revised mass and shape modeling estimates, coupled with radar, spectral and thermal inertia observations indicate that Psyche may have 30-60 vol % metal [5]. In one scenario, Psyche may be dominantly metallic (Fe-Ni alloys), but may contain up to 60% porosity to explain the current best estimate of Psyche's density (4.1-4.2 g/cm^3, [6]). The origin of such porosity is not understood. A possibility is that porosity could be due to impact-generated fracturing perhaps as the result of one or more hit-and-run collisions with subsequent re-accumulation, and/or the result of billions of years of collisional evolution in the main belt. The hypothesis that Psyche is heavily fractured is bolstered by recent impact experiments on Fe-Ni targets (Fe-Ni manufactured ingots and iron meteorites) [7], in which impacts cause metal cracking thereby introducing significant bulk porosity.

In this work, we conduct shock physics simulations using CTH [8] and iSALE [9-11] to simulate existing laboratory-based impact experiments. We employ the Johnson and Cook strength model [12] in both CTH and iSALE, using experimentally-derived parameters specific to the Fe-Ni target materials and compare the simulated crater morphologies as well as explore the effects of temperature on strength, strain and strain rate. Further, we utilize the Johnson and Cook failure model [13] in CTH to explore failure methods (i.e., cracking and porosity) in Fe-Ni alloys. We highlight the complexity and sensitivity of specific strength model parameters (i.e., Johnson and Cook strength and failure model material coefficients and target temperature) in producing internal damage structure. Our small-scale calibration simulations can be extrapolated to simulate larger-scale collisions within the strength regime on Psyche.

References:

[1] J. Hanuš et al. (2017) *Astronomy & Astrophysics*, 601, A114. [2] A. Matter et al. (2013) *Icarus*, 226, 419. [3] J. Bell. (1989) *Asteroids II,* 921. [4] L. Elkins-Tanton. (2017) *LPS XLVIII,* Abstract #1718. [5] L. Elkins-Tanton et al. (2020) *Journal of Geophysical Research (Planets),* 125, e06296. [6] M. Ferrais et al. (2020) *Astronomy & Astrophysics*, 638, L15. [7] S. Marchi et al. (2020) *Journal of Geophysical Research (Planets),* 125, e05927. [8] J.M. McGlaun et al. (1990) *International Journal of Impact Engineering,* 10, 1-4, pp. 351-360. [9] A. Amsden et al. (1980) *Los Alamos National Laboratories Report*, LA-8095:101p. [10] G. Collins et al. (2004) *Meteoritics and Planetary Science*, 39, 217. [11] K. Wünnemann et al. (2006) *Icarus* 180, 514. [12] G.R. Johnson and W.H. Cook. (1983) *Proceedings 7th International Symposium on Ballistics*, 1983, 541-547. [13] G.R. Johnson and W.H. Cook. (1985) *Engineering fracture mechanics* 21, no. 1, 31-48.