Viscous heating in shock-comminuted rocks: A reappraisal of the shock melting threshold by using a shock physics code

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Impact melts are among the most curious geologic samples because they provide clear evidence of hypervelocity collisions between two planetary bodies at several km/s. Thus, the required shock pressure for incipient melting after pressure release has been studied extensively. It is widely assumed that pressure release is an isentropic process. This assumption is expected to be valid when the shocked matter behaves as a perfect fluid. Since the archived shock pressure under typical collisions between two planetary bodies is thought to be much larger than the Hugoniot Elastic limit, the yield strengths of both intact and comminuted rocks have been neglected in a lot of cases. In this study, we focused on collisions at relatively low velocities, which are that the effects of the material strength cannot be neglected. The effects of internal friction in comminuted rocks, i.e., the yield strength of shock-comminuted rocks, on thermodynamic behavior on an entropy-pressure plane were investigated using the iSALE shock physics code to revisit the threshold of incipient melting against the peak shock pressure. We will present a preliminary result obtained through the numerical experiments at the meeting.
A vertical impact of a sphere onto a flat target are numerical modeled in a two-dimensional cylindrical coordinate. The analytical equation of state (ANEOS) for dunite were used for both projectile and target. Impact velocity was fixed at 6 km/s, which is slightly lower than the bulk sound velocity of dunite. The projectile radius was divided into 50 cells, which is thought to be large enough to investigate the shock pressure distribution with a high accuracy. We assumed that the projectile and the target have any temperature gradients at initial. The initial temperature was set to 220 K, which is close to a radiative-equilibrium temperature at the main belt region. The constitutive model for dunite parameterized in Johnson et al. (2015) was also used with the same input parameters except for the coefficient of internal friction. Lagrangian tracer particles were inserted into each computational cell. We stored the time variation of pressure and entropy into the tracers.
We found that the entropy gradually increases during pressure release in the case of a highly-frictional target contrary to the assumption of isentropic release. A larger value of the internal friction leads to a larger increase of entropy. We also found that the shock melting occurs after ~40 GPa shock compression under our experimental conditions if we used a typical value for the coefficient of the internal friction. This value is lower than a widely-used threshold for shock-induced melting. Our results suggest that (1) the shock melting occurs at a lower impact velocity than previously thought and that (2) the input parameters of the constitutive model in numerical models largely affect the thermodynamic response of geologic materials.

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