IMPLEMENTATION OF A NEW CONSTITUTIVE MODEL FOR ROCKS INTO THE SHOCK WAVE PHYSICS CODE CTH.

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Introduction

Impact cratering is a major geologic process that has shaped the surfaces of all of the terrestrial planets. Because crater morphology is affected by material properties that are below the surface, craters provide an ideal way to probe features that are hidden from view. In addition, because impact cratering is a process that has occurred ubiquitously throughout the solar system and throughout the solar system's history, surfaces all over a planet and of all ages on a planet can be studied using the same methods, allowing the construction of histories and maps of the subsurface.

Experimental laboratory craters are limited in scale; therefore, the only way to study planetary scale craters is through numerical computations. These computations work by simultaneously solving (1) the conservation equations (mass, momentum, and energy), (2) an equation of state (which describes the response of a material to changes in pressure), and (3) a strength model. The usefulness of the results produced by any given simulation is highly dependent upon the quality of the equation of state and strength model used. Thus, we are implementing a new strength model similar to Collins et. al. [1] into the shock wave physics code CTH [2] in order to more accurately model impacts into geologic materials.

Strength Model

The model degrades shear strength as a function of pressure, temperature, and total damage. Tensile strength is degraded as a function of temperature and total damage. Note that damage is a dimensionless quantity between 0 (completely intact material) and 1 (completely cohesionless material) which describes the amount of fracturing a material has experienced. Shear and tensile damage are tracked separately. Shear damage is accumulated with integrated plastic strain, while tensile damage is accumulated according to a simple crack-growth model.

Results

Figure 1 shows the results of a numerical simulation using the best old strength model in CTH for geologic materials (a) and the new model that we've implemented (b). The figures show the pressure field at $2e10^{-5}$ seconds after the impact of a 4 millimeter granite sphere into a granite half-space. Note the differences in the pressure field as well as the differences in the crater shape, even at this early time (before the cratering process is complete).

Future Work

We plan to use this model to study the effect of strength and layering in the target on impact crater formation with an application to understanding Martian crater forms. Studies of simple cases have shown that the effect is significant. For example, Oberbeck and Quaide experimentally studied the effect of a weak layer overlying a stronger layer, and were able to accurately estimate lunar regolith thickness based upon crater appearance [3].

More complex cases have not been extensively studied. Our current understanding of Mars, however, indicates that such studies are needed; Mars Orbiter Camera (MOC) images have revealed outcrops of layered sedimentary rock that are up to 4 kilometers thick [4, 5]. In addition, many Martian impact craters show a fluidized ejecta morphology which is generally believed to be due to ice or liquid water layers in the subsurface.

By quantitatively comparing my numerical simulations with Martian cratering data from the Mars Orbiter Camera (MOC) and the Mars Orbiter Laser Altimeter (MOLA), we will examine the properties of subsurface layers on Mars.

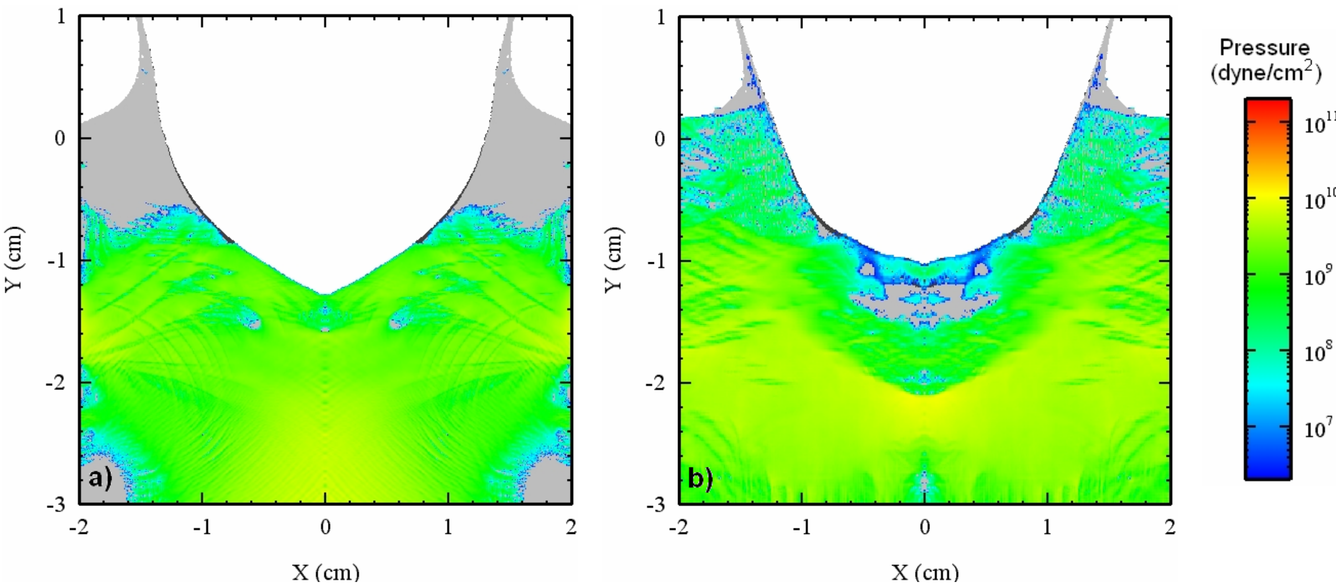

Figure 1: Pressure field 2e10^{-5} seconds after the impact of a 4 millimeter granite sphere onto a granite half-space with (a) the best old strength model in CTH (geological yield surface), and (b) the new rock strength model.

References

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