BRIDGING THE GAP BETWEEN HYDROCODES.

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Introduction: Impact cratering represents one of the most fundamental process shaping planetary surfaces. Our current understanding has been derived by a long history of remote sensing, geophysical data, experiments, and computer modelling. In particular, the recent improving in the computer capabilities has allowed to obtained more and more sophisticate models to describe the physics behind crater formation. This approach represents a valid means to study the crater process at planetary scale, size real sizes and velocities are not reachable in laboratory (e.g. [1]).

Shock Codes: Hydrodynamic computer codes, or shock codes, are sophisticated computer programs that can be used to simulate numerically highly dynamic events, and in particular handle the propagation of shock waves as well as the behaviour of geologic materials over a broad range of stress states and of deformation rates ([2], [3]).

All the available codes modelled the dynamics of a continuous media through a set of differential equations describing the principles of conservation of momentum, mass and energy from a macroscopic point of view. In grid codes, these equations can be solved from two different points of views (e.g. [3]). In the Eulerian description, the mesh is fixed in space and the material flows through it, making difficult to identify material interfaces at all times during the computation. In the Lagrangian description, the mesh is instead fixed with the material, hence both free and contact surfaces between different materials remain distinct throughout all the computation. In this case, the major inaccuracy occurs when the cells are significantly distorted. On the other hand, collision dynamic can be solved by meshless Lagrangian codes. Smooth Particle Hydrodynamics (SPH) relies in the discretization of the bodies into mass packages which are called particles ([4]). The locations of these particles are the sampling points of the numerical scheme. The particles move like point masses according to the Lagrangian form of the equation of motion. They carry all physical properties mass, momentum, internal energy of the part of the solid body which they represent. The particles interact during the simulation and exchange momentum and energy. In this case, boundary conditions represents the principal limitation of the code.

In order to describe the material response to the passage of shock waves, constitutive equations are needed (e.g. [3]). These are formulated as an equation of state and a strength model, which govern the bulk thermodynamic material response and deviatoric deformations, respectively. The formulation of these two additional equations is the representative between the different codes (e.g., [3]).

A large campaign of validation intra-codes and between hydrocodes and experiments was carried out by Pierazzo et al. In this work, we aim at comparing the results of two computer modelling having a very different approach to dynamical problems, that are iSALE and SPH.

Methods: Numerical modelling is performed through the iSALE and SPH shock physics codes.

iSALE. iSALE is a grid code initially developed by [5]. It has been enhanced through modifications which include an elasto-plastic constitutive model, fragmentation models, various equations of state (EoS), multiple materials, and a novel porosity compaction model (the ε-α-model) [6, 7, 8, 9]. In addition, the code is well tested against laboratory experiments at low and high strain-rates [9] and other hydrocodes [3].

For each of the studied cases, the model setup is based on a grid mesh, large enough to prevent the interference of reflection waves from the boundaries. The dynamics of the shock waves is studied in the Eulerian approach. The equation of states were either Tillotson or ANEOS tables, whereas different strength and damage models were considered ([6]).

SPH. We used the CUDA version of the code miluph which is a SPH code for the simulation of fluids and solid bodies. It includes an elastic-plastic constitutive model and a damage model for brittle materials firstly applied in SPH codes by [4]. The code can be used for the simulation of high-velocity impacts and self gravitating astrophysical objects or mixed hydro-solid simulations.

The particles with equal masses were initially distributed on a grid mesh. The extent of the particle distribution was chosen large enough to prevent the interference of reflection waves from the boundaries. We have used the Tillotson EoS for the presented cases.

Results and Discussion: We took into analysis several impact problems, in order to investigate the different approach adopted by the two codes to investigate crater formation.

Case 1. We modelled the laboratory experiment of Prater, which consisted on a 6.35–mm–diameter aluminum sphere perpendicularly impacting at 7 km/s onto a cylinder of alloy 6061–T6 (insensitive to strain rate). The adopted equation of state is the Tillotson EoS, while the strength model used is the Johnson–Cook one.

Case 2. We modeled a basaltic projectile impacting at 15 km/s in a semi-infinite surface with a basaltic composition. Our goal is to test the two codes under different material properties (strength, damage, layering, equation of states, etc.).

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