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Influence of Target Properties on Ejecta Scaling Relationships

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Abstract

Crater scaling relationships [e.g., 1, 2] relate observables of a cratering event (e.g., crater radius, ejection velocity) with the impactor characteristics (e.g., size, impact velocity), allowing for predicting the outcome of a cratering event. We show results for scaling parameters derived from numerical experiments. We focus on the dependence of ejection dynamics from target material properties like strength and porosity.

1. Introduction

Target material properties influence the cratering process and, consequently, are reflected within the scaling parameters of scaling relationships that are used to predict the outcome of the event [e.g., 3]. In laboratory studies, it is difficult to vary individual material parameters. In contrast, numerical studies allow for a systematic analysis of the influence of target properties on the outcome of a cratering event. In this study, we analyse the ejection dynamics in numerical experiments for different target materials and present scaling parameters for ejecta scaling [cf. 4 for more details]. These scaling parameters allow for using scaling relationships to predict the outcome of different impact scenarios (gravity, impact velocity, projectile size). According to theoretical considerations scaling parameters should be consistent for different formulations of scaling relationships like ejecta scaling or crater size scaling.

2. Method

We use the iSALE shock physics code [5-7] to conduct a systematic parameter study by simulating different impact scenarios. iSALE enables to describe the resistance of rocks against deformation and the thermodynamic response to compression by different material models. We use a Drucker-Prager rheology with coefficient of frictions between 0.0 and 1.0 for non-porous targets. We vary target porosities between 0% and 42% for materials with a coefficient of friction of 0.6. All simulated materials are cohesion-free. We use the ANEOS for quartzite [8]. We determine the ejection parameters (velocity and angle) by Lagrangian tracers. Material represented by tracers is considered as ejecta when it satisfies a specific criterion: the tracer has to be above a specific height above the pre-impact surface that we chose to be one projectile radius in all simulations. Note, the ejection velocity is consistent also for somewhat larger or smaller ejection-criterion-altitudes [4]. We plot the resultant ejection velocity v_{ej} normalised by $\sqrt{gR}$ against the normalised launch distance x/R, where g and R are the gravitational acceleration and transient crater radius, respectively (Figure 1). For deriving scaling parameters K and μ based on the ejection velocities, we use the following equation [2]:

$$\frac{v_{ej}}{\sqrt{gR}} = K\left(\frac{x}{R}\right)^{-\frac{1}{\mu}}. \qquad (1)$$

Using Eq. 1 requires excluding ejecta from close within the transient rim where the power law approximation fails. Therefore, we use a fixed minimum ejection velocity of ~80 m/s for all models that is high enough to exclude ejecta near the rim, and which allows for comparability between the models.

3. Results

The increase of material strength (i.e, the coefficient of friction) causes a reduction in crater size under equal impact conditions. Hence, ejection velocities in a normalised plot show a stronger decrease with ejection position for larger strength (Fig. 1 i), which correlates with the onset of ejection at larger normalised ejection positions. The increase of porosity causes a reduction of the initial ejection velocities at small ejection positions (Fig. 1 ii). The normalised velocities at $x/R=1$ is about equal for all porosities. Consequently, the decrease of velocity is the greatest for non-porous target materials. The scaling parameters are given in tables Tab. 1 & 2.

Table 1: Scaling Parameters, non-porous material.

Coefficient of friction	K	μ
0.0	0.43	0.49
0.2	0.53	0.49
0.4	0.63	0.47
0.6	0.77	0.46
0.8	0.81	0.46
1.0	0.82	0.47

Table 2: Scaling Parameters, material with coefficient of friction 0.6.

porosity	K	μ
0%	0.77	0.46
10%	0.66	0.47
20%	0.62	0.49
30%	0.61	0.52
42%	0.70	0.62

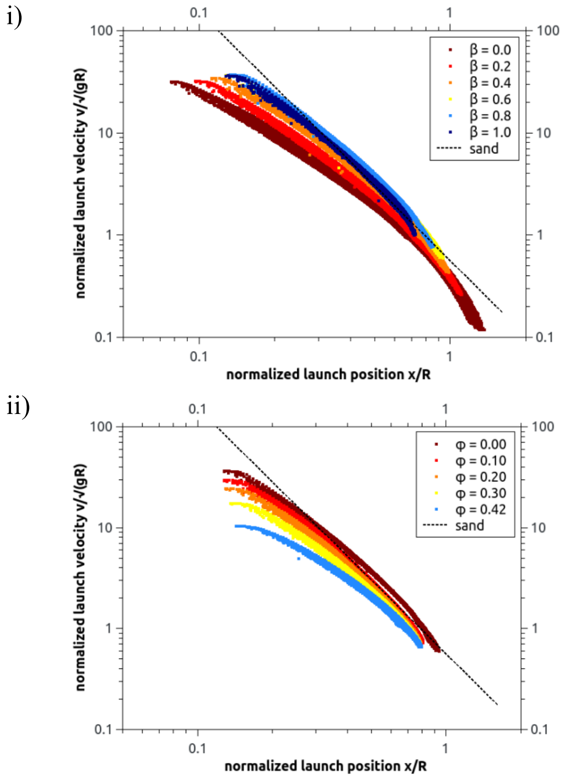

Figure 1: Ejection velocity for non-porous materials with coefficients of friction from 0.0-1.0 (i), and for targets with a coefficient of friction of 0.6 and porosities from 0-42% (ii). Impact conditions: velocity 5 km/s, projectiles radius 25 m, Earth gravity. The sand line is from [2].

4. Summary and Conclusions

We present results for scaling parameters for target materials with various strength and porosity. Target properties influence ejection velocities, and fitting Eq. 1 to our numerical ejection data yields the given scaling results. These scaling parameters deviate from results based on crater size (e.g., μ=0.41 for 42 % porosity [2] vs. μ=0.62, this study). However, our value falls into the range μ=0.5-0.66 given by [9]. Further experiments also show deviations of scaling parameters depending on the observables they are derived from [10]. This could be linked to differences in early-stage (e.g., ejection, crater growth) versus late-stage processes (e.g., crater size). Therefore, we think that care must be taken when scaling ejection characteristics, and parameters for such purposes should be chosen based on ejection studies.

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