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The MEMIN research unit: First results from impact cratering experiments into quartzite and tuff

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Abstract

The MEMIN research unit is focused on performing and evaluating impact cratering experiments into geological materials. As a research unit, MEMIN uses a multidisciplinary approach, with different subprojects analyzing various aspects of the same cratering experiments, including crater morphology, ejecta dynamics, subsurface deformation, etc., along with numerical simulations of the impact process.

A series of impact cratering experiments into quartzite and tuff targets is planned for June 2012. We intend to have completed a preliminary evaluation of these experiments for the EPSC conference.

1. Introduction

1.1 Previous MEMIN experiments

The research unit has already successfully performed 18 impact experiments into sandstone (*Seeberger Sandstein*). The results of these experiments are currently under review for a special issue of M&PS (see also [1]). In these experiments, steel, iron meteorite and aluminum projectiles ranging in size from 2.5 to 12 mm were accelerated to velocities of 2.5 - 7.8 km/s. The projectiles impacted into blocks of either dry sandstone or sandstone saturated with water to 50% or 90%.

Results (Fig. 1) show that the sandstone's 23% porosity reduces crater volumes and cratering efficiency relative to non-porous rocks. Saturation of pore space with water to 50% and 90% increasingly counteracts the effects of porosity, leading to larger but flatter craters. Higher ejecta speeds as well as narrower ejecta cones are observed if the impacts are conducted on wet sandstones. The transient crater grows at a faster rate and reaches a larger diameter if the target is water-saturated. Subsurface analysis of the cratered target shows that enhanced grain comminution and pore space compaction occur in the dry experiment, while a wider extent of localized deformation in the saturated experiment suggests a direct influence of pore water on deformation mechanisms.

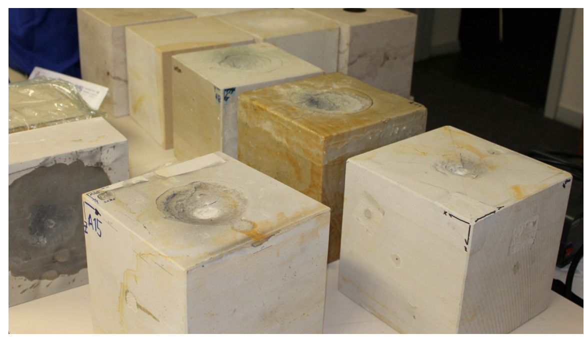

Fig. 1: A selection of experimental impact craters formed in 20 cm edge-length sandstone targets at impact velocities of ~5 km/s. Experiments using tuff and quartzite targets will be compared to these results.

1.2 Goals of the current experiments

The aim of the planned experimental campaign is to study the effects of porosity on the cratering process in more detail. The cratering results we have obtained from sandstone (23% porosity) will be compared to experiments performed on low-porosity and high-porosity targets. We will use a quartzite (*Taunus Quarzit*) with <~1% porosity and a tuff (*Weiberner Tuff*) with ~40% porosity.

2. Planned experimental setup and evaluation

Impact experiments will be performed at the SLGG accelerator of the Fraunhofer Ernst-Mach-Institute in Freiburg, Germany. 2.5 mm diameter steel spheres will be accelerated to 5 km/s and impact into cubeshaped targets with an edge-length of 20 cm. Cratering and ejecta dynamics will be filmed by a high-speed framing camera at ~10^5 fps. Ejected material will be caught by specially devised “ejecta catchers” consisting of Vaseline and phenolic foam. An array of ultrasound sensors will be attached to the target to record the initial pressure wave of the impact and subsequent post-impact vibrations.

After the experiments, crater morphology will be quantified using a 3D laser scanner to determine depth, diameter and volume. Ejection angles and other dynamic behavior will be characterized and quantified from the videos and catcher imprints.

3. Expected outcome

When comparing experiments with the same impact conditions (projectile mass, density and velocity) the crater volume will most likely be affected by the target’s strength and porosity. An increase in either value reduces crater size. Interestingly, rock strength is usually reduced for increasing porosity values. The relationship between uniaxial compressive strength and porosity in a rock material is suggested to follow a power law, e.g. [2]. Thus, crater volumes may actually show only little variation between non-porous quartzite, sandstone, and highly-porous tuff. The high porosity of the tuff may have an effect on the penetration depth and the resulting depth-diameter ratio of the craters, as seen e.g. in [3].

Porosity may also affect the behavior of the ejection process. In experiments with sandstone, saturation of the sandstone’s pore space led to the formation of much narrower ejecta cones [1]. It is currently not clear if this is an effect of the water itself or the reduction of porosity. The planned experiments will help to clarify this. Furthermore, strength and porosity of the targets will influence the ejection velocity and transient crater growth. The results can be used to better constrain current scaling laws for crater size and ejecta behavior. We intend to complete an initial evaluation of the experimental data and present these results at this year’s EPSC.

The long-term benefits expected from these experiments are improved models of crater formation in different target types, and a validation of numerical models of the experiments, which in turn should lead to a better understanding of the underlying process that occur during impact cratering.

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