STRAIN-RATE DEPENDENT BRITTLE DEFORMATION DURING IMPACT CRATERING.

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Introduction: Hypervelocity collisions of asteroids, comets, or meteroids with planetary bodies induce shock waves that propagate through both projectile and target. The amplitude of shock decays with distance travelled by the shock wave due to geometric spreading and consumption of energy. The degree of attenuation is material dependent. The volume of rocks that is affected by shock metamorphism is generally smaller than that affected by brittle failure under varying strain rates [1]. Brittle failure is usually regarded as a strain-rate insensitive process. However, abundant studies showed that above a critical strain-rate a rate dependency of brittle deformation exists [2] that is associated with a dynamic strength enhancement of rocks. The strain rate dependency occurs through the propagation velocity limit (Rayleigh wave speed) of cracks and their reduced ability to coalesce, which, in turn, significantly increases the strength of the rock. Crack branching is an important phenomena of brittle failure in this rate-dependent regime and is responsible for the formation of shatter cones [3; 4]. We present the methodology to investigate brittle deformation of rocks under dynamic loading conditions and determine the dynamic strength enhancement factor for a variety of rocks.

Methodology: We use a newly developed pressurized air driven Split-Hopkinson-Pressure Bar (SHPB), that is specifically designed for the investigation of high strain-rate testing of rocks, consisting of several 10 to 50 cm long strikers and bar components of 50 mm in diameter and 2.5 meters in length each. The whole set-up, composed of striker, incident- and transmission bar is available in aluminum, titanium and maraging steel to minimize the acoustic impedance contrast, determined by the change of density and speed of sound, to the specific rock of investigation. In SHPB experiments [2] one-dimensional longitudinal compressive pulses of diverse shapes and lengths - formed with pulse shapers - are used to generate a variety of loading histories under 1D states of stress in cylindrical rock samples, in order to measure the respective stress-strain response at specific strain rates. Dynamic mechanical parameters can be obtained in compression as well as in spallation configuration, covering a wide spectrum from intermediate to high strain rates (10^0-10^3 s^{-1}). Subsequent microstructural analysis of the deformed samples is aimed at quantification fracture orientation, fracture pattern, fracture density, and fracture surface properties as a function of the loading rate.

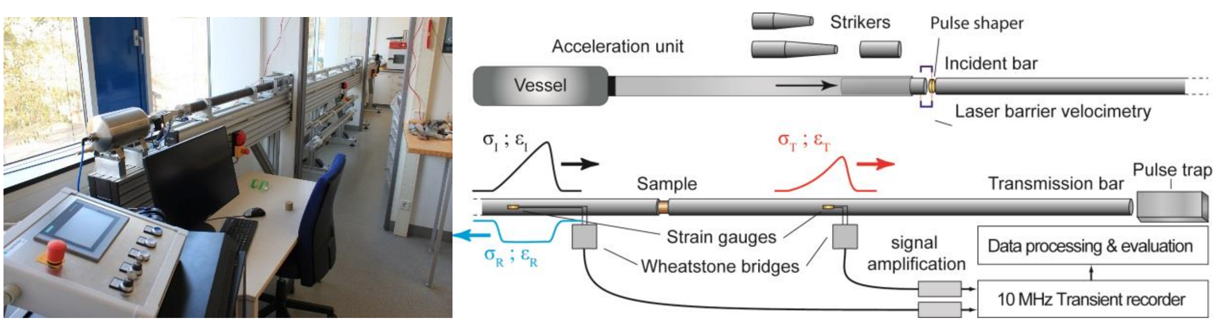

Fig. 1. Schematic setup of a Split-Hopkinson-Pressure Bar of the ALU-Freiburg

Results: So far we have investigated Seeberger sandstone used in the MEMIN program, see, e.g., [5], and Carrara marble. The onset of a strength increase is indicated at ~10^{+0} s^{-1} and at ~10^{+1} s^{-1} for marble and sandstone, respectively. The dynamic strength enhancement factor reaches a value of 2.8 and 1.7 at ~10^{+2} s^{-1} for marble and sandstone, respectively.

Discussion: Linking mechanical and microstructural data to natural dynamic deformation processes has relevance for the understanding of brittle deformation during early crater formation. The dynamic, strain rate dependent behavior with strongly increasing strength and changing fracturing process has not been consequently considered in modeling of impacts. Incorporation of dynamic material data, e.g. in the SALE-code is desired.

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