STRIKE: Simulating the Rubble-Pile Influence on the DART Kinetic Impactor Experiment

K. Wünnemann, R. Luther, S. Baldauf, R. Röhlen,
Institute of Geological Sciences, Freie Universität Berlin & Museum für Naturkunde - Leibniz Institute for Evolution and Biodiversity Science

In Short

- The DART impact event is a test of the capabilities of deflecting asteroids on hazardous orbits for Earth
- Studying the deflection efficiency, which depends on the target properties and heterogeneities
- Simulate the ongoing processes during the DART impact for future deflection mission scenarios

Abstract

On 27th September 01:15 (CEST), the DART space craft impacted the 170-m-sized moonlet Dimorphos of the binary asteroid system Dydimos, which will further be characterised by ESA's upcoming Hera mission. The DART mission is a large-scale impact experiment and a proof of concept mission for the kinetic impactor technique as mitigation method of hazardous asteroids [1]. Previous studies have shown that the material properties of an asteroid have significant effects on the ejection behaviour from impact craters and the related orbital change of the asteroid [2, 3] (Figure 1).

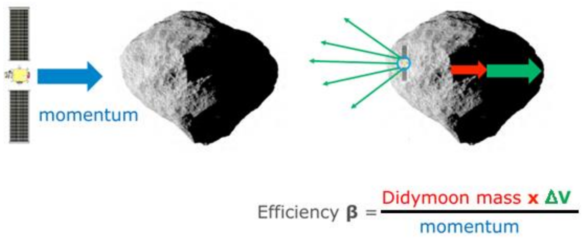

Figure 1: Schematic of the Momentum exchange for the kinetic impactor technique. The efficiency β represents the effectiveness of the orbital change (velocity change Δv).

Most hypervelocity impact modelling studies so far focus on crater formation in homogeneous materials in the strength regime [e.g. 4 and references therein]. However, as the first pictures from Dimorphos show, the impact happened in rather weak granular material in low gravity regime. Modelling crater formation on such small and weak bodies is still a demanding task. Hypervelocity impact simulations typically focus on fast shock wave processes on short time scales. Due to low gravity, crater formation lasts much longer relative to shock wave processes and has been modelled by a very limited number of authors [5] so far.

Recently, the awareness of the effect of heterogeneities on impact processes has risen and more simulations are conducted with explicitly resolving e.g. boulders. However, most simulations make use of simplifications like using 2D cylindrical symmetries to reduce computation costs [e.g. 6]. Although this is a reasonable approach, it turns realistic 3D boulders into toroid shaped objects. The simulation of realistic 3D boulders has only started recently [7], and is still a demanding task in terms of resolution and computational power. From first images, the asteroid itself (apparently) is a complex body consisting of boulders and dust (i.e. rubble pile asteroid) like e.g. Ryugu or Bennu [e.g. 8 & 9]. Understanding the ongoing processes during the DART crater formation is crucial to predict the outcome for future kinetic deflection missions, which might not be test missions.

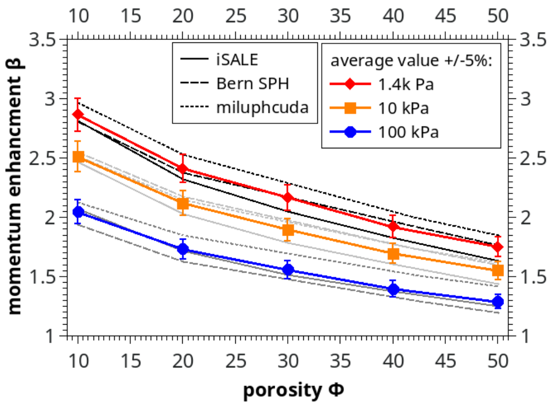

Figure 2: Efficiency of the momentum exchange for different porosities *Φ*. The results are from [10]. The colours indicate the average values for material cohesions of 1.4 kPa, 10 kPa and 100 kPa from three different shock physics codes.

In previous studies, we have investigated in detail the target response to a kinetic impact for various intermediate strong homogeneous materials in a 2D cylindrical geometry [3, 4, 7, 10] (Figure 2). Simulating the DART impact correctly is linked to answering the following questions:

- 1. What is the effect of reducing the strength of the target asteroid below previous assumed values? Where is the transition from local to global effects?
- 2. What is the effect of adding heterogeneities to the target asteroid? Is the cratering behaviour compared to homogeneous materials significantly altered? Can we reproduce laboratory experiments?
- 3. Most previous models have been conducted in 2D, while boulders are 3D objects. Also, the DART spacecraft impacted the target at some impact angle with respect to the surface. What is the effect of a realistic 3D geometry on the outcome of the DART impact?

These research questions represent current boundaries of state-of-the-art simulations and few studies expand beyond these limits. Pushing the material strength to very low levels in a low gravity regime as it is the case for asteroid Dimorphos requires long simulation times and is a computationally demanding objective, which has not yet been reached with an Eulerian shock physics code like iSALE. At the same time, the resolution needs to be sufficiently high to accurately simulate heterogeneities within the target. Conducting a detailed parameter study in 3D that accounts for varying boulder properties at low target strength, different boulder distributions (in size and space), and impact angles will yield novel results to the community (e.g. boulder fragmentation/ejection, crater size, global reshaping, asymmetries in the ejection process). We aim at validating our models against experiments that we have conducted previously within the framework of the DART & Hera missions. Our results are useful for follow up studies on the evolution of the asteroid system or for long term ejecta evolution models. The final aim is to reproduce the DART impact event as closely as possible.

References

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