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Momentum enhancement for the DART kinetic impactor

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Abstract

We study kinetic impacts of a spacecraft as an option to deflect sub-kilometer sized potentially hazardous asteroids that may collide with Earth. Near-Earth asteroids of this size are difficult to observe and at the same time are believed to be very common and to consist of a wide variety of materials with varying bulk densities. The momentum delivered by such an impact of a spacecraft may alter the asteroid's orbit and henceforth avoid an impact with our home world.

In addition to a direct transfer of momentum from the projectile to the target, a kinetic impact will also involve post-impact effects caused by material ejected from the impact site. This will result in a momentum transfer efficiency beta > 1 which is only weakly constrained. Thriving for constraining this beta factor, we investigate the impact of a spacecraft onto an asteroid similar in size to the secondary body of the binary near-Earth asteroid (65803) Didymos, the target of NASA's Double Asteroid Redirection Test (DART) and ESA's Hera mission concepts.

We present results from simulations with our own 3D smooth particle hydrodynamics (SPH) hypervelocity impact code. Depending on the impact angle and target porosity, we find beta factors between 1.15 and 1.93, which is compatible with results obtained in a previous study and by others using various methods.

1. Method and Simulations

We deploy our 3D smooth particle hydrodynamics (SPH) hypervelocity impact code (e.g., [10, 12, 5]) which implements elasto-plastic continuum mechanics with a fragmentation model for fracture and brittle failure [4, 1] and the P - α porosity model [7]. A tensorial correction as outlined in [11] warrants first-order consistency.

For the impact simulations we use a resolution of 1M SPH particles. The physical system is based on a rocky target with 160 m diameter that is hit at 6 km/s and angles of 0° (head-on) and 45°, respectively. The projectile is modeled as a single SPH particle with a mass of 500 kg. The target porosities range from 0 % (competent rock) to 75 %. The momentum transferred to the target is enhanced by a factor of beta which is determined by the total momentum carried away to infinity by the escaping ejecta. We calculate this beta factor as described in [9].

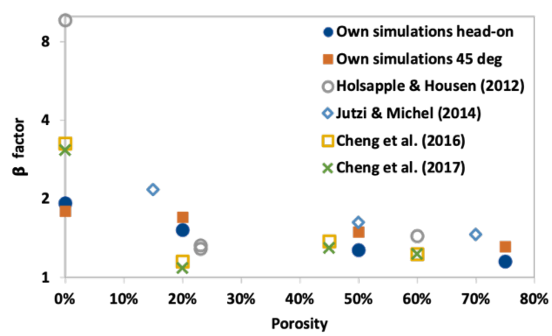

Figure 1: Comparison with existing results (**β** corrected for impact velocity v_p: β-1 ~ $v_p^{3\mu-1}$, [6]). References: [6] Holsapple & Housen (2012), [8] Jutzi & Michel (2014), [3] Cheng et al. (2016), [2] Cheng et al. (2017).

2. Results and Conclusions

Table 1 gives the beta factors for the simulated scenarios. Our results show larger momentum enhancement factors for compact (as opposed to highly porous) target material. As shown in Fig. 1, they are compatible with studies using scaling models for predicting momentum transfer efficiency [2, 3, 6], another SPH impact code [8], and own previous results of a slightly different set-up [9] (coincides with the blue circles in Fig. 1).

Table 1: Results for various impact configurations and porosities of the target.

Impact angle	Target porosity	Beta factor
Head-on (0°)	0 %	1.93
Head-on (0°)	20 %	1.52
Head-on (0°)	50 %	1.27
Head-on (0°)	75 %	1.15
45°	0 %	1.79
45°	20 %	1.70
45°	50 %	1.49
45°	75 %	1.31

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