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Isochoric Beam Deposition for Asteroid Deflection

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The study of asteroid deflection maneuvers show two deficiencies that would make the reliable deflection of large objects (1-3 km in diameter) impossible: Reliability and efficiency of the maneuver. Predicting the deflection from hydrocodes has shown a degree of dependence on the choice of strength model, inhibiting reliable prediction (see Stickle et al. (2019)). For efficiency of deflection (rate of transfer of momentum input to a change of momentum of the deflected object), nuclear devices have been shown to be the first choice. But even classical nuclear devices are so limited in efficiency, that this restricts the achievable Δv to a very narrow band (see Horan IV et al. (2021)).
Our ansatz to solve both problems is isochoric energy deposition by a particle beam. We plan to study this in a fully dynamical scale model, using the CERN hadron beam, where a meteorite sample target mimics the asteroid. Real-world, we will use a proprietary nuclear fusion scheme to realize this. In contrast, impactor mechanical deposition (as applied in NASA's DART mission in 09/22) is isentropic and needs a less efficient higher pressure level to deposit the same amount of energy (see Pasquali et al. (2019)). Hence, the isochoric deposition leads to a faster increase in temperature.
The transfer of momentum from the CERN hadron beam to the target consists of many components, ranging from elastic transfer (which already works at low thermal loads) to vaporization or even ionization at high energy deposition per volume. Vaporization or ionization lead to a rocket-like exhaust of the target from ejected material and in this regime should contribute the largest share of momentum transfer.
First results with FLUKA show that beam deposition should be much more efficient in achieving momentum transfer than any classical nuclear device. For the reliability question note that for the specific impulse I_{sp} of the target at vaporization or ionization
$I_{sp} \sim \frac{T}{M_{mol}}$
Here T denotes the temperature at ejection of the material and M_{mol} the molar mass. Since only the temperature at ejection enters, the goal is to show that isochoric heating arises fast enough to lead to heavily reduced dependence on the choice of strength model.
Main goal of the diagnostics is to show the transfer of momentum from beam to target in the different regimes. Key criteria for the choice of diagnostics are e.g. the spatial and temporal resolution to resolve the momentum transfer (since e.g. the phase of acceleration at one bunch of the CERN beam will only be on a nanosecond time scale).

References:

- Stickle et al., *Benchmarking impact hydrocodes in the strength regime: Implications for modeling deflection by a kinetic impactor*, Icarus 2019
- Horan IV et al., *Impact of neutron energy on asteroid deflection performance*, Elsevier 2021
- Pasquali et al., *Dynamic response of advanced materials impacted by particle beams: the MultiMat experiment*, Journal of Dynamic Behavior of Materials 2019

Themes for the contribution

1 R&D to support concepts

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