Working Group 1: Impact simulations

Image credit: ESA
Working Group 1: Impact simulations

Chairs: Kai Wünnemann / Martin Jutzi

Members of planetary science / astronomy community (cratering, collisions, small bodies, etc.)

- Modelling
  - Grid-based codes
  - SPH codes
  - Scaling-laws
- Experiments

Impact modeling + experiments by hypervelocity impact and engineering community

- Frauenhofer EMI
- SimChoc
- CEA

In collaboration with DART team
Goals of impact working group

Predict impact outcome

- Efficiency of momentum transfer
- Range of expected crater morphologies and properties of the surrounding surfaces

Complimentary to DART studies

Efficiency $\beta = \frac{\text{Didymoon mass} \times \Delta V}{\text{momentum}}$
Examples of ongoing modeling & experiments

Al sphere on Al half space modeling
(Based on AIDA benchmark studies)

LULI2000 facility, 1.7 TW/cm², 5ns at w irradiation focused onto 1mm thick Al target
## Examples of ongoing modeling & experiments

### EXPERIMENTAL REPRODUCTION OF DART IMPACT DIAGNOSTICS

<table>
<thead>
<tr>
<th>Feature</th>
<th>Impact flash</th>
<th>Momentum transfer</th>
<th>Impact ejecta</th>
<th>Cratering</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In-situ</strong></td>
<td>Emission spectroscopy</td>
<td>Ballistic pendulum</td>
<td>High-speed visualization</td>
<td>3D crater profilometry</td>
</tr>
<tr>
<td><strong>Post mortem</strong></td>
<td>Post mortem analysis</td>
<td>Weighing</td>
<td>Ejecta catcher, witness plates</td>
<td>3D scan</td>
</tr>
</tbody>
</table>

**Examples:**
- Emission spectroscopy
- Ballistic pendulum
- High-speed visualization
- 3D crater profilometry

*Fraunhofer EMI*
Initial impact modeling study

- **Test case:**
  - **Target (Asteroid Didymos B):**
    - Diameter ≈ 160m
    - Other physical properties such as density, porosity or strength are not well constraint so far
  - **Impactor:**
    - Impact velocity: 6 km/s
    - Impactor mass: 500 kg
    - Impact angle: head-on / 45° (3D models only)

**Goal:** illustrate differences due to different model approaches and assumptions regarding material properties
Initial impact modeling study

- Various groups using various methods
  - iSale shock physics code
    - Raducan et al.
    - Luther et al.
  - SPH shock physics codes
    - Maindl and Schäfer
    - Jutzi et al.
Initial results

iSale modeling by Raducan et al.

Results: Ejecta distribution for $Y_0 = 1 - 100$ kPa, $\phi_0 = 20\%$ and $f = 0.6$
Initial results

iSale modeling by Raducan et al.

Strong dependence of momentum transfer efficiency on material properties (strength, porosity)!

Figure 17:

-as a function of porosity and coefficient of internal friction, for three different cohesional strengths:

\(Y_0 = 1\) kPa,
\(Y_0 = 10\) kPa,
\(Y_0 = 100\) kPa.
Initial results

iSale modeling by Luther et al. (\(Y_0 = 1\) kPa; same conditions)

Overall good agreement, small difference due to different analysis of simulation data

Strong dependence of momentum transfer efficiency on material properties (strength, porosity)!

Sabina D. Raducan, Gareth S. Collins, Thomas M. Davison

HERA Benchmark

Figure 17: \(\beta - 1\) as a function of porosity and coefficient of internal friction, for three different cohesional strengths: \(Y_0 = 1, 10, 100\) kPa.
Initial results

SPH modeling by Maindl and Schäfer

Figure 2: Cumulative distribution of ejected mass versus velocity (cf. Holsapple and Housen, 2012).

Table 3: Values for head-on and 45 deg impact scenarios and different target porosity.

<table>
<thead>
<tr>
<th>Target porosity (%)</th>
<th>head-on</th>
<th>45 deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.93</td>
<td>1.79</td>
</tr>
<tr>
<td>20</td>
<td>1.52</td>
<td>1.70</td>
</tr>
<tr>
<td>50</td>
<td>1.27</td>
<td>1.49</td>
</tr>
<tr>
<td>75</td>
<td>1.15</td>
<td>1.31</td>
</tr>
</tbody>
</table>

Using the method outlined in Sect. 2.2 we find the values given in Table 3 and Fig. 3. As we expected from prior studies of others, momentum enhancement factors are larger for compact targets as opposed to material with high porosity. The factors decrease from 1.93 (non-porous) down to 1.15 (75% porous).

References


SPH modeling by Maindl and Schäfer
Both methods show similar dependence on porosity and strength

For ~ 100 kPa, ~ 50 % porosity, head-on impact:

\[(\text{Beta} - 1) \sim 0.3\text{-}0.5\]

\[-\text{good agreement}\]
Conclusions of initial modeling study

• Preliminary results indicate an overall good agreement between iSale and SPH calculations

• Results (beta factor, crater etc.) are very strongly depended on material properties
  ▸ strength is most important
  ▸ porosity and friction properties play also a role

• These properties need to be better constraint
  ▸ Laboratory experiments
  ▸ In-situ measurements at the actual scale!
Next steps

• Predict the impact outcome as function of material properties and impact conditions
  ‣ momentum transfer efficiency
  ‣ range of expected crater morphologies and properties of the surrounding surfaces

• Study of more complex effects
  ‣ shape, local topography, rotation etc.

• Connect in-situ observations with properties of subsurface
  ‣ improve understanding of impact processes