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Kinematic Impacts – Improved Modeling of Asteroid Deflection
Experimental and Numerical Approach

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Rome, Italy, 19th-24th September
CONTENTS

Motivation and requirement for modelling
Newly adopted approach
Numerical and Experimental design
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Future Work
MOTIVATION

Aims to model the kinematic impact asteroid deflection scenario....long-term impact evolution of the solar system

Limited by:

• Kinematic impacts that occur at the Centre of Mass of the asteroid
• Characterisation of the asteroid (analogue) physical/material characteristics
• Assumptions regarding the ejecta distribution and profile
MODELLING – APPROACH

Developing a model to account for:

- Impacts onto non-spherical, initially rotating bodies
- Occur from a given proximity to the CoM
- Variation in impact geometry
- Variation in asteroidal composition (Athen, Apollo etc)

Provide a realistic and improved deflection and cratering response of (kinematic) impacting events

Support this development, wished to provide validation data through experimental cratering events
EXPERIMENT - APPROACH

ESA Education Office – 2010 Spin Your Thesis! Campaign

8 m Large Diameter Centrifuge, with a payload capability of 80 kg

Intended to:

• Reproduce and investigate impact cratering events onto porous asteroid analogue bodies
• Provide cratering response data – validation and advancement of numerical models

Assess projectile density and target material (asteroid analogue) porosity as a function of crater formation and ejecta distribution
SIMILARITY ANALYSIS

Crater’s volume can be expressed as:

\[ V = f[a, U, \delta, \rho, Y, g, n...] \]

Standard tools of dimensional analysis:

\[ \frac{\rho V}{m} = f\left[ \frac{ga}{U^2}, \frac{Y}{\rho U^2}, \frac{\rho}{\delta}, n, \pi_M \right] \]

Further reduced to:

\[ \frac{(g_C)(a_C)}{U_C^2} = \frac{(g_A)(a_A)}{U_A^2} \]

\[ a_A = a_C \left( \frac{g_C}{g_A} \right) \left[ \frac{U_A}{U_C} \right]^2 \]

‘Gravity regime’ dominates the cratering process

(Schmidt & Holsapple, 1987; Housen & Holsapple 2002)
SIMILARITY ANALYSIS

Increasing role of gravity

\[ \pi_2 = \frac{g a}{U^2} \]
# EXPERIMENT

Target material - mixture of quartz sand and expanded perlite

### Table 2: Target Material Mixture

<table>
<thead>
<tr>
<th>Mixture (Percentage by Mass)</th>
<th>Average Density (g/cm³)</th>
<th>Average Porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expanded Perlite</td>
<td>Quartz Sand</td>
<td>Water</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>27</td>
<td>52</td>
</tr>
<tr>
<td>11</td>
<td>59</td>
<td>30</td>
</tr>
</tbody>
</table>
EXPERIMENT

For each sample, impact events occurred at increasing levels of acceleration

- Recorded each impact onto high speed cameras
- Measured the crater diameter, shape, cross-section depth
- Preserved selected samples through application of a epoxy resin

Enable later topographical scans

Analysis of possible microscopic compaction as a function of distance via a SEM
EXPERIMENT AT ESA/ESTEC

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OBSERVED TRENDS

- With very high porosity samples (96 %), under increasing acceleration:
  - More ejecta remained within the crater bowl.
  - Noticeable & increasing central peak
  - Crater becomes smaller, with some irregular impact craters.
OBSERVED TRENDS

- At high porosity (approx 70 %) sample, under increasing acceleration:
  - Crater becomes slightly wider, with an decreasing depth.
  - Much less ejecta escapes the crater rim.

- At mid porosity (approx 60 %) under increasing acceleration:
  - Crater shape is far more coincident between tests
  - Decreasing crater size, with less ejecta
CLOSING REMARKS & FUTURE WORK

- Ongoing analysis will provide data for the advancement and validation of numerical code
  - Include detailed material characterisation of the asteroid-analogue target material and cratering response
  - Analysis is ongoing – data was collected last week!
- 2010 Spin Your Thesis! Campaign provided a solid foundation, and prove of concept for the experimental design

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Thank you for your Time

ANY QUESTIONS?