Simulation of Debris Creation in hypervelocity Impact

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OUTLINE

1. Background

2. Software to simulate hypervelocity impact and typical applications

3. Simulation for orbital object break up (debris creation) in hypervelocity collision

4. conclusions
1. background

- Orbital debris is increasingly concerned because of more aerospace activities manned spacecraft.

- As the large relative velocity, a fatal damage could be occurred if a spacecrafts is impacted by debris even with very small mass.
- debris $> 10 \text{ cm}$ $\sim 20,000$ objects
- debris $1 \sim 10 \text{ cm}$ a million
- debris $< 1 \text{ cm}$ tens of million
The resources of space debris

(1) human aerospace activities

- Separation of satellite from launch vehicle
- Space operation
- Last stage of launchers
- Satellites without function (out of use)

(2) Collision between orbital objects,

10 cm debris collision ---- new debris cloud containing more than one million fragments 1 mm in size and larger can be created.
1. Simulation of debris cloud evolution
The evolution procedure of given debris cloud

**Spherical**  60s,

**Ellipsoidal**  1800s, 4500s, 18000s

**Funiform**  9h, 12h, 60h
Gyroidal
1d, several d, >10d

Omnidirectional filling
2y (LEO)
NASA Model for debris creation

- NASA model is built based on the test and space surveillance data.

- NASA Model cannot consider the material property and the configurations of impact objects.

\[
N_{\geq L_c}(L_c) = 0.1(MV)^{0.75}L_c^{-1.71}
\]
2. Software to simulate hypervelocity impact and typical applications

Hypervelocity Impact ($V > 1 \text{ km/s}$)

Available Commercial software

Autodyne 2D and 3D

LS – Dyna
Hypervelocity impact

Fragment: sphere diameter 9.53mm, 1.2g;
Target: plate thickness 2.2mm
Impact velocity: 6.64km/s.

Experiment phenomenon                  computational simulation
SPH simulation principle
Hypervelocity impacting with LS-Dyna

a) 5μs  b) 10μs  c) 15μs  d) 20μs
Damage after impact
Typical Study with LS-Dyna or Autodyne

- Simulating the phenomena of impact with different bullet velocities, shooting angles, mass and sizes.
- Estimating the critical damage conditions for space structure, and used for protecting design.

This work use it to simulation the body break up in hypervelocity impact

Then to estimate the number of debris with special sizes.
3. Simulation for break up in hypervelocity collision

Use FEM Mesh to establish SPH particles
Use 0-1 drawings to statistic number of debris.
Parameters Determination

Debris size vs FE mesh size
Parameters Determination

Debris size vs simulation time

- Quantity of fragments larger than L
- Simulation termination time (μs)
Simulation example of hypervelocity collision

LS-DYNA keyword deck by LS-PRE
Non-central hypervelocity collision
Non-central hypervelocity collision
Non-central hypervelocity collision
Non-central hypervelocity collision
Central hypervelocity collision
Central hypervelocity collision
Central hypervelocity collision
Central hypervelocity collision
Central hypervelocity collision
Example for real happened space collision

Thanks David Wright for the fig.
Central impact simulation result (2)

Small fragment view at 0-1ms after the impact
Collision on different position

\[ m_e = \frac{2 \min\left( m_n^C, m_n^l \right)}{m^C + m^l} \]
Fixing the position of Iridium33 and change the impact location of Cosmos2251 we can get the DENIM distribution.

The maximum number is 0.38.
## Fragments statistics

<table>
<thead>
<tr>
<th>No</th>
<th>δz (cm)</th>
<th>δx (cm)</th>
<th>Cosmos2251 NIM (kg)</th>
<th>Iridium33 NIM (kg)</th>
<th>DENIM</th>
<th>DSFM</th>
<th>DLFM</th>
<th>Fragment amount</th>
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**DENIM**  Dimensionless Equivalent Normal Impact Mass  
**DLFM**  Dimensionless Large Fragment Mass  
**DSFM**  Dimensionless Small Fragment Mass  

Observation for 10 cm fragment is 1719
Debris orbits 1 hour after the collision including debris > 1cm.

It does not need 1-3 years. Several hours are enough for the debris to spread over all LEOs.
4. Conclusions

(1) The work uses SPH method to simulate the orbital object break up in hypervelocity impact.

(2) Compared NASA model, this simulation can consider more situations of object, including materials as well as configurations.

(3) Real happened spacecraft collision simulation is conducted. The result comply to the observation date.

(4) Further study should be continue to obtain more effective model.
Thank You for Attention!