Modeling and Simulation of a High Fidelity Electronics Assembly Responding to Drop Test

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Miroslav Tesla, Jennifer A. Cordes, Janet Wolfson
Engineering Analysis & Evaluation Division
AETC, U.S. Army ARDEC, Picatinny Arsenal, NJ 07806-5000
973-724-9503 (fax: 973-724-2417), miroslav.tesla.civ@mail.mil
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GOALS, SCOPE

• **Goals:**
  – Joint effort of DOD and DOE to quantify the capabilities of computational codes to accurately predict the response of an instrumented fuze to a known shock.
  – The purpose of the modeling and simulation was to predict the board accelerations in a blind study. Other agencies made similar predictions using a variety of finite element codes. Other tests were also conducted. This paper is limited to the work done at Picatinny Arsenal on a test article 3 (TA3) labeled by the Air Force as Series 1 Test 1.

• **Scope**
  – Model: MTS TA3, housing, boards and major electronics components filled with potting, MTS test apparatus.
  – Abaqus Explicit 2016HF2, dynamic analysis.
  – Evaluate: Acceleration during the impact. Predict acceleration readings for all 4 accelerometers placed on 4 boards. Compare accelerometer readings during MTS test with FEA predictions.
- General Purpose Finite Element Software: Abaqus Explicit 2016HF2
- Analysis: dynamic, non-linear materials, non-linear geometry
- Analysis time: 0.001 seconds
- Full model
- Parts: Imported from CAD or defined in Abaqus CAE. All parts modeled as deformable.
- Elements: 8-node linear brick elements, reduced integration, hourglass control
- Loads: Shock load per Test Unit104_20H_F1_16_1 (Series 1- short duration) input data - test data from AFRL Eglin).
- Boundary: Constrained Guides and Seismic Mass
- Initial Conditions: Initial velocity 17 ft/s
- Friction: Friction coefficient 0.3, all contact surfaces.
- Damping: material viscoelastic damping.
– Geometry was defeatured.
– General contact with coefficient of friction 0.30 for all contact. Slipping effects, temperature and pressure dependences are ignored.
– Threaded connections were not modeled, instead contacting surfaces were tied.
– Retainer preload was not applied.
– It is assumed that potting material filled all cavities above the “Potting Cap”. Weight of parts were adjusted to match weight of the assembly. Interaction between Closure Ring and Housing were assumed as glued (tie constraints). Fixture and Retainer materials were assumed as steel AISI 4340.
The axial fixture was bolted to the MTS drop tower table adapter plate using 3/8-16 – 1” bolts.

The drop tower table was dropped at heights of 20” and 72”. Mitigating material was used between the drop tower table and the seismic mass to control the pulse shape.

Inputs provided to the performer consist of the measurement of the 5 exterior accelerometers.

Axial fixture mounted on MTS drop tower table adapter plate which in turn is mounted on the drop tower table.

MTS Drop Test at Eglin AFRL
METHOD: ACCELEROMETERS’ LOCATION

a) Board 4 - Burst Point Module
b) Board 3 - Burst Point Module
c) Board 2 - Firing Module
d) Board 1 – Firing Module
Electronic components modeled
Electronic components modeled
RESULTS
BOARD ACCELERATIONS

Abaqus
Board 1 Accel
BW filt. 10kHz fo4 (gs)

Unit104_20H_F1_16
1 Board1 BW filter 10kHz (gs)

Abaqus
Board 2 Accel
BW filt. 10kHz fo4 (gs)

Unit104_20H_F1_16
1 Board2 BW filter 10kHz (gs)

Abaqus
Board 3 Accel
BW filt. 10kHz fo4 (gs)

Unit104_20H_F1_16
1 Board3 BW filter 10kHz (gs)

Abaqus
Board 4 Accel
BW filt. 10kHz fo4 (gs)

Unit104_20H_F1_16
1 Board4 BW filter 10kHz (gs)
Example of the Peak and Duration Calculation

The peak and duration values were extracted from the first pulse. Example of the peak and duration calculation were shown. The value of the green triangle is the peak. The time difference between the red squares is the duration. The values of the red squares were defined as 10% of the peak values.
<table>
<thead>
<tr>
<th>Accelerometer Location</th>
<th>Source</th>
<th>Peak (kGs)</th>
<th>Duration (ms)</th>
<th>% Diff of Peak</th>
<th>% Diff of Duration</th>
<th>Sum of Peak and Duration % Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Board 1</strong></td>
<td>Test 104_72H_1</td>
<td>11.181</td>
<td>0.142</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Abaqus (1GC_MTS_TA3_r45)</td>
<td>13.520</td>
<td>0.120</td>
<td>20.9</td>
<td>15.5</td>
<td>36.4</td>
<td></td>
</tr>
<tr>
<td><strong>Board 2</strong></td>
<td>Test 104_72H_1</td>
<td>14.416</td>
<td>0.126</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Abaqus (1GC_MTS_TA3_r45)</td>
<td>13.726</td>
<td>0.117</td>
<td>4.8</td>
<td>7.1</td>
<td>11.9</td>
<td></td>
</tr>
<tr>
<td><strong>Board 3</strong></td>
<td>Test 104_72H_1</td>
<td>12.360</td>
<td>0.134</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Abaqus (1GC_MTS_TA3_r45)</td>
<td>14.151</td>
<td>0.116</td>
<td>14.5</td>
<td>13.4</td>
<td>27.9</td>
<td></td>
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<tr>
<td><strong>Board 4</strong></td>
<td>Test 104_72H_1</td>
<td>20.852</td>
<td>0.105</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Abaqus (1GC_MTS_TA3_r45)</td>
<td>14.234</td>
<td>0.114</td>
<td>31.7</td>
<td>8.6</td>
<td>40.3</td>
<td></td>
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<tr>
<td><strong>Board Averages</strong></td>
<td>Test 104_72H_1</td>
<td>14.702</td>
<td>0.127</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Abaqus (1GC_MTS_TA3_r45)</td>
<td>13.908</td>
<td>0.117</td>
<td>5.4</td>
<td>7.9</td>
<td>13.3</td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

SUM OF SQUARED ERRORS (SoSE)

\[ SoSE = \text{CumSum}(Errors^2) \]
RESULTS

• Computational Information (1GC_MTS_TA3_r45):
  – Computer Program Used: Abaqus
    2016HF2
  – Number of Elements: 4,575,104
  – Number of Nodes: 5,464,022
  – Number of nodes defined by the user: 5,464,022
  – Total number of variables (degrees of freedom) in the model: 16,423,353

• Analysis Type
  – Solver: Abaqus Explicit
  – Duration: 19 hours
  – Time Step: 2.271e-9 sec
  – Updating Criteria:

• Computer: 72 cpus were used for 19 hours on ARDEC HPCC-4 computer
• Queue Time: None
Conclusions

• Modeling and simulation should go hand-in-hand with testing. Tests provide loads, validation, and material data for modeling and simulation.

• Exact predictions for accelerations are difficult due to variations in materials, tolerances, loads, directionality of loads, constraints, friction, preloads, contact, etc.

• This analysis demonstrates good match between board accelerations collected during test performed on MTS drop tower and Abaqus predictions. The peak acceleration has a reasonable good match for all four boards. The shape of the acceleration response was also reasonably accurate for the four circuit boards.