Bullets Behaviour in Ballistic Simulants

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- a. REPORT: unclassified
- b. ABSTRACT: unclassified
- c. THIS PAGE: unclassified

Limitation of abstract: Same as Report (SAR)

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Goal

• Create a FE model capable of predicting the effect on the gelatin when stuck by different projectiles
• Perform a parametric study on the effect of calibre on wound track

• The FEM needs to account for damage in the gelatine
  – Velocity decay
  – Dynamic cavitation
  – Permanent cavitation
  – Final penetration depth
• And projectile fragmentations

• Increases *Physical Understanding* of impact events and wound effects
Modelling of Terminal Ballistic Events

• Terminal ballistics events include
  – Impact, shock and blast loading on targets
  – Blast, lethal and blunt impact on human and animals
  – Penetration and perforation of targets
  – Behind armour effects

• Hydrocodes are used to model numerically terminal ballistic events
  – Finite element code used for analyzing response of targets under static or dynamic loading conditions
Constitutive Model for 10% Gelatin

- The mechanical behaviour of ballistic gelatin is a typical hyperelastic.
- Under SHPB tests, samples typically fail through the initiation of radial cracks.
- Temperature has an effect.
- Increasing stiffness with increasing strain rate.
Constitutive Model Implementation

- Collect materials information at high strain rate
  - Compressive/tensile data
  - Penetration and wave speed
- Constitutive models
  - A traditional hyperelastic model was used but:
    - was insufficient for the intermediate and high strain rate
  - A rate-dependant hyperelastic constitutive model was used
    - Required tensile data
    - Sensitivity study demonstrated that the impact response was not significant dependant on the tensile response
Steel Sphere (BB) Impact Model

- The BB impact was used as a baseline to develop the material model and any associated failure criteria.
- The nominal diameter was: 4.5mm (BB-type).
- Lagrangian formulation was used.
BB Steel Sphere

- The resulting temporary and permanent cavities are in reasonable agreement with typical gelatin response.
- The permanent cavity is on the order of the projectile diameter, in agreement with Fackler.
- The overestimation of the permanent cavity is due to element erosion.

<table>
<thead>
<tr>
<th>Velocity (m/s)</th>
<th>Target Penetration (mm)</th>
<th>Predicted Penetration (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>25.2</td>
<td>28.5</td>
</tr>
<tr>
<td>90</td>
<td>43.6</td>
<td>45.2</td>
</tr>
<tr>
<td>120</td>
<td>61.9</td>
<td>58.2</td>
</tr>
</tbody>
</table>

Temporary cavity | Permanent cavity
9mm Ball

• Results for a 2D 9mm NATO Ball model
  – Projectile does not deform and begins to tumble after approximately 150 mm penetration (6po)
  – Initial temporary cavity is approximately 2x the projectile diameter
  – 2D axi-symmetric analysis was in agreement with the experimental data
5.56mm bullet, high velocity

- Results for 5.56mm
  - Projectile does fragment and began deforming at 3po DP
  - The steel core fragment and detached from the projectile
  - The steel core was stopped at approximately 6po DP, while the lead completely penetrated the gelatine
5.56 mm vs. 6.67 mm
Average Bullet Speed

- Only 5.56 mm releases all its E.K. on the block
- 5.56mm decelerate quickly, has small neck length and fragment early
- 6.67 mm exits with low velocity and releases most of its initial E.K.
- Calibers from 7.62 mm and up behave in the same way
Conclusion

- In general:
  - Numerical modelling plays an important role in the study of terminal effects of small arms
  - Better understanding of the phenomena that are difficult to examine using experimental methods
  - Optimization of the number of experimental trials and savings of time and money
  - Fast trade up analysis for bullet design