

Bullets Behaviour in Ballistic Simulants

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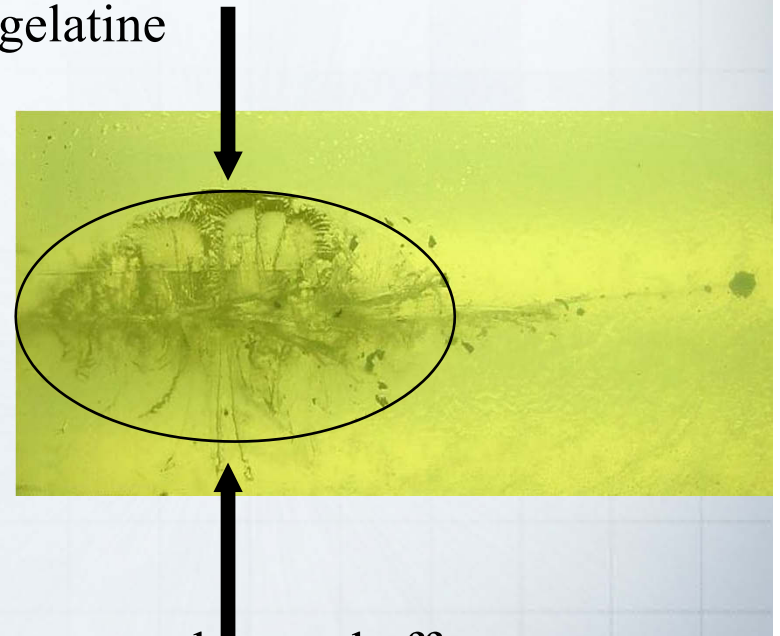
WOUND BALLISTICS SYMPOSIUM
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Goal

- Create a FE model capable of predicting the effect on the gelatin when struck 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



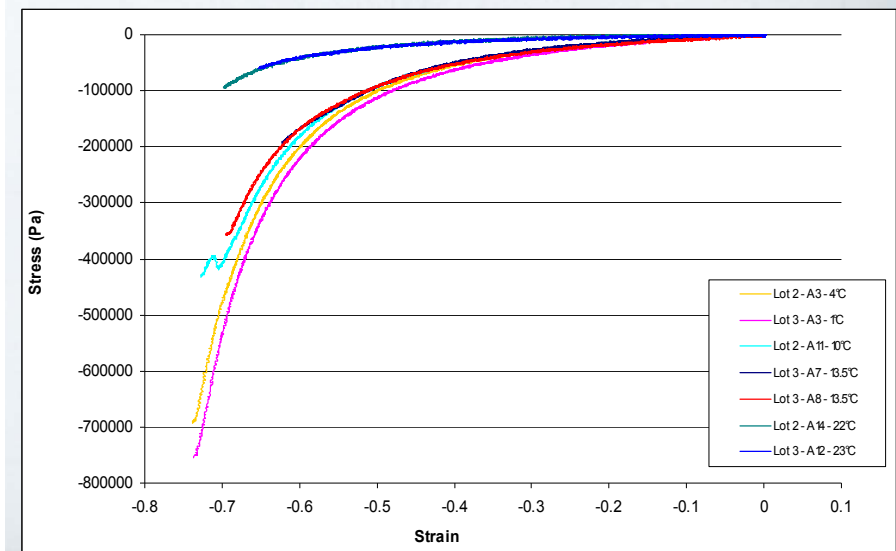
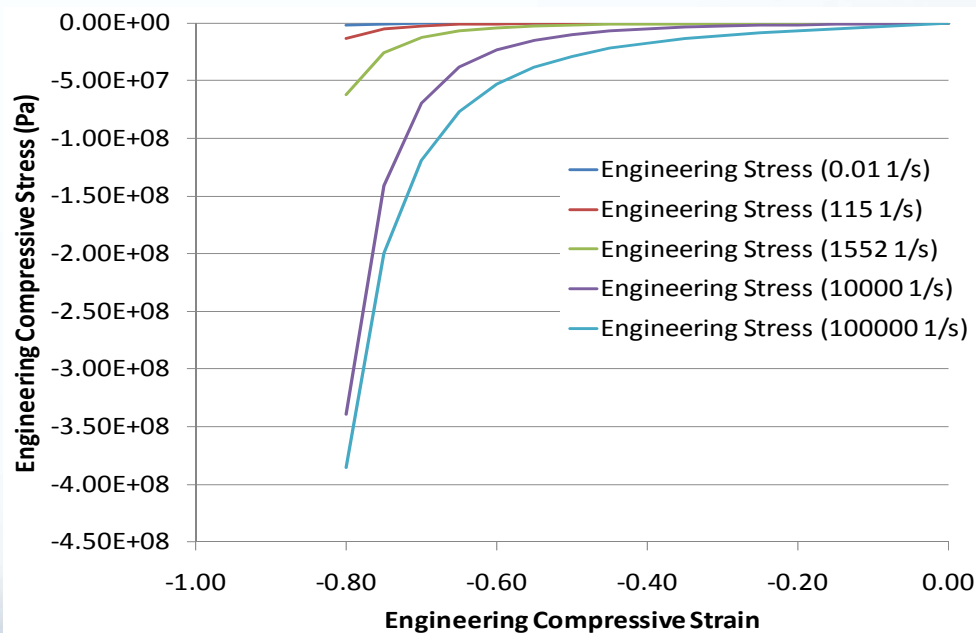
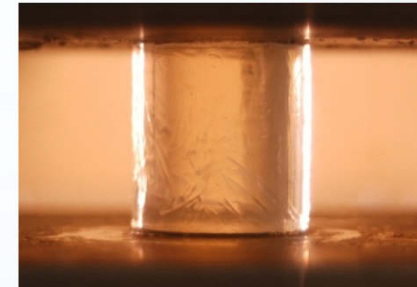
Modelling of Terminal Ballistic Events

- 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

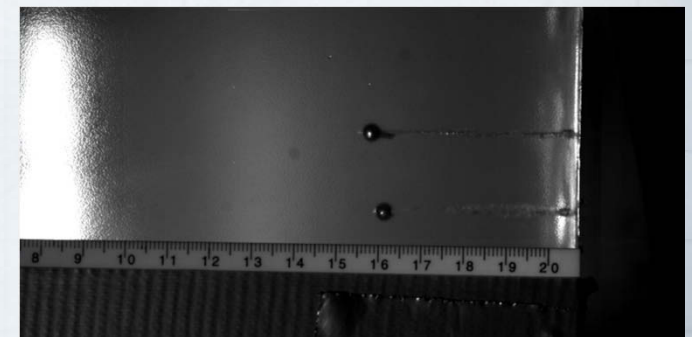
- The mechanical behaviour of ballistic gelatin is a typical hyperelastic
- Under SHPB tests, samples typically fail through the initiation of radial cracks
- Temperature has an effect
- Increasing stiffness with increasing strain rate



Temperature effect on quasi-static response of 10%, 4°C ballistic gelatin at 0.01s⁻¹

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

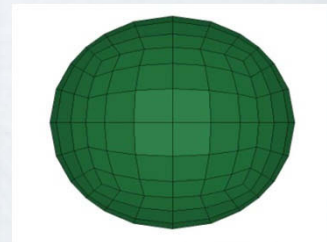
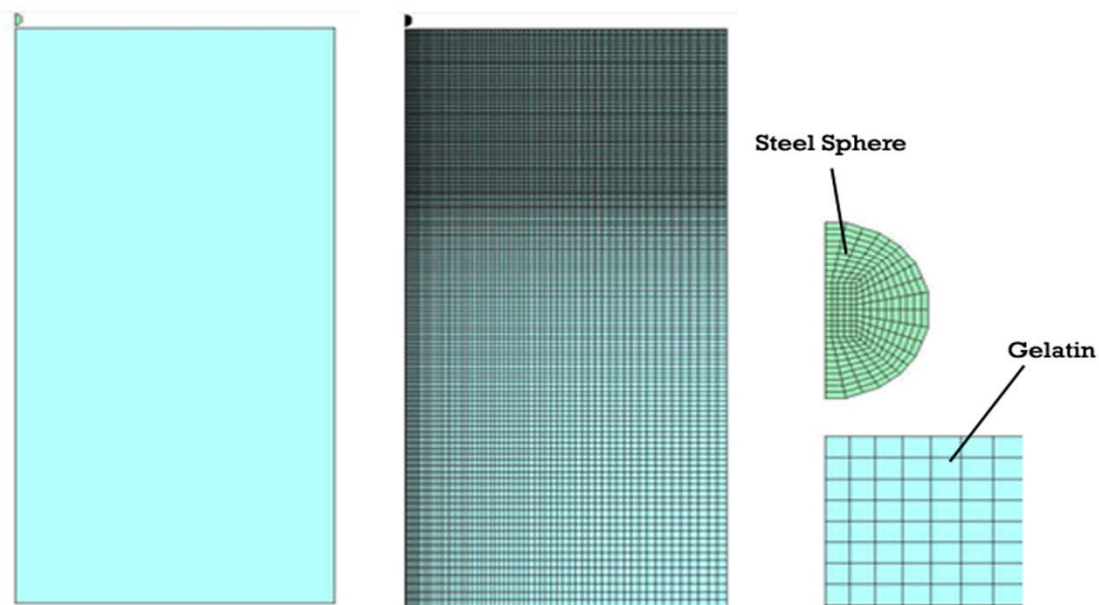


BB sphere

Steel Sphere (BB) Impact Model

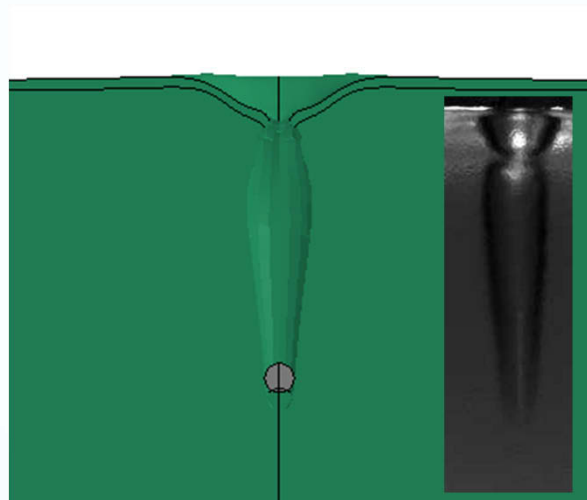
- The BB impact was used as a baseline to develop the material model and any associated failure criteria
- The nominal diameter was: 4.5mm (BB-type)
- Lagrangian formulation was used

Axisymmetric Model

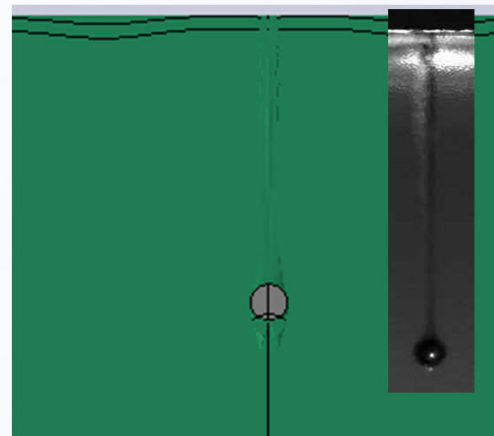


BB Steel Sphere

- 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 over estimation of the permanent cavity is due to *element erosion*



Temporary cavity

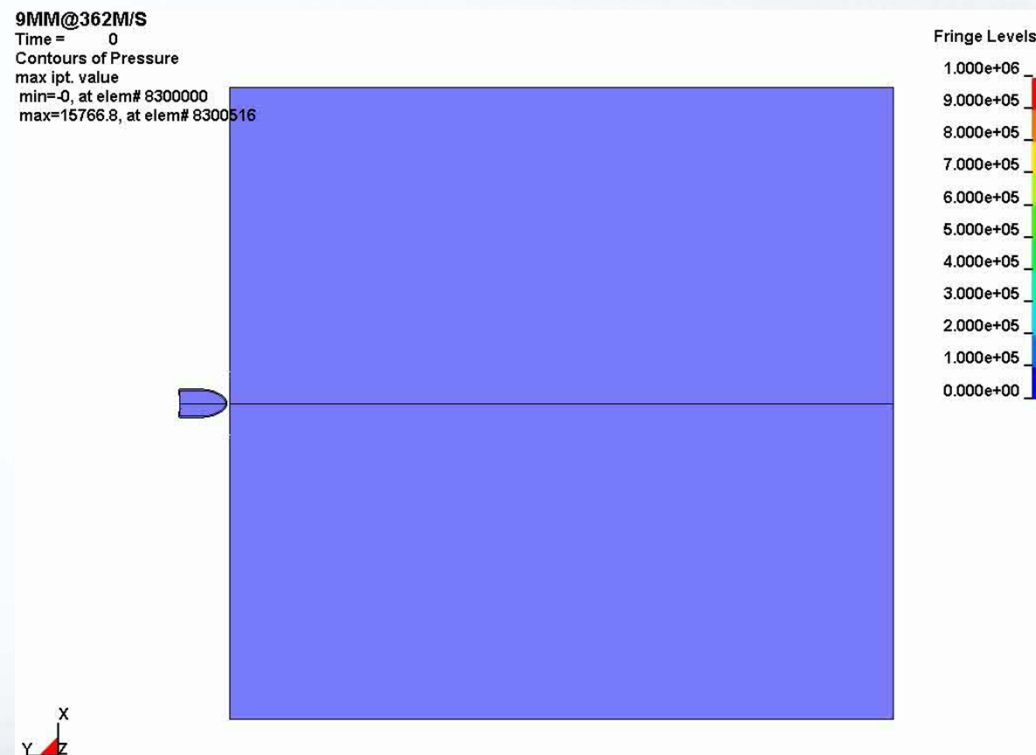


Permanent cavity

Velocity (m/s)	Target Penetration (mm)	Predicted Penetration (mm)
60	25.2	28.5
90	43.6	45.2
120	61.9	58.2

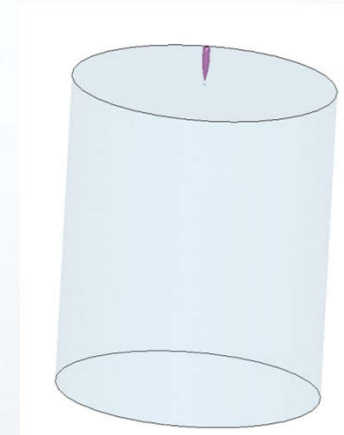
9mm Ball

- 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

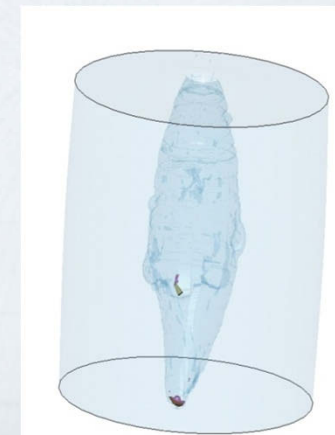
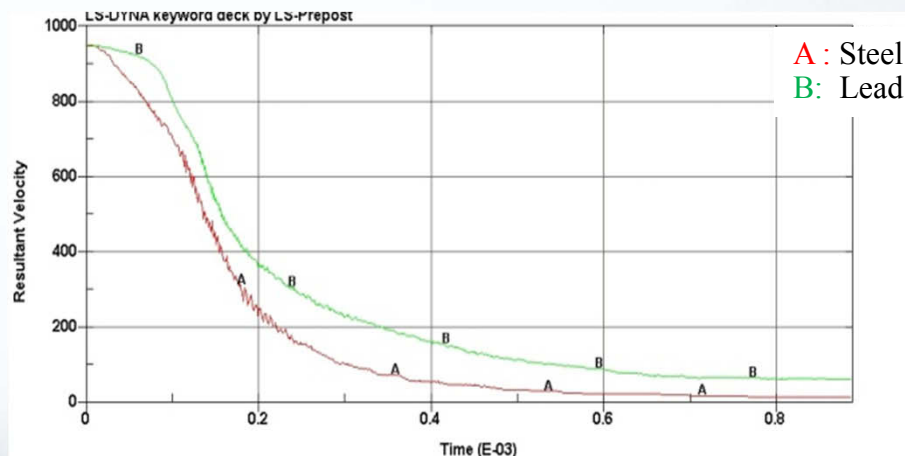


5.56mm bullet, high velocity

- 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



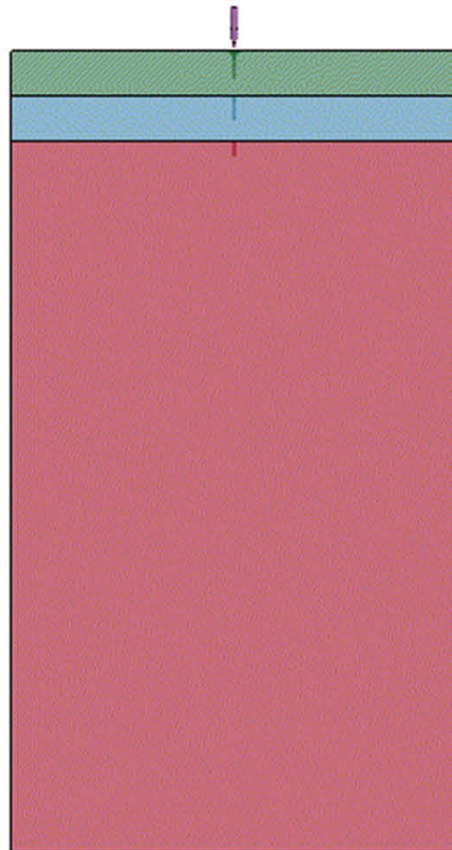
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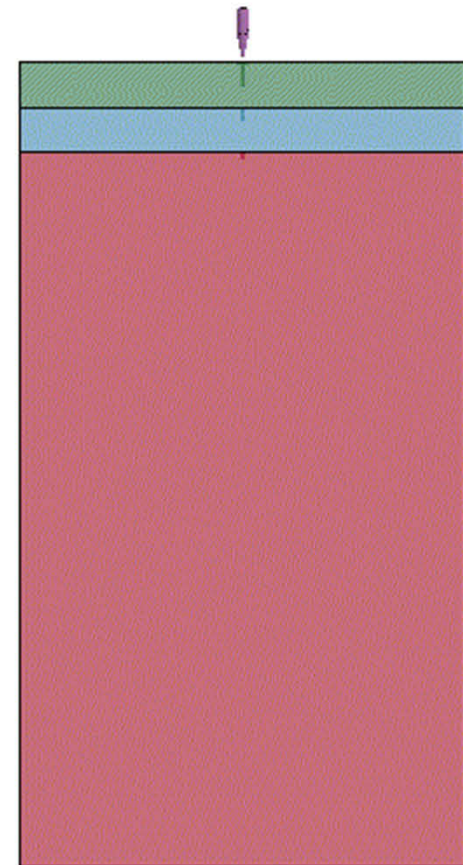
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5.56 mm vs. 6.67 mm

3d gelatin
Time = 0

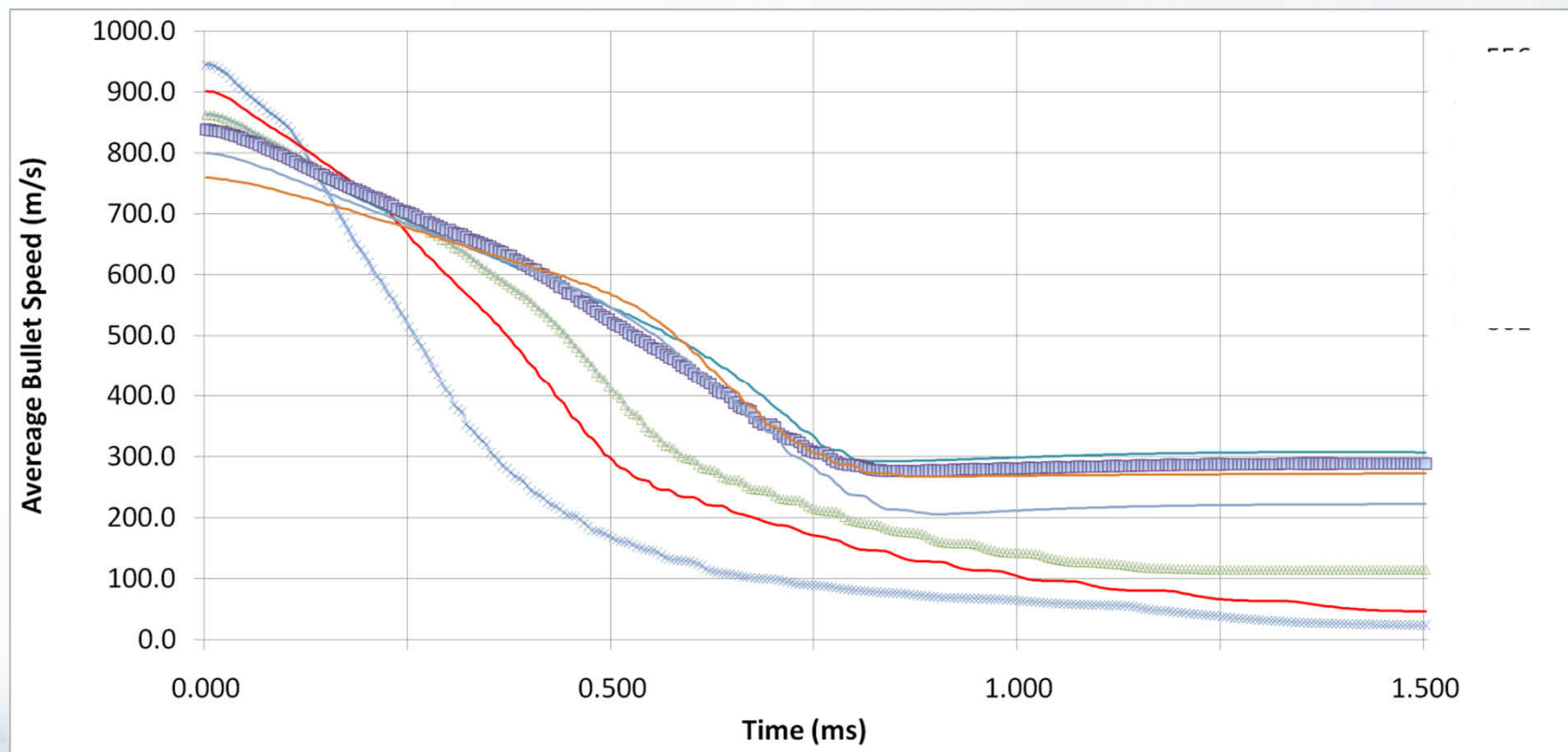


3D GELATIN
Time = 0



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

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