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The Effect of Velocity on Jacketed Rod Efficiency

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Objective

The objective of this work was to determine the penetration performance of steel jacketed rods against armor steel (RHA) targets at velocities above 2.2 km/s.

This effort sought to extend the velocity range above the previously considered 2.2 km/s in an attempt to reach the penetration performance of tungsten rods.

Introduction

This study consisted of hypervelocity experiments and supporting numerical simulations. Steel jacketed rods with core to jacket diameter ratios (mu) of 0.6 and 0.4 were investigated at nominal velocities of 2.6 and 2.8 km/s.

The results of the experiments were compared to the simulations for resultant crater size and normalized penetration (P/L).

Penetrators

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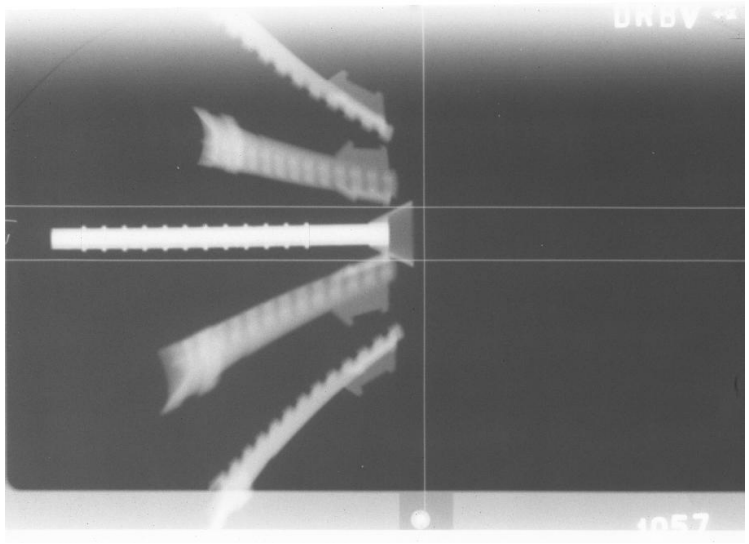

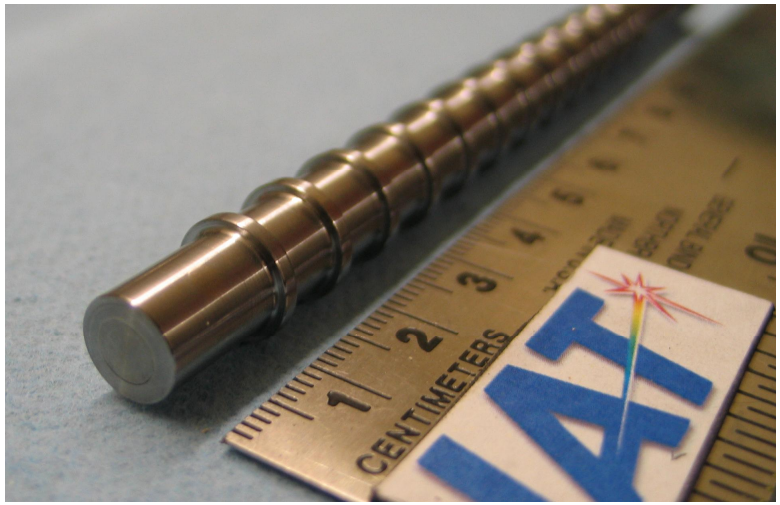

<u>Materials</u>:
W-Ni-Co Core rod
4340 Steel Jacket
Co-based brazing alloy for bond

ID/OD Ratios (Mu): 0.6, 0.4
L/D = 15
Rod mass and length were constant
Velocities: ~2.6 and 2.8 km/s

Penetration Channels

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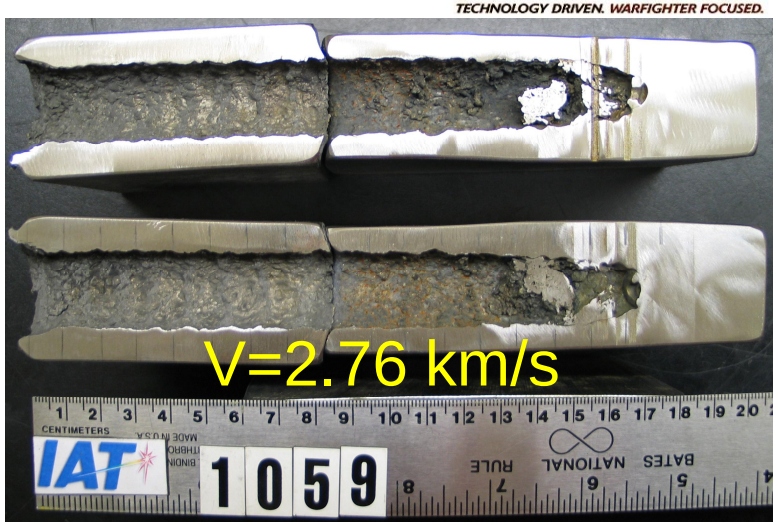
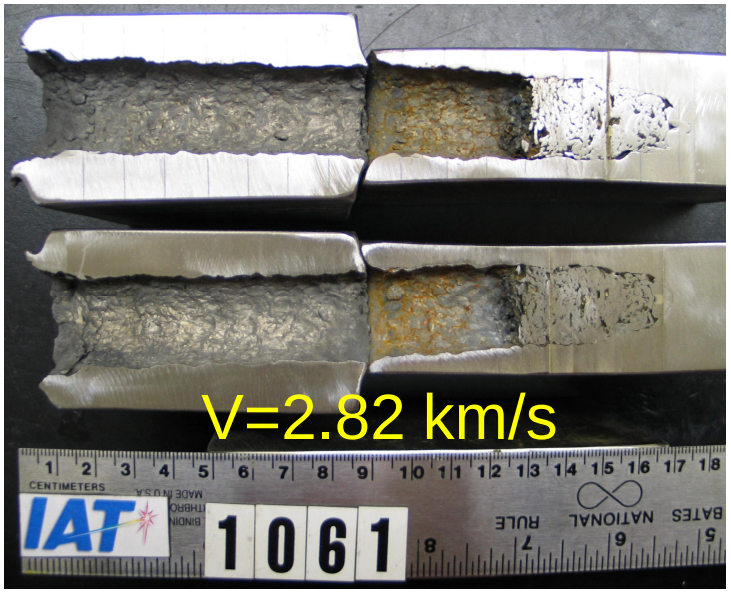
Mu=0.6



Mu=0.4



In general, the mu=0.6 craters were deeper but the mu=0.4 had larger crater diameters and more material in the bottom.

malized Crater Diameter

A comparison of the normalized crater diameter (H/D) from the jacketed rod tests to the Bjerke* relation for tungsten rods was made. For the jacketed rod data, the crater diameter (H) was normalized by the jacketed rod diameter (D_j) and the diameter of an equal mass and length tungsten rod (D_e).

$$D_e = \left[D_c^2 \left(\left(\frac{1}{\mu^2} - 1 \right) \frac{\rho_j}{\rho_w} + 1 \right) \right]^{1/2}$$

Average density

* Bjerke, Int. J. Impact Engineering **12**, 281-292, 1992

malized Crater Diameter

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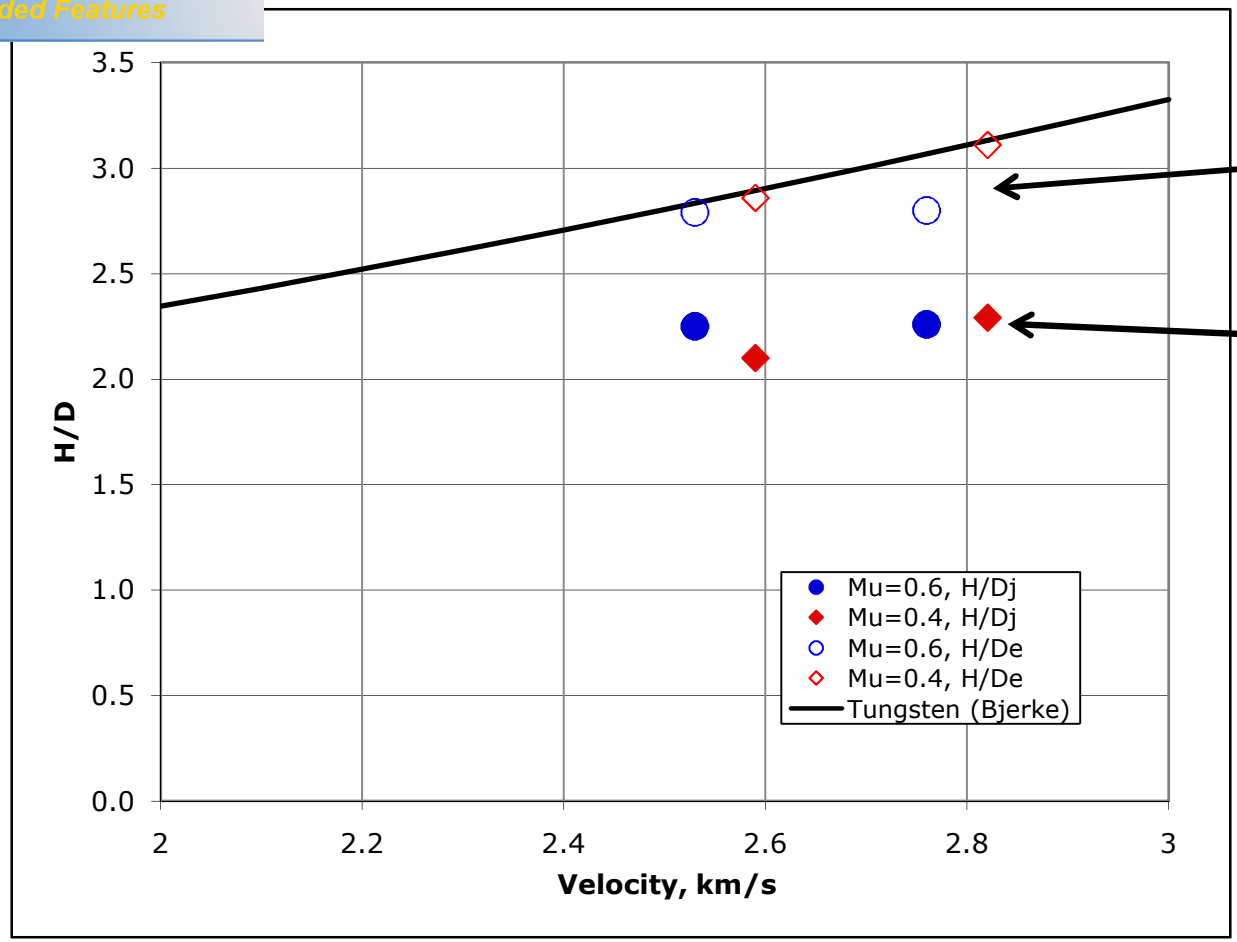

The crater diameter appears to scale as the square root of the average density.

Penetration Results

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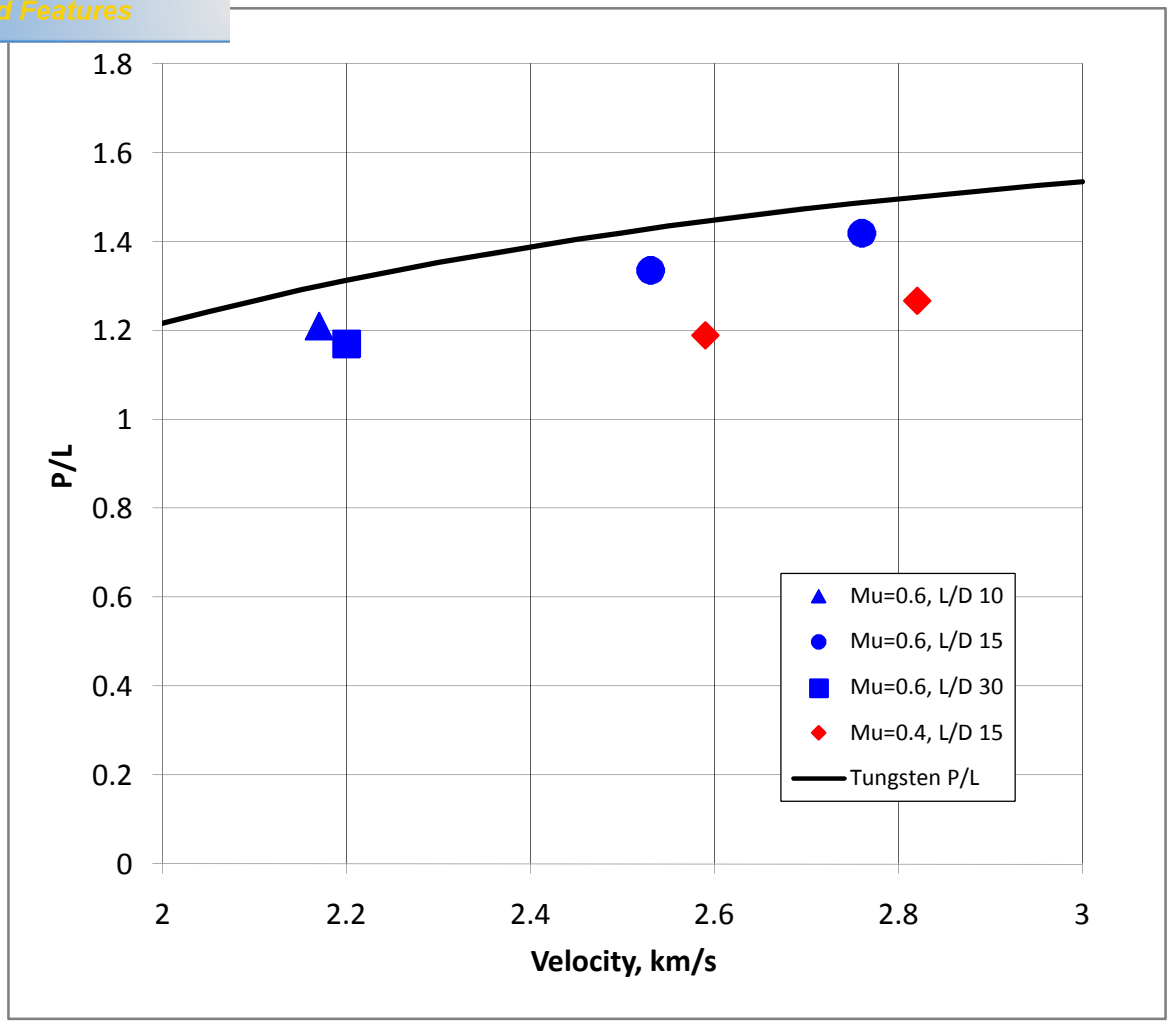

P/L does not depend on L/D at 2.2 km/s (10-30).
Jacketed rods never penetrate as well as all-tungsten rods but closely approach the performance as velocity increases.

Numerical Modeling

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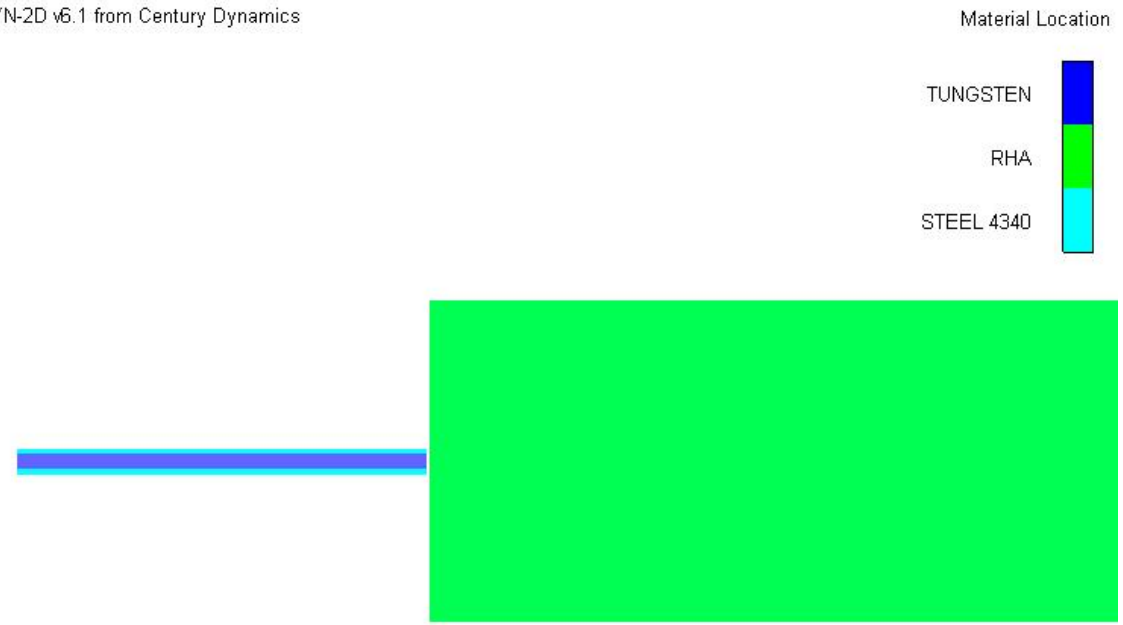
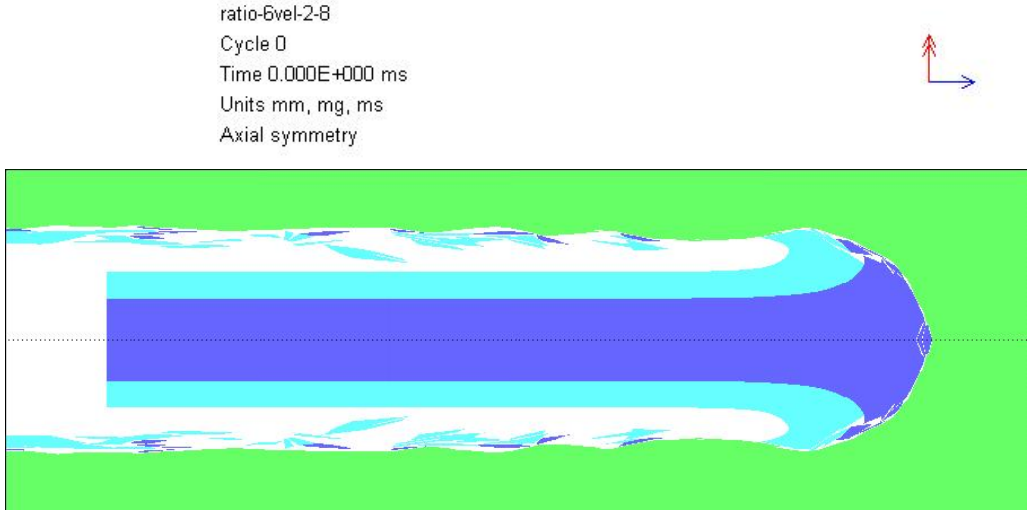
2D axis-symmetric AUTODYN Lagrangian solver.

Simulated tungsten rods, and Mu=0.4 and 0.6 jacketed rods at V=2.2, 2.6, 2.8 km/s.





rical Modeling – Crater Size

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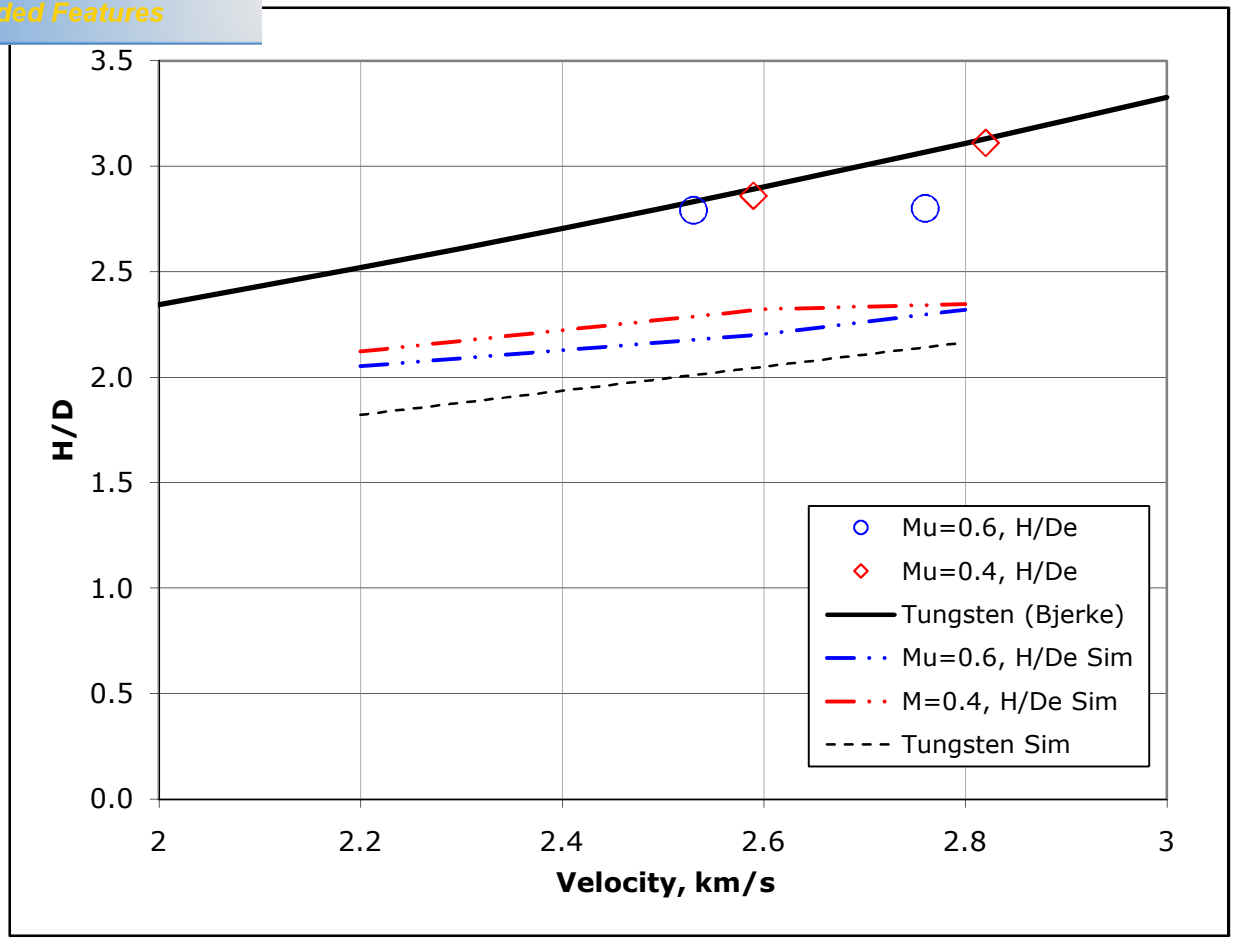

The simulated crater size is significantly less experimental data.
In the simulations, craters from tungsten rods are smaller than craters from jacketed rods, which is not correct.
AUTODYN is not accurately modeling the crater growth.

...ical Modeling - Penetration

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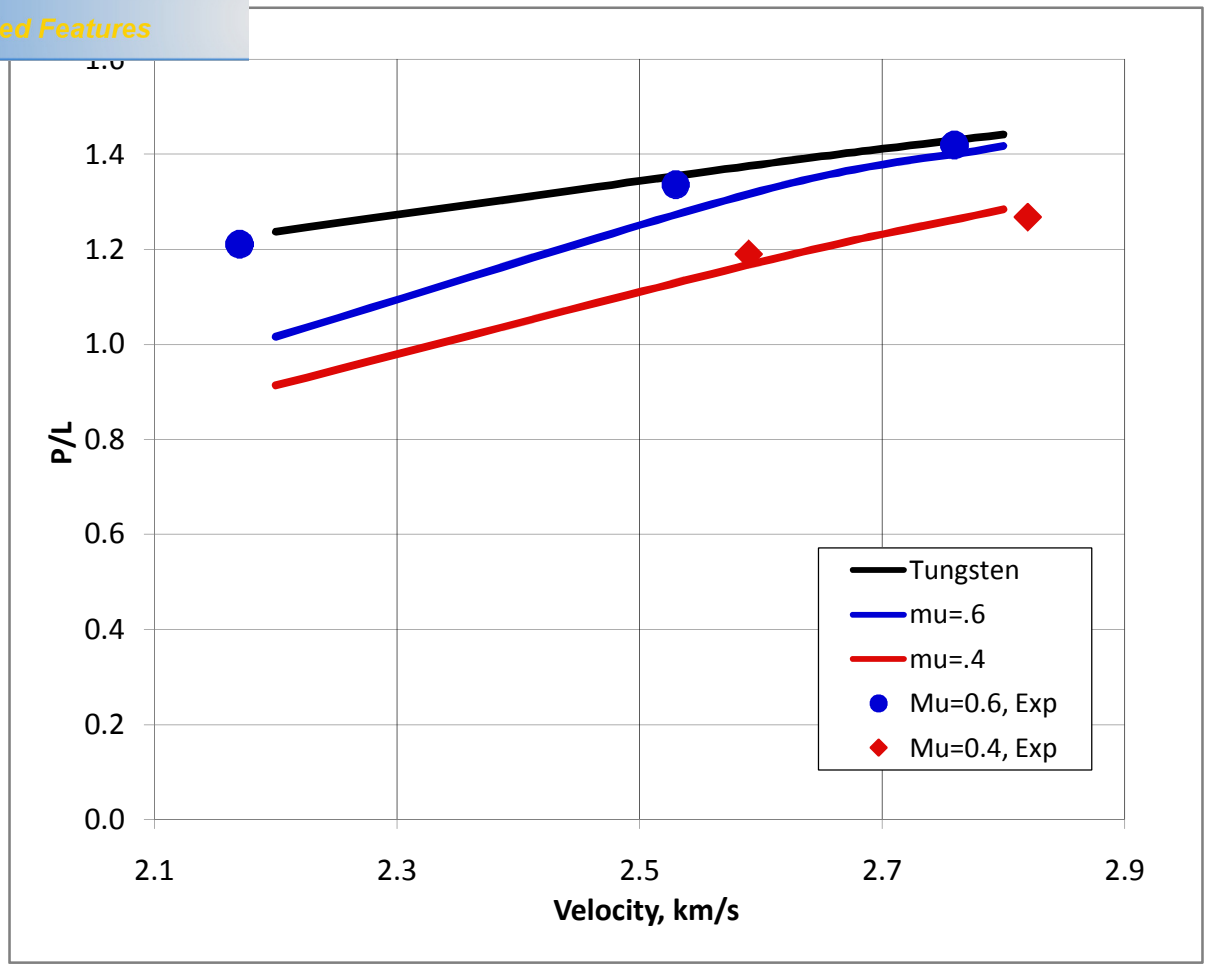

Despite the inaccuracies of the crater size, at high velocity, the simulations agree well with the normalized penetration from the experiments.
At 2.2 km/s, the simulations do not agree with the data. This is likely because in that calculation the crater is not large enough to allow the jacket material to flow freely after it erodes.

Conclusions

For mu=0.6, jacketed rods approach but never attain the penetration of tungsten rods.

The penetration of mu=0.4 rods is less than mu=0.6 rods.

The simulations matched the penetration for velocities above 2.6 km/s, but under-predicted penetration at 2.2 km/s.

For these jacketed rods, the crater diameter scales as the square root of the average density.

The simulations under-predicted the crater diameters for both jacketed and tungsten rods.