SAND2017-3742C

Characterizing In-Flight Temperature of Explosively Formed Projectiles in CTH

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Overview

The use of software for development and design is only as useful as the code's validation against experiment. Due to recent studies at the Army Research Lab, in-situ temperature of hypervelocity projectiles can now be measured, which was previously inaccessible. CTH temperature calculations are benchmarked against those of an explosively formed projectile (EFP). Results show CTH is in good agreement with experiment, with accuracy being strongly dependent on strength model.

Experiment Setup

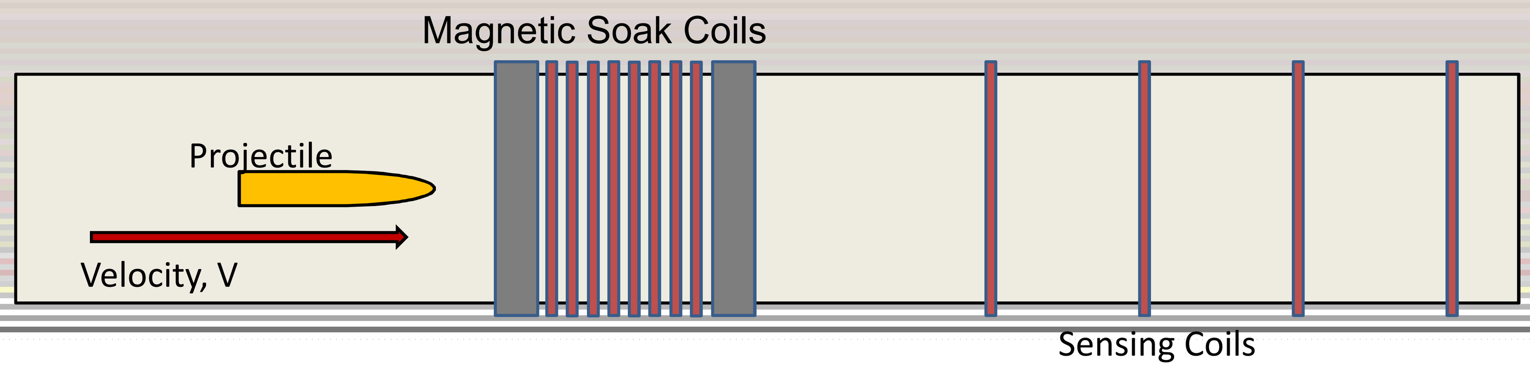

Fig. 1. Schematic of the hypervelocity temperature measurement Technique developed by Uhlig [1].

In a technique developed by Uhlig, a hypervelocity projectile is saturated, in flight by a magnetic field and the decay of this field is tracked. The decay time is directly related to conductivity, which is then correlated to the bulk material temperature.

Computational Model

Using CTH, an axisymmetric 2D domain 10x100 cm in size was established, with a flat mesh consisting of 0.0125 cm wide cells. The EFP configuration was based on the setup by Uhlig.

EFP formation is a complicated thermomechanical process. To model this process accurately, an appropriate equation-of-state and constitutive model are required. Several constitutive models are evaluated for their ability to capture the temperature and formation shape.

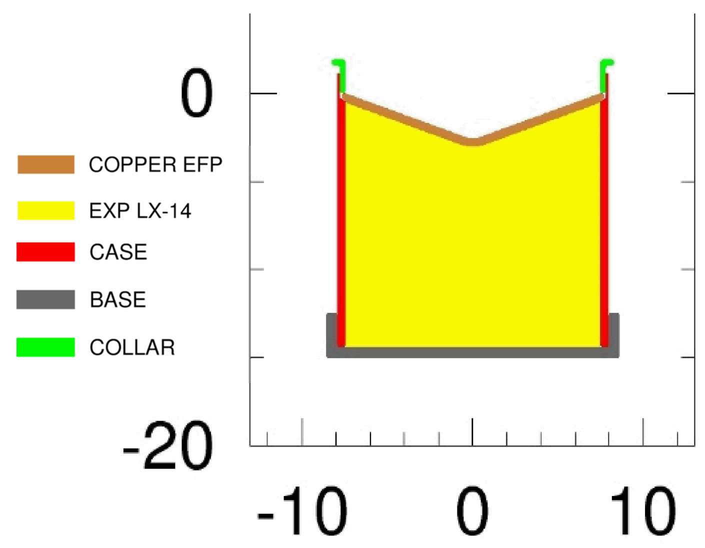

Fig. 2. Setup of the computational Domain. Units are in centimeters.

Material	Copper Liner	LX-14	304SS Casing	6061Al Collar	Polycarb. Base
Equation of State	Sesame Table	Jones-Wilkins-Lee	Mie Gruneisen	Mie Gruneisen	Mie Gruneisen
Strength Model(s)	JO, SGL, PTW, MTS	None	EPPVM	EPPVM	EPPVM

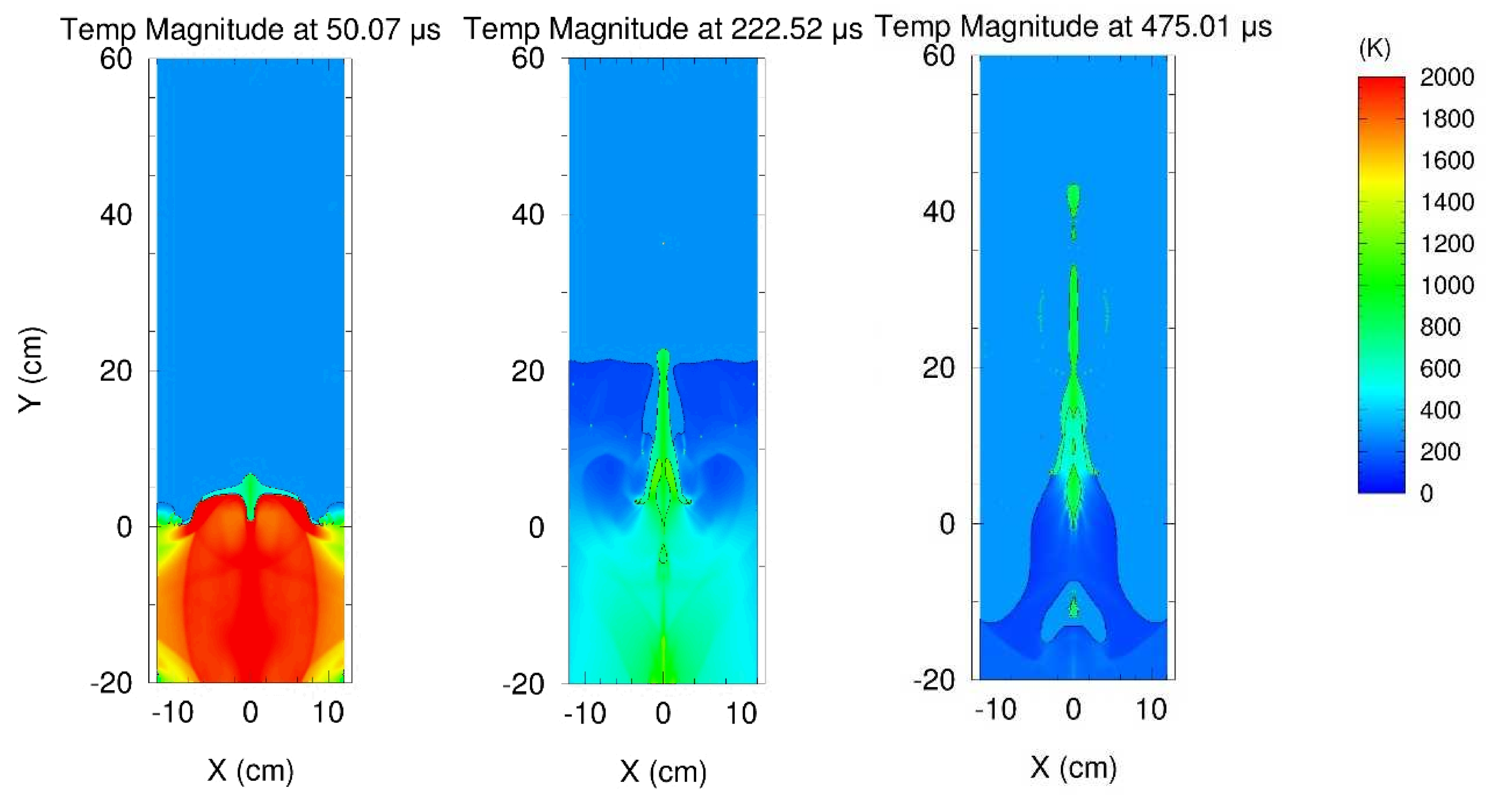

Fig. 3. Example EFP simulation in CTH throughout slug formation.

Results

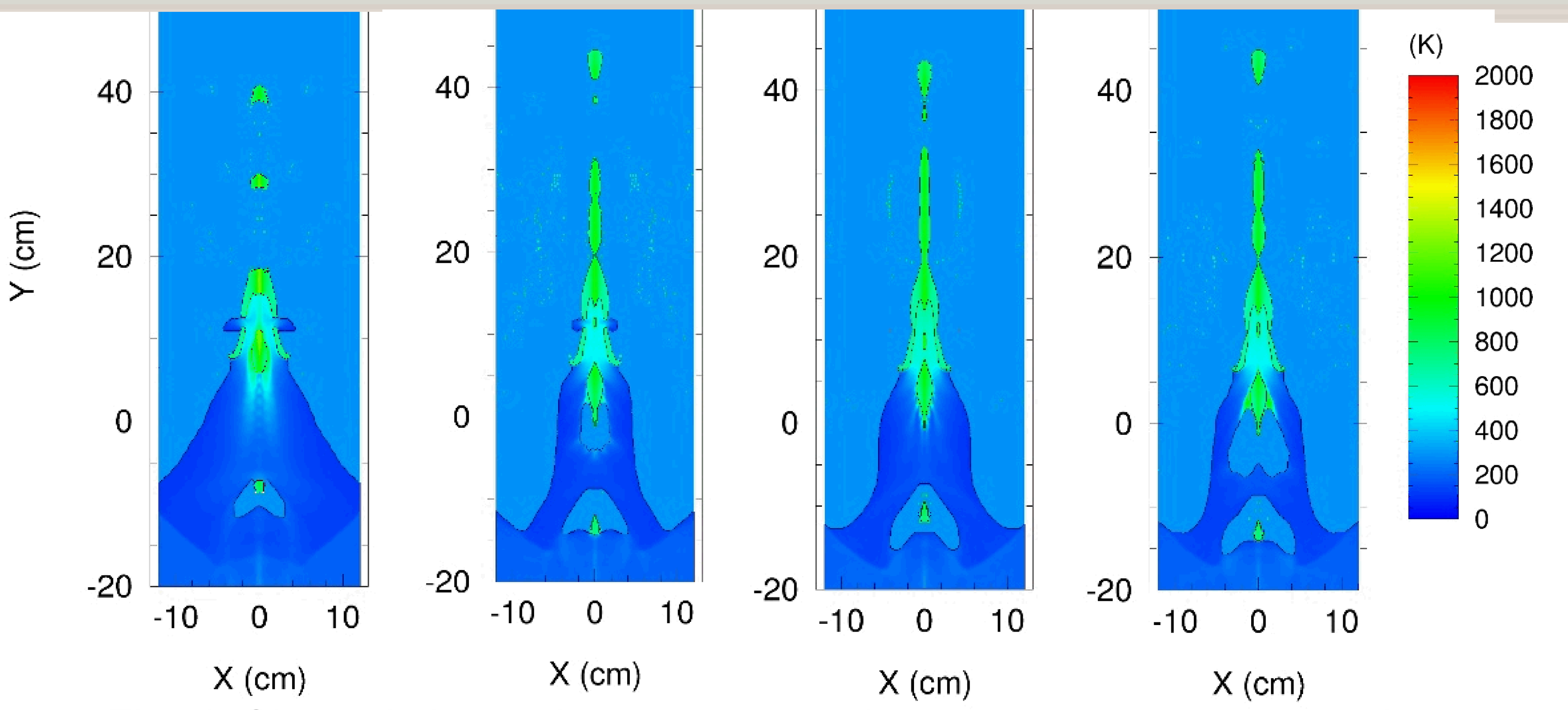

Fig. 4. Shaped charge jet structure and temperature post separation at 475 microseconds post detonation. Left to Right: SGL, JO, PTW, MTS.

Software	Strength Model	Temp. (K)	Experimental Temp. (K)	Error: -/Avg./+
CTH	Johnson-Cook	750	725±60	12%, 3.4%, 4.5%
	Steinberg-Guinan-Lund	950		42.8%, 31%, 21%
	Preston-Tonks-Wallace	820		23%, 13%, 4.5%
	Mechanical Threshold Stress	850		27.8%, 17%, 8.2%

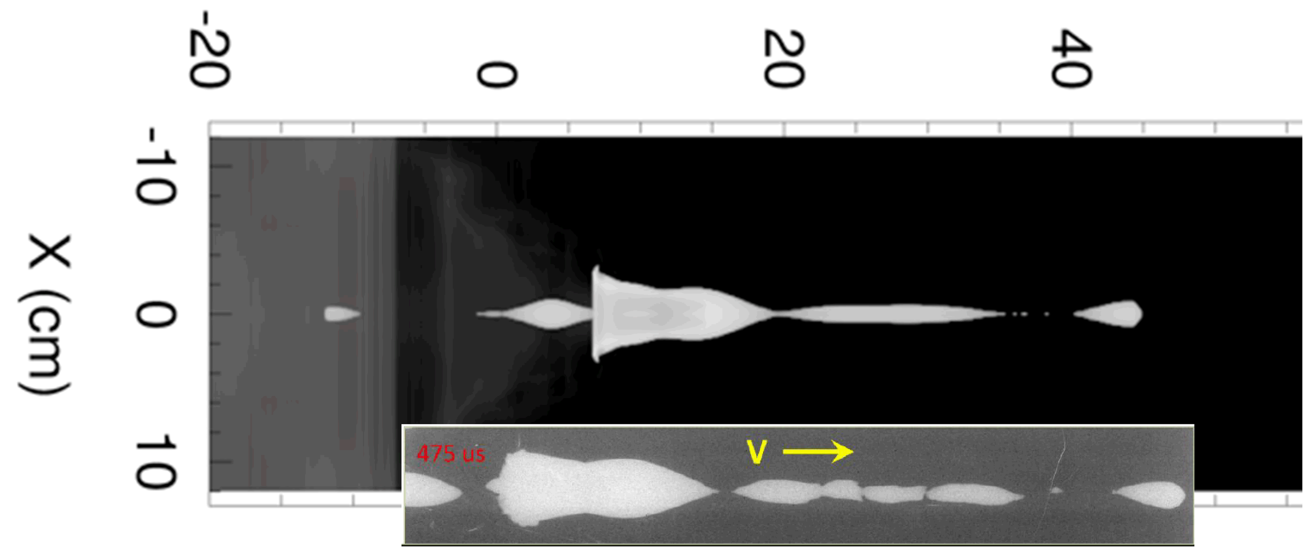

Fig. 5. Experimental radiograph compared to an EFP simulation conducted in CTH.

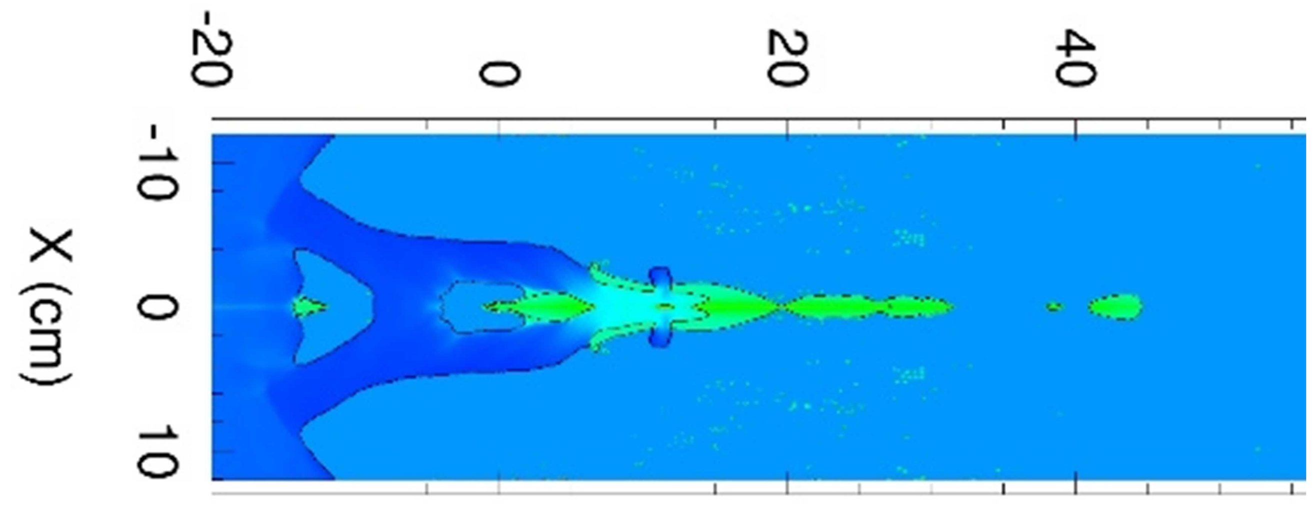

Fig. 6. Simulation conducted with the Johnson-Cook strength and fracture model implemented.

Conclusions

CTH was shown to accurately simulate an EFP, observing both calculated temperature and formation structure. Simulations agreed closely with experimental values when using the Johnson-Cook strength model, with an error of 3.4% compared to the average experimental measurement. With the inclusion of a fracture model, the experimental mean temperature was matched.

[1] Uhlig and Hummer. 2013. In-Flight Conductivity and Temperature Measurements of Hypervelocity Projectiles. Procedia Engienering, 58 (2013), pp 58-57.

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SAND No. 2016-6779 D