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Numerical Simulation of Bullet Heating While Traveling in a Grooved Barrel

*** Moshe Arad [1], David Touati [2] and Sharon Peles [3]**

[1] Israel Military Industry
Ramat Hsharon 47100,
ISRAEL
arad555@gmail.com

[2] Israel Military Industry
Ramat Hsharon 47100,
ISRAEL

[3] Israel Military Industry
Ramat Hsharon 47100,
ISRAEL

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ABSTRACT

The first stage in the firing of barrel ammunition is the in-bore travel. During this phase, the ammunition heats up due to the gas temperature of the propellant burn products, the friction between the barrel and the ammunition body, and in the case of jacketed ammunition the plastic deformation cause by the grooves. Attempts to model erosion using first principles have been and are currently being made [1–3], although it is believed that significant additional work is still required to understand the fundamental physics involved.

Over the past decades, more sophisticated ammunition with temperature sensitive components has become available. Included among this ammunition is the rifle bullet which contains HE (high explosive), pre-made fragments and sophisticated micro-electro-mechanical elements (MEMS) such as smart fuzes. For this kind of ammunition the functionality of the components depend upon the surrounding temperature which should be monitored during travel in the barrel. The use of a high resolution computer simulation is thus a key component in the prediction of the heating of the ammunition during in-bore travel.

In this paper the trajectory of a HE 0.5" round within a rifled barrel was simulated. A coupling of non-linear transient mechanical and thermal solvers was used to simulate the dynamics, plastic deformation, transient heat transfer, thermal stress and mechanical effects including a transformation of plastic work and friction to heat, and was implemented in the LS-DYNA finite-element code. LS-DYNA software is capable of solving steady state and time dependent transient heat transfer problems. The heat transfer solver is embedded within the other capabilities of LS-DYNA and allows for the modeling of coupled mechanical-thermal stress and thermal flow. The numerical model and the parts of the 0.5" round are shown in figure 1. The grooved barrel modeled in the simulation is shown in figure 2. The barrel consists of eight grooves with approximately thirty diameters per revolution. Simulation data included the mechanical and thermal properties of the parts of the 0.5" round and the rifled barrel. The numerical model contains of about half a million hexahedral elements. The round was loaded at its base with a uniform time-dependent pressure. The pressure loading was calculated by means of the output data of the interior ballistics code for this case.

The numerical simulation was used to study the effects of friction between the barrel and the round with regard to the following aspects: distribution of plastic deformation, temperature distribution (relative to the surrounding temperature), muzzle velocity of the round, and round rotational velocity at muzzle exit.

In the simulation, a region of plasticity was observed in the grooved regions of the round. The regions of plastic strain were of 1mm depth. The strain values and strain regions didn't change with a change in the coefficient of friction. The temperature changes in the round, as it traversed the grooved barrel, were calculated for different friction coefficients between the barrel and the round. From the simulations, it was observed that regions of high temperature existed in the grooved areas of the round. The regions in the round which underwent temperature changes were only 1mm deep. A linear relationship between the friction coefficient and the rise in temperature was observed numerically, and analytically. An analytical calculation of the thickness through which the heat can pass during the round's traversal within the barrel, showed that this thickness is smaller than the thickness of the round's copper jacket. Simulation results indicated that the coefficient of friction has a strong influence on the round's temperature as it exits the barrel, and a negligible effect on its muzzle velocity and rotational speed.

REFERENCES

[1] S. Dunn, D. Coats, G. Nickerson, S. Sopok, P. O'Hara, and G. A. Pflegl. "Unified Computer Model for Predicting Thermochemical Erosion in Gun Barrels." AIAA 95-2440, *Proceedings of 31st AIAA/ASME/SAE/ASEE, San Diego, CA, Joint Propulsion Conference and Exhibit*, July 1995.

[2] P. Weinacht, and P. J. Conroy. "A Numerical Method for Predicting Thermal Erosion in Gun Tubes." ARL-TR-1156, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, July 1996.

[3] P. J. Conroy, P. Weinacht, and M. J. Nusca. "120-mm Gun Tube Erosion Including Surface Chemistry Effects." ARL-TR-152, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, 6 October 1997.

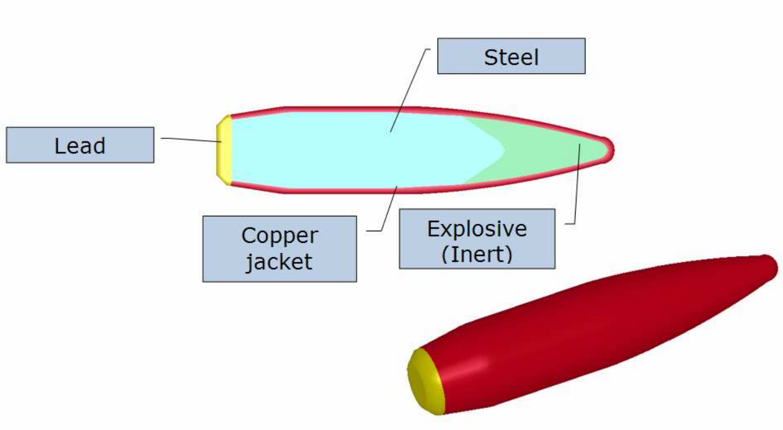

Figure 1: The 0.5" Round's Component Parts - Simulation Model

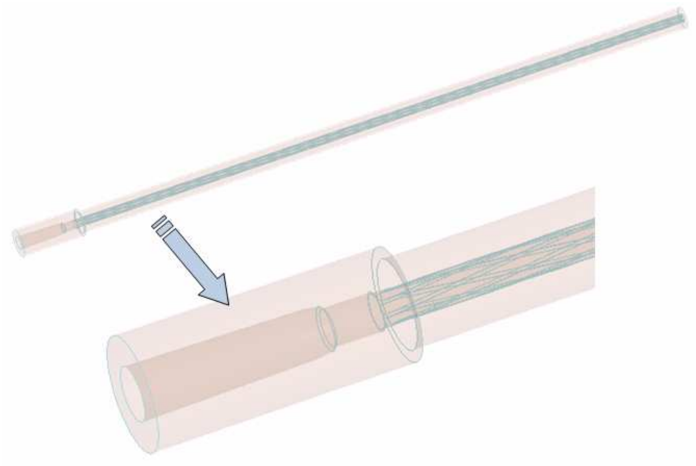

Figure 2: The Rifled Grooved Barrel - Simulation Model