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Flash Tube Seal Dynamics in 30 mm Ammunition

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Certain 30 mm ammunitions use a flash tube to augment the primer and to provide an ignition source for the propellant. The flash tube must provide abundant hot gases/particles and pressurize the propellant bed sufficiently so that the initial burn rate of the propellant is high enough to propel the projectile to the muzzle within the few milliseconds that constitute the action time of the cannon. Rupture of the seal at differing rupture pressures was shown to affect the initial pressure in the chamber enclosing the propellant bed, as well as the amount of burning particles released into the bed.

Keywords: ignition, primer

Introduction

Various 30 mm ammunitions use a flash tube (see Figure 1) to augment the ignition stimulus of the primer and to provide an ignition source for the propellant bed in each round. The flash tube must be fast acting, provide abundant hot gases/particles, and increase the pressure in the propellant bed sufficiently so that the initial burn rate of the propellant in the bed is high enough to propel the projectile to the muzzle within the few milliseconds that constitute the action time of the cannon.

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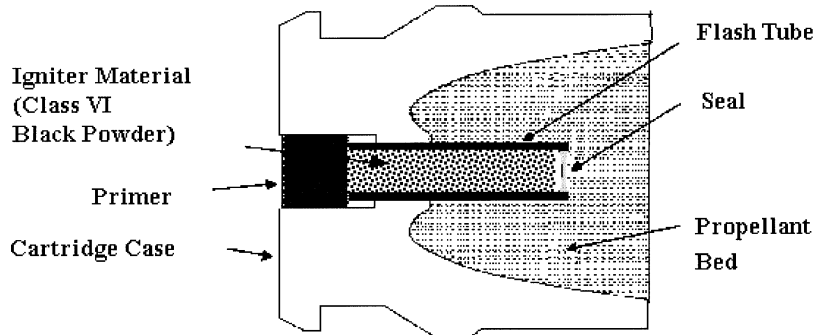


Figure 1. Schematic of breech end of 30 mm round.

The lacquer seal on the output end of the flash tube is thought by some to do more than just keep the black powder in the flash tube [1]. It should be sufficiently strong so that the primer output remains in the flash tube until the black powder is ignited and combustion products from the black powder have built up enough pressure and hot particle density. When it does rupture, the pressure released, with the accompanying gas flow, should be sufficiently high to increase the pressure in the propellant bed so that the initial burning rate of the propellant is high enough to complete the ballistic cycle in the time required. A previous study [2] of the rupture pressure of the flash tube lacquer seal at up to rupture pressures of 78 Mpa indicated that significant gas generation would be achieved before the flash tube vented into the main propellant bed. Gas flow at these pressures is expected to play a significant role in the ignition of the main propellant charge and rapid functioning of the round. However, that study examined only the flash tube venting into open air. This study also examines the use of the flash tube in an inert propellant bed to simulate actual function of the flash tube.

Experimental

The experiments were conducted on two test fixtures at the U.S. Army Research Laboratory (ARL) at Aberdeen Proving

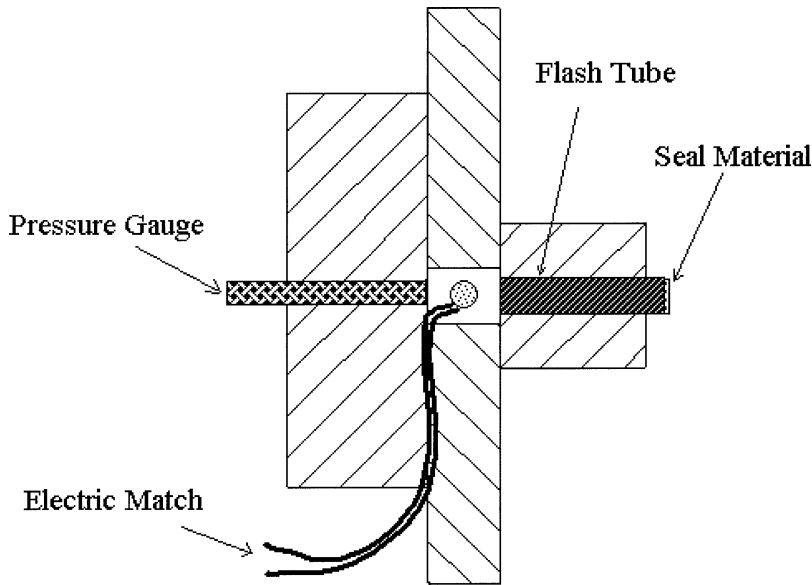


Figure 2. Simplified schematic of open air fixture to obtain the dynamic rupture pressure of flash tube seal.

Ground, MD, USA. Figure 2 shows a simplified schematic of a fixture to test the dynamic rupture pressure of a flash tube lacquer seal as experienced by the flash tube. The flash tube was filled with 350 mg Class VI black powder [3, 4] and held in the fixture. An electric match provided the ignition stimulus and was placed behind the black powder in a void volume that was approximately the same as that of the conventional primer. The pressure was monitored with a Kistler 211B1 pressure transducer behind the electric match. The pressure-time history was recorded on a Nicolet Integra 20 digital oscilloscope. The rupture event was also monitored with a Phantom IV high-speed camera.

A second fixture simulated the inside of an M788, M789, or M799 round. This simulator was filled with inert propellant. The flash tube was held in a truncated casing (truncated to form a stub base with the proper interior geometry of the

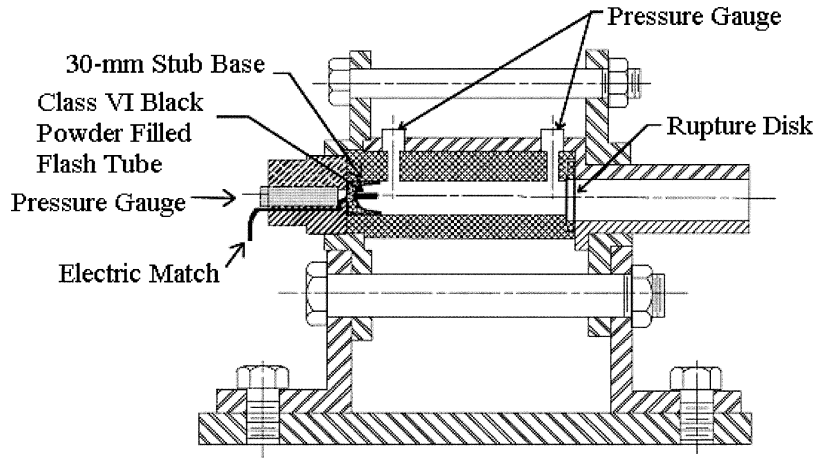


Figure 3. Simplified cross section of fixture to simulate early-phase burning in 30 mm ammunition.

round) of an M789 round. The black powder in the flash tube was ignited by an electric match and the pressure monitored. Pressure in the propellant bed region was measured near the projectile location and near the breech. Figure 3 shows a simplified cross section of this fixture.

Results and Discussion

A previous study determined the strain-related physical properties of the lacquer seal [2]. However, these results described only the physical behavior of the lacquer seal itself. Effects such as the solid black powder pushing up against the seal or possible weakening of the seal due to the temperature of the flame, etc., were carefully removed. In the current study all the effects of a flash tube in typical operation were examined since the flash tube itself was filled with the correct loading of the proper grade of black powder.

Figure 4 shows the pressure-time history produced by the ignition of 350 mg of Class VI black powder in a properly functioning flash tube that vents into open air (see also Figure 2).

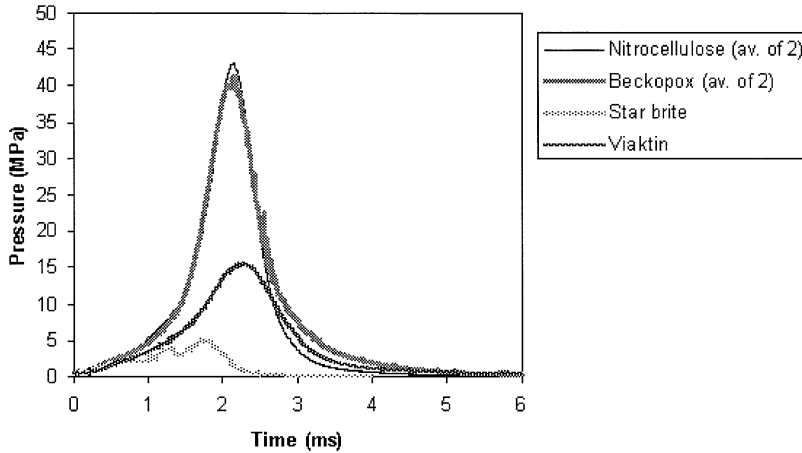


Figure 4. Pressure-time histories of interior of flash tube using selected seal materials.

The pressure-time history of a standard nitrocellulose seal indicated that maximum pressure was reached at approximately 2 ms from black powder ignition [1]. Rupture and essentially complete venting occurred by 4 ms. The maximum pressure reached was approximately 41 Mpa.

Other coating materials were tried as possible nitrocellulose replacement. Pressure-time histories of the rupture of several of these materials are also depicted in Figure 4. Beckopox (Solutia, St. Louis, MO), a heat-cure material, most closely matched the nitrocellulose lacquer. Other materials such as Viaktin (Solutia, St. Louis, MO) and Star brite (Star brite, Ft. Lauderdale, FL) show dramatically different behavior in this application. The rupture pressures from these two materials were much lower than that of the nitrocellulose seal. The rupture pressure of the Star brite seal was especially low. This degraded behavior was deemed sufficient to simulate damaged nitrocellulose seals. A damaged seal (cracked or missing, for example) would likely produce a lower maximum pressure and possibly lose a portion of the black powder into the propellant bed before ignition.

The results from the Viaktin and Star brite suggest that not all of the black powder was consumed. Indeed, the high-speed video showed burning particles ejecting from the Beckopox and nitrocellulose seals only. After each test the table on which the fixture was attached was swept for unburnt particles. Such particles were found only for the tests with Viaktin and Star brite seals. It may be that during the early-stage ignition of the flash tube that some portion of the black powder was forced out of the flash tube prior to its ignition. Such particles of black powder would not contribute to rapid ignition of the propellant bed.

The simulator fixture in Figure 3 was used to identify some of the conditions in the propellant bed during and after the functioning of the flash tube. The first test was with a standard nitrocellulose seal. Figure 5 shows the pressure-time history. The maximum pressure in the flash tube was approximately 42 MPa prior to rupture at near 1.7 ms. The breech pressure began to rise steeply at 2.2 ms to approximately 2 MPa by

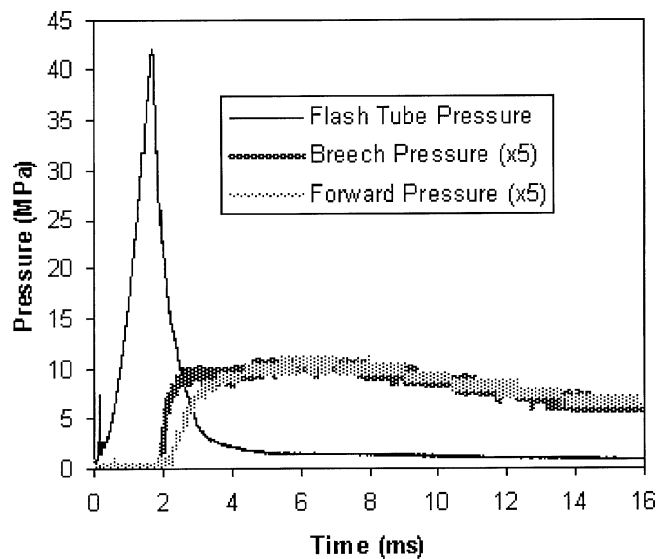


Figure 5. Pressure-time history of rupture of nitrocellulose seal in 30 mm simulator.

2.8 ms, and the forward pressure rose more slowly to the same pressure by approximately 4 ms. The soot penetration into the inert propellant bed was approximately 60%.

The test simulation of a damaged seal used a flash tube with a Star brite seal. The ignition of the flash tube produced the pressure-time history in Figure 6. The pressure in the flash tube reached a maximum pressure of 2.5 MPa in 1.5 ms, but did not begin to vent fully until approximately 3 ms. At this point the pressure in the propellant bed began rising and continued rising for approximately 4 ms until it reached a maximum pressure of approximately 0.02 MPa that held steady for at least 15 ms. Such pressure behavior could indicate that black powder particles left the flash tube without burning and entered the propellant bed prior to combusting. The soot penetrated approximately 50% of the propellant bed. There is no way to tell how much of the soot was deposited from the prolonged burning after the flash tube vented.

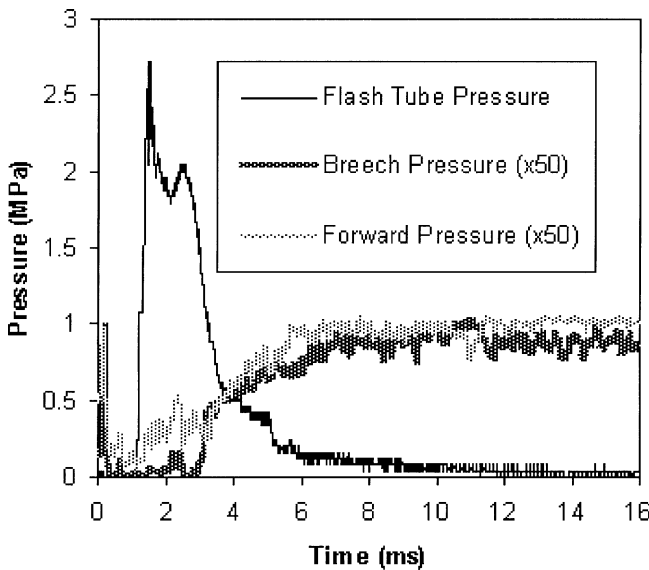


Figure 6. Pressure-time history of rupture of simulated damaged seal in 30 mm simulator.

Comparison of the pressure-time histories (Figures 5 and 6) of a properly functioning flash tube seal and a damaged flash tube seal shows dramatic differences. The damaged seal produced more than an order of magnitude reduction in pressure in the flash tube and approximately a two orders of magnitude reduction in pressure in the propellant bed. These reductions in pressures and burning particles should produce degraded performance in the functioning of ammunition with a damaged seal.

Conclusions

The lacquer seal on a flash tube for 30 mm ammunition was shown to perform more functions than a simple environmental seal. Use of fixtures that vented the output from the flash tube into open air or into an inert propellant bed demonstrated that proper functioning of the seal could greatly affect the conditions present during the early-phase combustion of the propellant bed. With damaged or defective seals, both pressure in the propellant bed and burning particles vented from the flash tube decreased dramatically with the ability of the seal to hold pressure as the black powder was ignited.

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