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Interior and Exterior Ballistic Development of a 20mm Saboted Penetrator Projectile

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Abstract

The interior and exterior ballistic development of a 20mm saboted penetrator projectile is discussed. Exterior ballistic performance test results are also presented.

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Acknowledgements

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Interior and Exterior Ballistic Development of a 20mm Saboted Penetrator Projectile

1. Introduction

The penetration of various targets by Armor Piercing (AP) projectiles has been an object of interest to military munition developers for many years, Ref. 1. The munition designer is always on the look out for a more effective penetrator at a cost comparable with existing penetrator ammunition. Also, in todays climate of environmental awareness, the materials in the munition must pose no threat to the environment in their manufacture, storage and use or disposal.

The munition designer may also find that a particular penetrator material and shape is effective when used against, say steel armor, but not as effective when used against concrete armor. So, the search goes on for penetrator materials that when used against their intended targets produce deeper penetration.

In order for the munition designer to evaluate different candidate penetrator materials, he must have a method of directing the projectile against a target with a prescribed velocity and in a repeatable manner. The method is usually a gas gun or a propellant gun. The guns may or may not be rifled. Regardless of the gun used, it must produce repeatable projectile velocities and repeatable angles of impact. This report discusses the development of a method to launch 20mm penetrator projectiles with repeatable velocities and angles of attack. Projectile behavior inside the barrel (interior ballistics) and outside (exterior ballistics) the barrel is discussed.

2. Interior Ballistic Development of the 20mm Saboted Penetrator Projectile

2.1. Gun Description

The platform chosen to launch the 20mm penetrator was a 20mm gun barrel with a special breech to allow electric firing. The barrel has a 1 in 15 (one projectile rotation in 15 inches of barrel length) twist to the rifling. Figure 1 is a photograph of the gun barrel. The gun barrel is

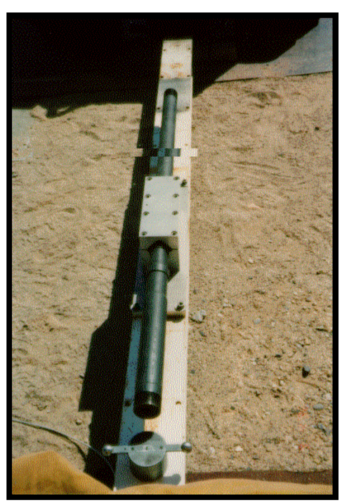

Figure 1: Photograph of 20mm Gun Barrel

shown mounted on its wide flange beam with the breech cap removed. Although a smooth bore 20mm gun barrel was available, it was not used because the military services 20mm penetrator projectile is fired from a rifled barrel for the obvious reason that it is required to maintain a stable flight attitude for perhaps 1000 meters. Thus the decision to launch the projectile from a rifled barrel was made because it more nearly matched actual service condition. The gun barrel was chambered to receive the military services 20mm Mk103 electric primed cartridge case.

The breech was a massive thick-walled, heat-treated 4340 steel threaded cap equipped with an electric firing pin assembly. The electric firing option was selected because it allows remote triggering, and it provides a precise fiducial from which to time other events such as camera shutter trigger pulses. The firing circuit consisted of a Reynolds FS-55 control unit which charged a Reynolds FS-55 low voltage module to 300 volts. The 300 volt pulse was delivered to the electric firing pin via 30 meters of Reynolds "C" cable. During the course of the test program, it was found that the firing pin tip must make electrical contact with the M52A3B1 electric primer. The 300 volt output pulse from the Reynolds X-unit was sufficient to initiate every ballistic trial; however, it was found that at 200 volts or less the primer would not initiate. We believe that this "no-fire" condition was caused by insufficient joule heating of the thermally sensitive igniter inside the primer.

2.2. Cartridge Case Handload[*] Development

The type of gun powder has an enormous influence on the interior and exterior ballistics of the projectile. Even though there are dozens of gun powders available for the handloader to select from, there are just a few that will produce a pressure pulse in the chamber that best matches the projectile early time interior flight dynamics and results in the most accurate, stable exterior flight.

The gun powders chosen for evaluation in this program were the Olin Ordnance military rifle smokeless powders WC870, WC886, and IMR7828, Ref. 2 and 3.

Both of the WC (Winchester Canister) powders are so-called ball or spherical powders. The IMR7828 is an extruded powder which has a higher burning rate than the WC870 powder. *Table 1* presents a comparison of projectile weight versus computed velocity for several WC870 and IMR7828 powder weights. For a 100 gram (1540 grain) projectile, the typical powder charge is 39.5 grams of WC870; therefore, we started the 100 gram projectile ballistic trials with that amount.

[*] The term handload refers to the practice of producing one's own custom ammunition instead of using factory mass produced ammunition. In addition to the satisfaction of assembling one's own ammunition, handloading is done to achieve greater accuracy than that of factory loads.

Projectile Weight (grams)	Projectile Weight (grains)	Projectile Velocity (ft/sec)	Projectile Energy (ft-lbs)	Powder Weight (grains)	Powder Type	Pressure (ksi)
100.0	1540	3000	30938	455	WC870	
100.0	1540	3200	35200	518	WC870	
100.0	**1540**	**3400**	**39738**	585 605	WC870 WC872	60.5 ksi
100.0	1540	3600	44550	648	IMR7828	
100.0	1540	3800	49638	722	IMR7828	
100.0	1540	4000	55000	800	IMR7828	
80.0	1232	3000	24750	360	IMR7828	
80.0	1232	3200	28160	410	IMR7828	
80.0	1232	3400	31790	462	IMR7828	
80.0	1232	3600	35640	518	IMR7828	
80.0	**1232**	**3800**	**39710**	578	IMR7828	
80.0	1232	4000	***44000***	**640**	**IMR7828**	**>60.5 ksi**
71.4	1100	3600	31821	463	IMR7828	
71.4	1100	3800	35455	516	IMR7828	
71.4	**1100**	**4000**	**39286**	871	IMR7828	

Table 1: Projectile Velocity versus Powder Weight for Several Powder Types

Several tests into the development we increased the powder weight to 41.5 grams, which is the maximum amount of WC870 that can be loaded into the Mk103 case. The chamber pressure generated by that amount of powder was probably in excess of 60,000 psi. The excessive pressure caused the primer to extrude from the primer pocket with the result that propellant gas vented from the chamber before the driving band on the projectile could seal. The result was a very low projectile velocity due to gas leakage. We reduced the powder weight to 40.5 grams of WC870 and conducted several more trials. The chamber pressures were still high as evidenced by some gas leakage past the projectile. We further reduced the powder weight to 40.0 grams (617 grains) of WC870 and conducted over fifty ballistic trials. Forty grams proved to be the optimum weight of WC870 when used with our combination of rifle barrel and projectile.

The other powders, Olin's WC886 and the IMR7828, both proved to have too high a burn rate when used behind the 100 gram projectile in the Mk103 case. However, when we used the 80 gram projectile, the IMR7828 produced acceptable chamber pressure, projectile velocity and exterior ballistic performance.

2.3. Penetrator Projectile Description

The penetrator projectile assembly is shown in Figure 2 (all dimensions are in millimeters). It consisted of three items: a penetrator, a driver, and a guide. The penetrators were approximately 13.6mm in diameter and 50mm long; each weighed about 50 grams. The driver was a converted

20mm military target practice projectile. The conversion consisted of machining the aluminum nose cone off and then boring the projectile case out to allow a light press fit between penetrator and driver. The press fit is necessary so the penetrator maintains the same angular velocity (2700 revolutions per second) as the driver. The guide was a Lexan sleeve machined to the driver outside diameter and bored to allow a slip fit over the penetrator. Finally, the guide was given a generous leading edge chamfer to allow a smooth engagement with the barrel lands. The projectile assembly weighed 100 grams, which is the weight specified for the military services M55A2 target practice projectiles.

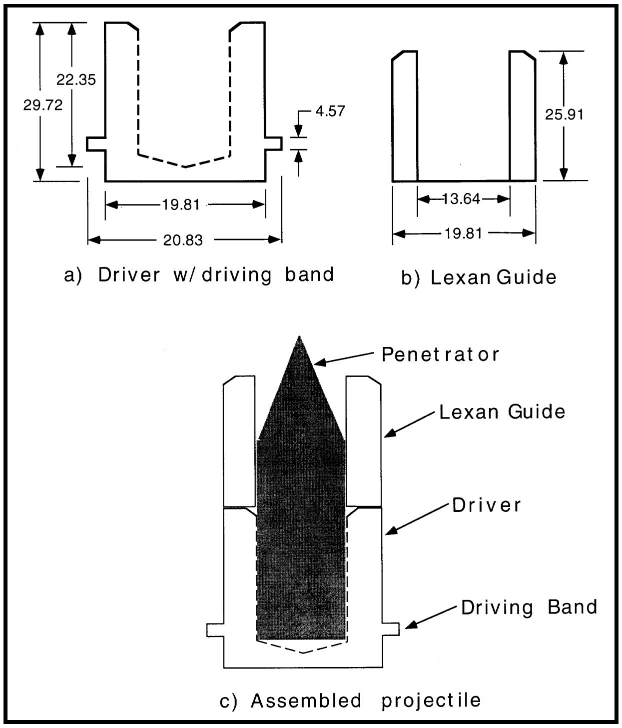

Figure 2: Projectile Configuration

3. Exterior Ballistic Performance

In order to evaluate the projectile flight, a series of ballistic trials was undertaken. Figure 3 is a photograph of the test apparatus showing the key elements of the testbed. The photo shows, from left-to-right, the 20mm gun, chronometer container with its blast and debris shields and the concrete target. Figure 4 is a detailed schematic of the testbed.

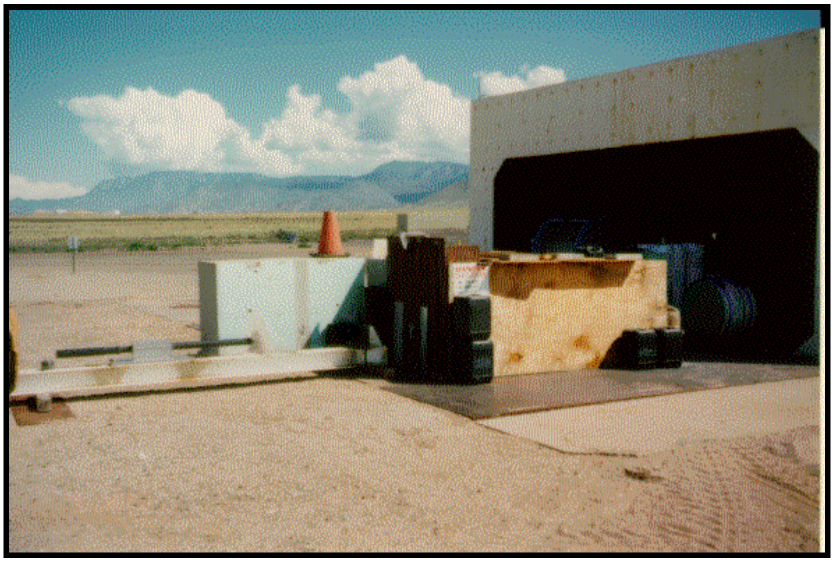

Figure 3: Photograph of Ballistic Trials Testbed

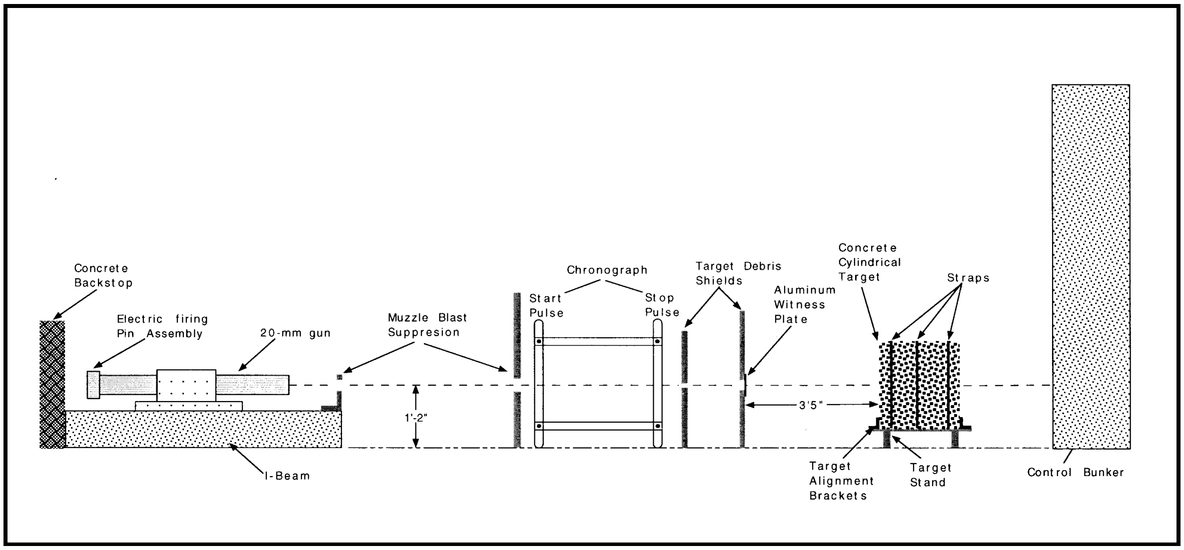

Figure 4: Schematic of Ballistic Trials Testbed

The multiple shields between muzzle and chronograph are necessary to physically protect the chronograph from errant fragments and to prevent muzzle blast from triggering the chronograph start screen before the bullet does.

The rear shields are required to prevent debris ejected from the concrete target from damaging the chronograph. The thin aluminum witness plates give a static record of the projectile attitude at that particular range in its flight. If the projectile yaws or pitches the hole left in the witness plate will not be circular.

Velocity was measured with a Oehler Model 55 self-illuminating chronograph. The Chronograph consisted of start and stop screens with a remote processor and readout. The Oehler 55 is capable of resolving projectile velocity with $\pm$ 1% accuracy.

4. Results and Conclusions

Table 2 presents projectile weight versus velocity for the final set of ballistic trials. As shown in the table, the projectile velocities were very consistent. The witness plates from these trials also indicated that the projectiles flew with no yaw or pitch.

Shot #	Projectile Weight (gm)	Projectile Velocity (m/s)
1.	N/A	1032
2.	45.53	1036
3.	49.26	1040
4.	46.15	1008
5.	46.84	1036
6.	46.30	1037
7.	46.30	1032
8.	45.68	1031
9.	46.08	1033
10.	44.49	1031
11.	44.44	1031
12.	46.25	1041
13.	46.53	1039
14.	46.46	1038
15.	45.82	1031
16.	46.00	1030
17.	46.53	1030
18.	43.92	1033
19.	47.12	1033
20.	44.24	1029

Table 2: Projectile Velocity versus Weight

The interior ballistics of the spin stabilized saboted penetrator projectile produced very desirable exterior ballistic performance; that is, the projectiles flew with repeatable velocity (mean velocity = 1033 ± 7 meters per second) and the projectile axis coincided with its trajectory.

In conclusion, we believe that this saboted projectile when loaded into a Mk103 case with 40 grams of WC870 powder and fired from the 20mm barrel, provide a excellent tool to evaluate the terminal ballistic performance of various penetrator materials.

5. References

1. Stone, G. W., “Projectile Penetration into Representative Targets,” SAND94-1490, Sandia National Laboratories, October 1994.
2. Kruse, Duane, private communications, Olin Ordnance corporation.
3. Army Ammunition Data Sheets, Small Caliber Ammunition, DoD TM 43-0001-27, Department of the Army, HQ, Washington, D.C.

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