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FULL METAL JACKET PROJECTILE PENETRATION ANALYSIS OF KEVLAR ONLY BULLETPROOF VEST

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ABSTRACT

Kevlar is a common and light weight material used for bulletproof vests. This paper presents the results that were observed for different .22, 9 mmP, .40, .45, .38 special, .357 and .308 ammunition penetrating 30 layers of 200 grams per square meter (GSM) Kevlar material, which are common for bullet proof vests. The projectile velocity, projectile kinetic energy, projectile penetration depth into the ballistic gel behind the Kevlar sheets, kinetic energy per cross sectional area of the projectile, and the number of layers of Kevlar that are penetrated, are presented.

KEYWORDS: Composite; Kevlar; Bulletproof vest; Ammunition comparison; Full Metal Jacket

INTRODUCTION

Kevlar was discovered in 1971 [1] and are used in today's body armour [2]. Kevlar is considered five times stronger than steel [3] and has the ability to absorb energy [4], which other body armour materials have not been able to. Different experimental testing [5 – 14] and numerical modelling [15-17] studies have been performed on Kevlar.

Many high velocity tests have been performed on Kevlar, where the motion of the projectile is performed either with compressed air or a dropped weight [18], but these tests don't take into account the effects of the type of ammunition and the firearm characteristics. There is a conception that the larger the projectile is, the better the performance is with penetration through Kevlar [19].

Contributions and aims of this paper is to evaluate:

- The effectiveness of projectile size (.22, 9 mm Para, .40, .45, .357, .38 special, and .308), and kinetic energy, when it penetrates 200 GSM Kevlar material.
- The effectiveness of the Kevlar only bullet proof vests (30 layers of 200 GSM Kevlar) is on different .22, 9 mmP, .40, .45, .38, .357 and .308 projectiles and in how many layers the projectile was stopped.

In the tests performed in this paper, the layers of Kevlar that a projectile can penetrate are considered as the layers that are damaged. It is to be noted that the authors are not associated with the companies manufacturing the ammunition and obtained no financial gain for performing the tests. The results given are unbiased, and are purely as observed in the tests conducted. Due to these uncertainties, many of the tests conducted in the present study had to be repeated numerous times, for example, when the projectiles deviated out of the ballistic gel, or external interference was observed that might have an effect on the results.

EXPERIMENTAL SETUP AND AMMUNITION CHARACTERISTICS

The experiments were performed with the setup of having the projectile shot through a firearm chronograph, which was placed 2 meters away from the firearm, after which it would penetrate the Kevlar samples, followed by the ballistic gel placed behind it [20]. The ballistic gel was developed as described by Stopforth and Adali [20]. The chronograph allowed for the average projectile velocity to be recorded.

The Kevlar samples consisted of 3 layers, layered in the order of 90/±45/90. They were bound together with epoxy resin and hardener. The next sample placed behind would be in such a way so that each layer is 45 degrees offset of the previous layer, and secured with bolts.

In the past research and experiments performed [20], if has been seen that the Kevlar was able to stop the hollow points, or jacketed hollow point (JHP) ammunition, yet the full metal or full metal jacket projectiles penetrated further through the Kevlar material. Due to the results of these experiments, the full metal jacket (FMJ) projectiles penetrated more than the hollow point projectiles, and therefore the FMJ projectiles are the focus of investigation in this paper. Table 1 shows the different ammunition considered, with their characteristics. All recordings were taken independently, except were indicated, when technical reasons did not allow for such recording to be taken.

Projectile number 16, number 17 and number 18 were tested with the maximum amount of layers of Kevlar that was available, consisting of 39 layers of 200 GSM Kevlar, with 9 layers of 400 GSM Kevlar behind it.

A video of the results of the tests conducted can be viewed at https://www.youtube.com/watch?v=VBtI2v-HD9Q.

RESULTS AND DISCUSSION

Figure 1 shows the projectile velocity and kinetic energy. Figure 2 shows the kinetic energy per cross-sectional area of the projectiles, and figure 3 shows the number of layers that the projectile penetrated.

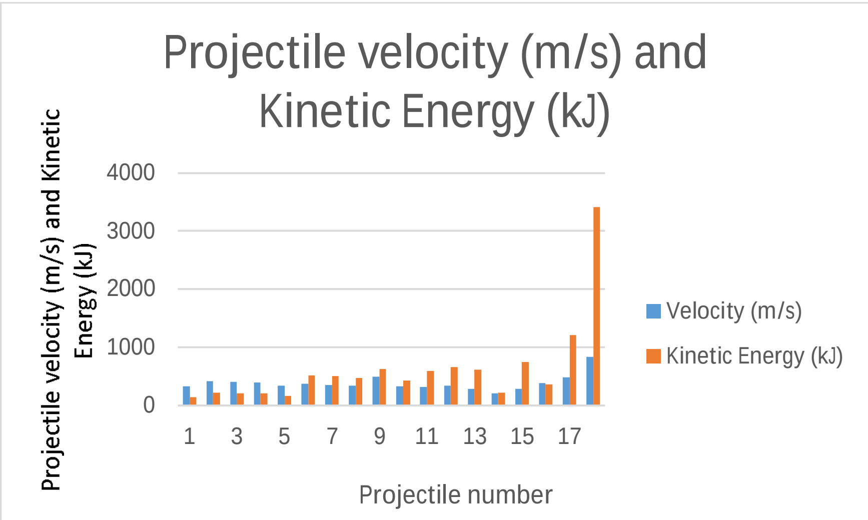

Figure 1: Velocity and kinetic energy of the different projectiles tested

Table 1: Ammunition and characteristics for the experiments performed.

Ammunition type	Projectile weight (grains)	Velocity (m/s)	Energy (kJ)	Penetration into ballistic gel - no Kevlar (mm)
1) CCI .22 Long Rifle (LR) 40 grs standard lead round	40	332	143	505
2) TM Swartklip.22 Long Rifle (LR) 39 grs High Velocity (HV) Sabre Tip	39	417	220	508
3) Federal .22 Long Rifle (LR) 40 grs Lightning	40	406	214	554
4) CCI .22 40 grs Blazer	40	398	205	556
5) Winchester .22 45 grs SB	45	337	165	523
6) Sellier and Bellot (S&B) 9x19 115 grs full metal jacket	115	373	520	774
7) Diplopoint 9x19 124 grs full metal jacket	124	354	505	778
8) KZN 9x19 124 grs Teflon coated	124	342	469	695
9) NGA 9x19 80 grs Eliminator	80	491	625	436
10) Lead Reloads 9x19 122 grs reloads (A)	122	328	426	743
11) Sellier and Bellot (S&B) 180 grs .40 FMJ	180	318	590	1004
12) Lead Reloads 170 grs .40 FMJ (B)	170	345	656	741
13) PMP 230 grs .45 FMJ	230	288	619	943
14) CBC .38 Special 158 grs lead round nose (Revolver)	158	209 (C)	224	354
15) PMP .38 Special 158 grs semi-jacket soft point (Rifle)	158	285	750	477
16) NGA .38 Special 78 grs Eliminator	78	380 (D)	365	--
17) Winchester .357 Magnum 158 grs hollow point	158	486	1209	477
18) PMP .308 150 grs MK1	150	838 (E)	3413	--

-- No recordings taken.

(A) 122 grs Round Nose, hardness: 9/10, Powder: 6 grs SOMCHEM 221;

(B) 175 grs Semi Wad-cutter, hardness: 9/10, Powder: 7.8 grs SOMCHEM 221

(C) MagTech/CBC 38 Spl 125 grain Lead round nose, Available from: http://www.magtechammunition.com/products/view-product?id=29

(D) The Eliminator Bullet, New Generation Ammunition cc, Licensed Manufacturers of Ammunition, Technical Newsletter, 1994, available from: http://www.retro.co.za/gundex/articles/NGA-Eliminator.pdf

(E) PMP Rifle Ammunition Ballistics, available from:
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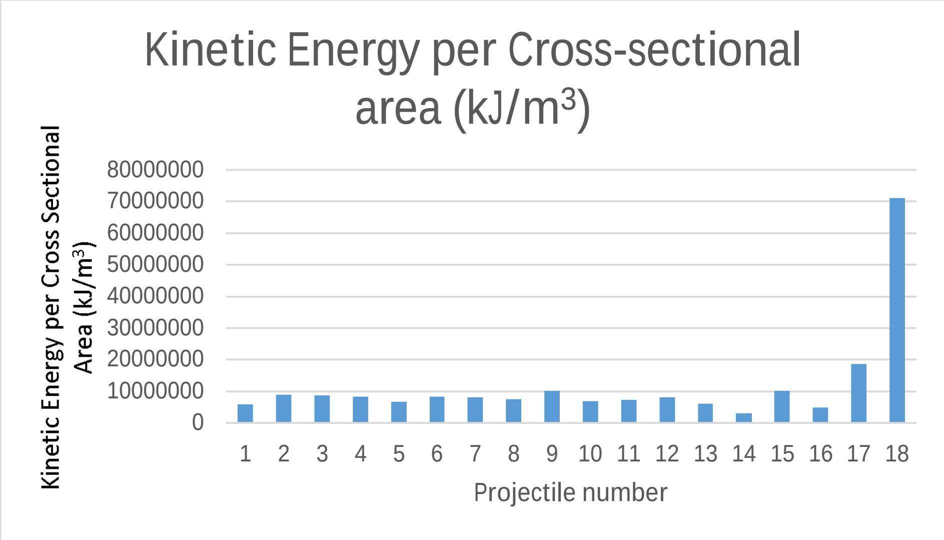
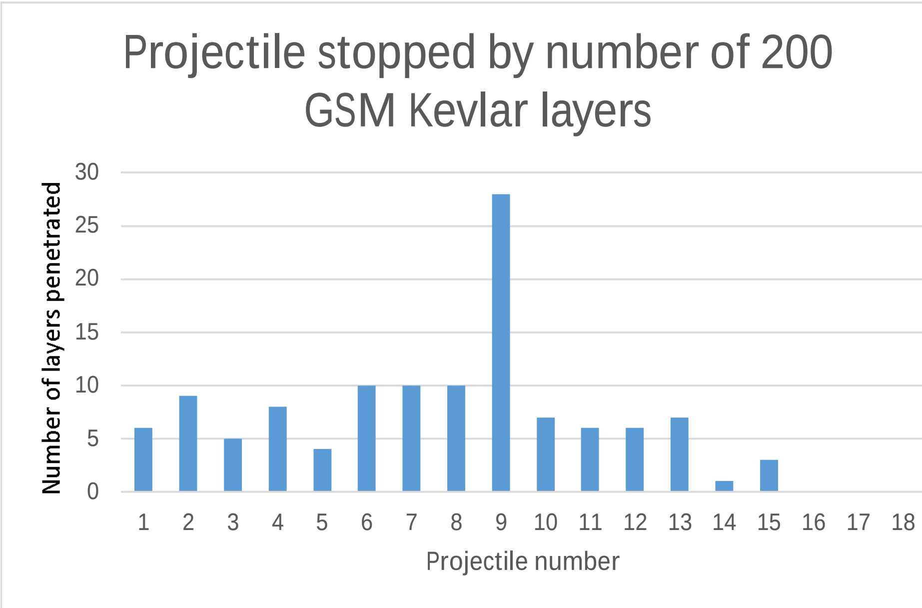


Figure 2: Kinetic energy per cross-sectional area of the projectiles tested

Referring to the .22 projectiles (number 1 to number 5): projectile number 2 had the highest velocity, resulting it also to have the highest kinetic energy and the highest kinetic energy per cross-sectional area. Projectile number 2 penetrated 9 layers of Kevlar followed by projectile number 4 with 8 layers of Kevlar. Projectile number 3 and number 4 both had a very close velocity, kinetic energy and kinetic energy per cross sectional area, yet the penetration of projectile number 3 only penetrated 5 layers of Kevlar. Projectile number 1, which had the lowest velocity, kinetic energy and kinetic energy per cross-sectional area, penetrated 6 layers of Kevlar. Projectile number 2 is the only .22 projectile that had a brass/copper coating, and was the lightest projectile of 39 grs. Projectile number 1, number 3 and number 4 had a weight of 40 grs, while projectile number 5 had a weight of 45 grs. There seems to be a correlation that the lighter the projectile, the more layers it penetrated into Kevlar, taking into account that the pressure generated by the gun powder could be very similar, therefore allowing the lighter projectiles to travel faster. Projectile number 3 and number 4 (both of 40 grs), had a similar velocity, yet projectile number 1 (also of 40 grs in weight), had the lowest velocity. Another factor to take into account is that projectile number 4 has a sharper point in comparison to the other projectiles.



NB - Projectile number:

(16) Went through 39 layers of 200 GSM Kevlar, and 9 layers of 400 GSM Kevlar, then went 475 mm into ballistic gel, after which it exited on the side of the ballistic gel.

Figure 3: Number of layers of Kevlar the different projectile penetrated. Projectiles number 16, number 17 and number 18 went through all the layers of Kevlar.

Referring to the 9 mmP projectiles (number 6 to number 10): Projectile number 9 had the highest velocity, kinetic energy and kinetic energy per cross-sectional area. Projectiles number 6, number 7, number 9 and number 10 had a close range of velocities varying from 332 m/s to 373 m/s, in comparison to projectile number 9. Projectile number 9 had the lowest weight of 80 grs, yet also had the least amount of penetration into the ballistic gel with no Kevlar to penetrate. It is also observed that projectile number 9 has a point on the tip of the projectile, therefore indicating that the point allows for penetration to occur better. It must be noted that the number of layers of penetration was taken to be the number of Kevlar layers were damaged, which this projectile did with this specific point, even though the rest of the projectile might not have penetrated. Projectile number 6 seems to show a similar characteristic in being the second lightest projectile, and having the second highest velocity, kinetic energy and kinetic energy per cross-sectional area. Therefore the characteristic of the lighter projectile being the most penetrating seems to be seen in this comparison.

Referring to the .40 projectiles (number 11 and number 12): Projectile number 12 had a slightly higher velocity, kinetic energy and kinetic energy per cross-sectional area, yet both projectile number 11 and number 12 were stopped by 6 layers of Kevlar.

Referring to the .45 projectile (number 13): Only one FMJ projectile was tested, which penetrated 7 layers of Kevlar.

Referring to the .38 Special projectile (number 14 to number 16): Projectile number 14 had a lower velocity, kinetic energy, kinetic energy per cross-sectional area and penetration into the Kevlar, compared to projectile number 15. The longer barrel of the rifle and the rifling, compared to the revolver, does increase the velocity of the projectile. Again, the light projectile number 16 did cause for a higher velocity, yet a lower kinetic energy, and kinetic energy per cross-sectional area compared to projectile number 15. Projectile number 16 penetrated the 39 layers of Kevlar and the additional 9 layers of 400 GSM Kevlar placed behind it, and it went 475 mm into the ballistic gel before exiting on the side of the ballistic gel. It must be noted that projectile number 16 has also the tip on the center of the projectile, which causes a larger penetration into the Kevlar, yet the lighter projectile also penetrated further into the Kevlar layers.

Referring to the .357 Magnum projectile (projectile number 17): This projectile penetrated 39 layers of 200 GSM Kevlar and 9 layers 400 GSM Kevlar behind it, when then penetrated 164 mm into the ballistic gel.

Referring to the .308 projectile (projectile number 18): This projectile penetrated the 39 layers of 200 GSM Kevlar and 9 layers 400 GSM Kevlar behind it, penetrating through the ballistic gel and destroying the wooden box that holds the ballistic gel, which could also be due to the shock wave of the projectile, as it also cause the camera which performed the recording to fall over.

CONCLUSION

The Eliminator projectiles (projectile number 9 and number 16) penetrated the 30 layers of Kevlar the most due to the point sticking out the center of it. Projectile number 2 performed almost similar penetration into the Kevlar in comparison to the 9 mmP projectile (number 6, number 7 and number 8), which also penetrated deeper than the .40, .45, and .38 Spl projectiles (excluding the Eliminator projectiles).

Projectiles number 17 and number 18 had the highest velocity and kinetic energy of the projectiles tests (excluding the Eliminator projectile – projectile number 9). The .308 projectile has also a sharper profile.

Generally, the trend is that the lighter the projectile, in comparison to other projectiles of the same calibre, the more kinetic energy and thus the deeper the penetration.

Considering the Kevlar bullet proof vests, the performance of stopping a projectile of a handgun, has shown to be able to save a life, yet the user would be cautious when the Eliminator ammunition is used, or ammunition that has a sharp tip in the front. Furthermore, the concern is with the .308 MK1 ammunition, which is the ammunition often used by the military. Due to the .308 projectile penetrating the 30 layers of Kevlar very easily, the need for a metal sheet would need to be considered. Further research needs to be done for a lighter material with similar performance to prevent the .308 projectiles.

Future work would be to identify experiments to determine how much more the penetration into the Kevlar would be, when a .22 projectile was sharpened, to have a different sharper profile, and compared with the penetration of larger calibre.

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