Design for a Repeatable Cost Effective Bullet Recovery Device

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ABSTRACT

The deformation of a projectile during ballistic interaction with material prior to its termination can detail its path and therefore contains valuable characteristics that can be used by investigators. However, firearms commonly expel bullets at velocities in excess of 228 m/s (750 ft/s). This means that stopping such a projectile requires the transfer of a relatively large amount of kinetic energy into other types of energy. Typically, this energy transfer results in physical damage which includes, but is not limited to, the deformation of the bullet itself. For the bullet to be captured without significant damage, deceleration during the capture must be minimized by increasing the distance over which the projectile stops by more than a few inches. To do so in a repeatable manner, a device design using stratifications of Kevlar and cardboard was built and tested. Six different firearms were used and six types of ammunition were used. The calibers ranged from .22 Long Rifle to 12 gauge. The degree of damage varied from minimal deformation to no visible deformation. The ability to capture projectiles mid-flight path after perforating some material without adding additional damage would allow for the previously incurred damage of interest to be assessed in the context of future investigations. In conclusion, the bullet recovery device design presented was able to capture any bullet tested without significant deformation, with few exceptions.

Introduction

In the world of forensics and injury biomechanics, investigators are often asked to look into gunshot wounds with unusual or surprising appearances and determine their cause. In some cases, the state of the bullet as it reaches the victim is a key piece of information, especially if it is believed to have impacted specific surfaces or materials prior to impacting the human target. Unfortunately, there are few ways to visualize the shape of a bullet as it reaches its target. One readily available way to observe a projectile after it hits a surface or object or as it approaches its target is to capture it on high-speed video footage **[1]**. However, video can be prohibitively expensive and time consuming, as well as technically challenging to implement in some situations. Mediums such as gelatin (and ballistic soap) are often used as a surrogate for human tissue, however, like the human body which they aim to replicate, such material are known to induce deformations in some projectiles **[2]**. Meanwhile, water recovery systems may achieve the desired results with most projectiles, but do so at great effort and in an impractical manner **[3]**. Therefore, instead, efforts were put forth to create a means to capture bullets without inducing additional deformation **[4-10]** in order to isolate the influence of an intermediate material. Such a bullet-capturing device was designed and tested and this write-up aims to discuss how it can be reliably reproduced along with its capabilities and limitations.

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One such bullet capturing device design was recommended by ballistic experts Lucien **[11]** and Michael Haag. These devices are commonly termed “recovery boxes” and their design involves the use of loose Kevlar material, usually from intact, retired, Kevlar ballistic vests. The material is removed from the vests and crumpled up in loose balls to be placed in a cardboard box. This design has served them successfully over the years. However, due to the loose placement of the Kevlar within the box, it is possible that a bullet would fail to be captured or would be captured with additional deformation as it passed through a low concentration of Kevlar. To circumvent this, a new version was designed and is provided here.

With a typical 9mm Luger caliber bullet being accelerated to more than 300 m/s (1,000 ft/s) before exiting the barrel of a firearm, slowing the projectile in a uniform and gradual enough manner so as not to cause deformation can be a challenging proposition. The deformation is tied to the forces acting on the bullet and, based on Newton’s second law, it is evident that the way to minimize the forces in question would be to minimize the rate of deceleration of the bullet. This, in turn, suggests that the bullet should be slowed down over a longer duration or a longer distance, which, in this situation, mostly takes the same form.

Using this thought process, one can reason that the distance used to accelerate the bullet to its full speed is a good approximation of the minimum distance necessary to properly slow down a bullet to a rest position without deforming it. This suggests that for handgun ammunition to be stopped without deformation, the deceleration should be applied over at least the distance equivalent to the barrel length of the handgun that fired it. Taking as an example, a Glock 17 with an 11cm (4.5 inch) barrel, this figure can be used as a first order approximation of the distance involved in decelerating the bullet.

Methods

Based on this information, sheets of Kevlar were acquired from widely accessible retail sources to ensure broad availability. This material was then characterized through preliminary testing to estimate the number of layers of material required to stop the various bullets. Since the Kevlar sheets used measured approximately 30 by 90 cm (1 by 3 feet), the sheets were wrapped around two layers of cardboard in a serpentine manner in order to make the most of the surface area. The Kevlar sheets were then spread out linearly along the expected course of the bullet using cardboard sheets as standoffs (or spacers) between layers of Kevlar. A stack of Kevlar and cardboard containing a dozen layers of Kevlar was then placed within a cardboard box (12 x 12 x 15 inches or 30 x 30 x 38 cm) for convenient transport and usage. **Figure 1** illustrates this simple design.

In order to qualify the performance of this design, cartridges of different types were fired using multiple firearms. The complete list of firearms and ammunition is shown in **Table 1.**

The device, shown in **Figure 2**, was placed at a distance of approximately 6 meters (20 feet) from the muzzle of the firearm, and shot perpendicularly into the front facing surface. Two devices were placed end-to-end in case one device was insufficient to capture a projectile. After each test, the bullet was retrieved from the device, and the Kevlar/cardboard material that presented a cavity due to bullet damage was replaced with an intact piece. The device was moved back when the test caused it to move, usually by marginal amount.

After being recovered, the state of each bullet was documented using photography before being stored for future examination. An unfired bullet of each type was also removed from its cartridge case for comparison.

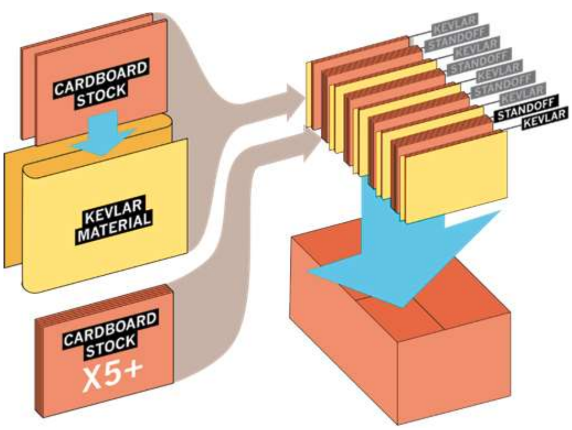

Figure 1: Bullet capturing device construction.

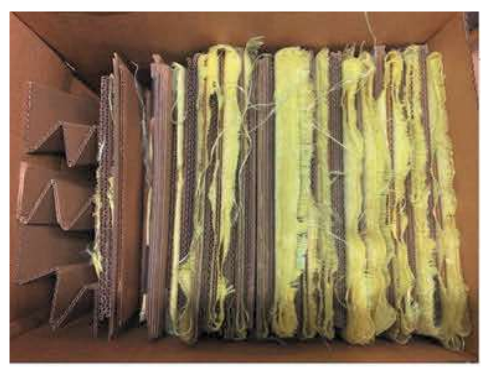

Figure 2: Top view of recovery box.

ID	FIREARM	AMMUNITION
9 mm Luger	Glock G17	Blazer 9mm Luger 124 Grain Full Metal Jacket (FMJ)
.22 Long Rifle	Glock G44	Blazer 22 Long Rifle (LR) 40 Grain
.4 Smith & Wesson	Glock G22	Speer Gold Dot, 40 S&W 165/180 Grain Gold Dot Hollow Point
0.223 Remington	Kodiak Defense Wk180C Gen 2	Federal American Eagle 223 FMJ 55 Grain
0.44 Magnum	Smith & Wesson 629	Campro .44 Magnum 240gr Truncated Cone Full Copper Plated (reloaded)
12 ga	Canuck Operator	Federal Premium 12 Gauge 1oz Rifled Slug 2¾"

Table 1: Firearms and ammunition used.

Results

The images below **(Figures 3-8)** display one “pulled”, unfired bullet removed from its cartridge case followed by fired, captured bullets in triplicate.

The 9mm Luger bullets were all successfully captured. The shape of the bullets was maintained as shown below **(Figure 3)**. Their penetration through the capture device was deeper than all other bullets, requiring the full length of one box and part of another for approximately 50 to 64 cm (20 to 25 inches) of penetration. The only visible changes observed on the projectiles were in the rifling impressions with the striations being less prominent.

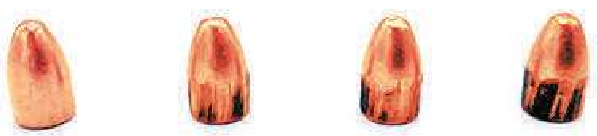

Figure 3: Intact 9mm bullet (left) compared to three (3) fired and captured 9mm bullets.

The .22 Long Rifle bullets were all captured but sustained some deformation. As shown in **Figure 4**, the nose of the bullets appears to be blunted to some extent. The bullets also appear to have lost some of their cylindrical nature, likely due to an asymmetrical loading at recovery. This is not particularly surprising given that these unjacketed bullets are composed of plain lead. These bullets were captured within approximately half of the device or approximately 15 to 25 cm (6 to 10 inches) of penetration.

Figure 4: Intact .22 LR bullet (left) compared to three (3) tested .22 LR bullets.

The .40 Smith & Wesson bullets tested appeared to retain their shape **(Figure 5)** despite the propensity of hollow point bullet to expand or “mushroom”. The “hollow” portion of the tip was filled with material (mostly cardboard) as it travelled through the recovery device. Fortunately, the pressure differential at the tip of the bullet was not sufficient to cause it to open and peel back. The bullets did travel through most of the device before coming to a standstill, penetrating to a depth of approximately 25 to 36 cm (10 to 14 inches).

In the case of the .223 Remington bullets, the bullet showed a propensity to yaw out of the confines of the bullet trap as two bullets were not recovered. Evidence of the bullet exiting the

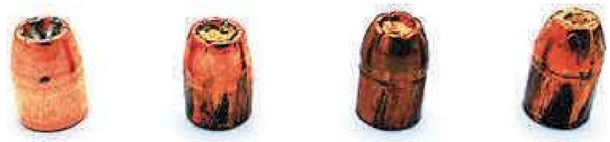

Figure 5: Intact .40 S&W 165Gr bullet (left) compared to one (1) intact 165Gr and two (2) 180Gr (right) fired and captured bullets.

bullet trap through the side was identified. For this reason, two more bullets were fired, and a total of three bullets were captured. The state of the bullets recovered showed variation, as shown in **Figure 6**. However, the bullets were generally intact. Amongst the damaged observed, the tip of each bullet appeared blunted, and one bullet appeared to have sustained some flexion along its long axis. Likely due to additional muzzle velocity and aerodynamic profile, the penetration the .223 Remington bullets was deeper than most, ranging from approximately 46 to 56 cm (18 to 22 inches).

Figure 6: Intact .223 Remington bullet (left) compared to three (3) tested .223 Remington bullets.

All .44 Magnum bullets were also captured successfully. The bullets sustained mild deformation at their base but retained their cylindrical aspect **(Figure 7)**. Moreover, a flattening of the soft lead tip can be observed in all three of the test bullets. The rifling marks can also be observed on the bearing surface or lateral aspect of the bullet. The bullets were stopped at the latter half of the capture device for a penetration of approximately 28 to 36 cm (11 to 14 inches).

Figure 7: Intact .44 Magnum bullet (left) compared to three (3) fired and captured .44 Magnum bullets.

The 12-gauge slugs fired into the capture device were recovered with some deformation, primarily along the long axis of the projectiles **(Figure 8)**. Abrasions can be seen on the frontal aspect of the slug, indicative of the interaction with the Kevlar fibers and cardboard. The center of gravity of the slug also appears to have shifted towards the posterior aspect, as evidenced by the encapsulation of the plastic bead. The slugs were captured approximately in the middle of the capture device at between 20 to 30 cm (8 to 12 inches) of penetration.

Figure 8: Intact 12-gauge slugs (left) compared to three (3) fired and captured 12- gauge slugs.

Discussion

The bullet capture device was able to recover the bullets from the tested cartridge types mostly in a minimally deformed state. The bullets which sustained the most deformation were the shotgun slugs and .22 Long Rifle bullets. The cause of the deformation can likely be attributed to the material of the projectiles. These projectiles are primarily composed of lead which is known for its malleability.

In the end, the device made it possible to observe interesting behaviors such as the deformation of the shotgun slug. As previously explained, the slugs retained their overall shape but their weight distribution, and features appeared to change. For example, material appears to have shifted down towards the posterior aspect of the projectile. For comparison, the edge of the lateral side wall of the unfired slug appears to be approximately 2 mm (0.08 inches), while the captured slugs showed a sidewall of more than 4 mm (0.16 in) on its bottom side. As evidenced in **Figure 8** and illustrated in **Figure 9**, the fired slugs also appear shorter than the unfired slug. The ridges seen on the unfired slug are also not in evidence on the captured test samples. This suggests a migration of the matter in such a way that the lead from the front part of the slug filled the ridges and moved further towards the tail end of the slug. Due to the uniform and repeatable nature of this deformation, it is assumed to occur as a result of the initial gas expansion within the firearm's barrel and not as a by-product of the projectile's capture. These features may be anecdotal in the context of this study but they represent the kind of valuable information about a projectile which could be gleaned by recovering the round.

The Kevlar-cardboard matrix chosen appeared ideal as it seemed to engulf the bullet upon capture. As the bullet passed through a layer of Kevlar, the fibers of the material were dragged along by the bullet. Through this effect, the fibers produced resistance even after the bullet had passed through the plane of the Kevlar sheet, essentially spreading out the effect of the Kevlar layer over a longer distance. This behavior is consistent with a gradual deceleration as the bullet travelled through each layer of Kevlar, instead of a large, sudden deceleration produced by each layer of Kevlar. This unexpected feature is thought to have improved the performance and increased the viability of this design.

The penetration depth of the different bullets ranged from approximately half of the capture device to one and a half times the length of the device (approximately 7.5 to 22.5 inches). The projectiles with greatest penetration, the 9mm Luger and .223 Remington bullets, are believed to have had greater penetration due to their more aerodynamic profile. The sharper profile of those bullets would have allowed them to slip between the fibers of Kevlar, reducing the effect of the first layers.

Although three of the .223 Remington caliber bullets were captured, two others managed to escape the device. Based on this unexpected result, modifications could be made to the device in order to limit the likelihood of such an outcome. Possible modifications include, but are not limited to, increasing the size of the device, adding Kevlar layers along the outer edges of the device (side, top and bottom), or using wadded up balls of Kevlar instead of flat sheets, or a combination of the two.

The purpose of this design was to create an easy to construct, technically simple bullet trap device that could deliver repeatable, useable results. Some may say that the role fulfilled by this kind of device is redundant to the use of other devices such as water tanks. However, such recovery devices are expensive and do not offer much flexibility when

Figure 9: Deformation of 12-gauge slug.

designing a study. Meanwhile, the proposed design of this bullet capture device is cheap and reusable. Moreover, if one keeps Kevlar and cardboard in stock, such a device can be assembled relatively rapidly.

It bears mentioning that the device produced in the context of this study behaved as it did as a function of the specific materials used. In other words, a different kind of Kevlar may produce different result. Two other Kevlar materials were tested as part of a preliminary test and results varied significantly. The other Kevlar material tested originated from discarded but never fired ballistic vests. The nature of the material in those vests was more akin to paper while the chosen, store-bought Kevlar was more like a weaved fabric. The chosen Kevlar was preferred for its accessibility, low cost and fibrous nature which led to the behaviour described previously.

The Kevlar in question must be arranged in a manner that slows the bullet gradually. Past experience with shredded Kevlar vests of various types has shown that there are two main categories found in retired vests: fabric like sheets, and waxy coated sheets. The waxy coated sheets are less preferable because the projectiles tend to melt into and become entrapped by the material. A third common style of Kevlar is a fibrous variety. This highly shredded Kevlar, often sold to laboratories for use in long cylindrical bullet trap devices, does not allow for quick deceleration. Of all types, the fabric-like sheets of Kevlar used in this study are most advantageous.

With a uniform Kevlar and cardboard combination identified, it is possible to use this technology to characterize the impact of certain bullet interactions. Such interactions may consist of comparing the effect of different materials (such as glass) on a specific ammunition type in order to correlate the shape of the resulting projectile to an injury after moving through such materials. Alternatively, the perforated material may be kept the same while different ammunition types used in the same incident are tested in order to examine a correlation with a specific injury. A recent casefile example where this technique was implemented involved a medically confirmed and documented bullet graze to the forehead. Knowing the state of one of the projectiles after it had passed through laminated glass made that particular projectile unlikely to have caused the injury. This finding allowed for a determination of the likely shooter that caused the bullet graze wound.

Conclusion

In conclusion, the bullet capture device presented was able to reliably capture bullets of different caliber, ranging from .22 Long Rifle to 12-gauge slug, without significant deformation. This device can be built easily and relatively cheaply, with commonly available materials. Future studies could explore the performance of this device in more detail, perhaps comparing it to other available methods.

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None

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