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P6_3 Bulletproof T-shirts

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Abstract

The world record number of T-shirts worn is 257, in this paper we calculate whether this many layers is sufficient to stop a 9 mm and a 7.62 mm bullet. Our conclusion is that only 168 shirts are needed to protect against a 9 mm round but you need 316 shirts to stop a 7.62 mm round (a typical Rifle bullet). We compare our results to traditional body armour and show that the T-shirts are at least 10x less effective.

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Introduction

Sanath Bandara holds the Guinness world record for the most t-shirts worn at 257 [1]. While an impressive feat, if Mr Bandara found himself facing a gunman armed with a 9 mm pistol, could he survive a shot to the chest? In this paper we will explore how effective cotton t-shirts act as body armour. We will use Newton's approximation for impact depth to estimate how many shirts can withstand a 9 mm Full Metal Jacket (FMJ) bullet and a 7.62 mm Rifle round.

Theory

Newtons equation for impact depth can be used to estimate impact depths of projectiles travelling with high velocities. While it may be unusual to apply this equation to cotton, we believe it is the best way to approach the problem. Newton's formula is derived by considering the transfer of momentum from the projectile to the medium as it penetrates. To derive the equation, we assume that the projectile leaves a cylindrical path behind it, and displaces all the mass that used to occupy the space. You can go on to state that the mass of the bullet is equal to the mass of the medium that has been displaced.

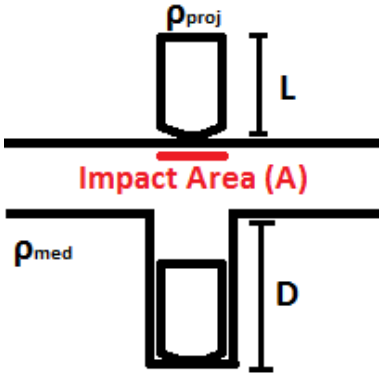

Figure 1: Diagram that shows how a projectile is predicted to enter a medium at high velocity, where D is the penetration depth (m) and L is the projectile length (m).

$$M_{\text{med}} = M_{\text{proj}} \tag{1}$$

$$M = \rho V \tag{2}$$

In Eq. (1), M_{med} and M_{proj} are the masses of the medium and projectile respectively. Eq. (2) states mass in terms of density (ρ) and Volume (V).

The projectile displaces mass in its path, leaving a cylindrical hole with displaced mass equal to the mass of the projectile. From these two equations, we can derive Newtons equation for impact depth:

$$\rho_{\text{med}} AD = \rho_{\text{proj}} AL \tag{3}$$

$$D = L\frac{\rho_{\text{proj}}}{\rho_{\text{med}}} \tag{4}$$

Results

A standard 9 mm bullet has a length of 19.0 mm [4], the bullets mass is 7.45 g, and by using Eq. (2), its density can be calculated to be 6164 kgm^{-3} by assuming it to be a cylinder. We used the density value of raw cotton for our calculations, and it was stated as 1540 kgm^{-3} [2]. We used Eq. (4) to show that the 9 mm bullet would penetrate 76.05 mm of cotton. A standard cotton shirt is stated as having a thickness of 0.45 mm [3], this means that the bullet would have passed through 168 T-shirts.

Our calculations show that the man would have survived an impact from a 9 mm bullet. We can repeat the calculations for the popular 7.62 mm rifle round used in many modern rifles. The round is 51 mm long and has a mass of 10 g [5] meaning it should penetrate many more T-shirts according to our equation. We calculated the density of a 7.62 mm round as 4300 Kgm^{-3}. This leads to an impact depth calculation of 142.40 mm, which is a total of 316 T-shirts, enough to fully penetrate through all of Sanath Bandara's layers.

Discussion

While its surprising to find that it is possible to stop a bullet with nothing but T-shirts, modern day body armour is thin enough to function in but can stop all but the most penetrating rounds. Most body armour is a combination of a Hard Metal/Ceramic layer and a Kevlar layer. Police armour that is designed to stop 9 mm bullets, can be as thin as 4-5 mm, while armour of 15 mm in thickness or more is able to stop 7.62 mm rounds [6]. Modern armour is therefore almost 10 times more effective than pure cotton at stopping bullets.

The first assumption that we made was to use Newtons equation for impact depth, which is traditionally used for high velocity impacts such as meteors. The 9 mm bullet in particular may not have had enough velocity in order for the equation to be applied. Newton's equation cannot account for the bullets shape being suited for maximum penetration, or account for the non-uniformity of the many layered cotton medium.

The second assumption is that we modelled the bullets as a cylinders in order to calculate their densities, we would expect the bullets to have higher densities than the ones calculated as the volume of the real bullet shape would be slightly lower than the approximated volumes.

Conclusion

Our results show that even given our assumptions, 257 shirts is enough to stop a 9 mm bullet but not a 7.62 mm round. The amount of shirts needed in order to be as effective as 15 mm Military body armour is only just beyond the world record at this point, however modern armour is far more practical. To further the study we could have used different models of bullet penetration, or further investigated bullet dynamics.

References

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