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P3_6 Testing Bulletproof Vests

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Abstract

Wearing the right type of body armour is vital for people working for the police or the military. This why bulletproof vests are very carefully examined and tested before being used. Here, we investigate if a III-A bulletproof vest is capable of stopping a 9x19 mm Parabellum bullet, so that the person wearing the vest is not injured. We find that the bullet penetrates 2 mm into the vest, which is not enough to cause any injuries to the person being shot. In addition, we also calculate the energy of the bullet after firing, which is 483 J, and the velocity imparted to the target, which is 0.04 ms^{-1}.

Introduction

Unlike the traditional hard body armour, bulletproof vests are considered soft body armour, as they are not made of metal but of advanced woven fibres. These fibres act like a very strong net, they push out on the bullet with the same force with which the bullet pushes, so the bullet cannot (fully) penetrate the vest. The interlacing of the fibres in the vest acts to disperse the energy of the bullet at the point of impact over a wider area, so the whole fibre net works to absorb the bullet's initial energy irrespective of where it hits [1]. A popular choice of material for bulletproof vests is Kevlar because of its high durability and lightness. The interior of such vest consists of several layers of Kevlar sandwiched between layers of plastic film. The exterior is then covered in a typical textile material for outside wear. Each layer of Kevlar net slows down the bullet until it completely stops. The material can also deform the bullet at the point of impact. The energy of the bullet is dispersed over the whole surface of the net, preventing penetration, and dissipating blunt trauma. Usually, the more layers a bulletproof vest has, the more protection it provides, but a vest with more layers is thicker and makes it harder for the wearer to move quickly. However, bulletproof vests are not impenetrable, and they do not offer protection against knife stabs.

Results and Discussion

We assume that a 9x19 mm Parabellum bullet, with a mass $m = 7.54\ g$ and diameter $d = 9\ mm$ [2], is fired at a target wearing a III-A bulletproof vest, which has a thickness of 9 mm [3]. This type of bullet has an initial velocity at firing of 360 ms^{-1} [2]. Assuming the air friction and drag force do not affect the bullet's velocity and that there is no wind, we can find the kinetic energy of the bullet for constant velocity:

$$E = \frac{1}{2}mv^2 = 483J \tag{1}$$

When neglecting the drag force, the depth the bullet penetrated the vest can be found using the

following formula [4]:

$$x = \frac{E}{AY} \tag{2}$$

where x is the depth, E is the energy upon impact, A is the cross-sectional area of the bullet and Y is the tensile strength of the material. For simplicity, we assume the vest is made entirely of Kevlar, which has a tensile strength of $Y = 3620$ MPa [5].

The cross-sectional area of the bullet is calculated from:

$$A = \pi \frac{d^2}{4} \tag{3}$$

After plugging in equation 3 into equation 2 and substituting the right values, we find $x = 2$ mm. The bullet has penetrated 2 mm into the vest, which has a thickness of 9 mm, so the III-A vest successfully protected the target.

In addition, we are interested in finding the velocity imparted to the target by the bullet. To find this, we use the conservation of momentum and assume the target has an initial velocity of zero and a mass $M(target) = 70$ kg:

$$V(b) \cdot M(b) + V_0(t) \cdot M(t) = V(t) \cdot (M(b) + M(t)) \tag{4}$$

where (b) means bullet and (t) means target. $M(bullet) << M(target)$, so we can assume:

$$V(b) \cdot M(b) = V(t) \cdot M(t) \tag{5}$$

From equation 5 we can find $V(target)$ as:

$$V(t) = \frac{M(b) \cdot V(b)}{M(t)} = 0.04 ms^{-1} \tag{6}$$

The results obtained here may differ slightly in reality as our study does not consider the effects of the air friction and drag force on the bullet. Real vests are also not made entirely of Kevlar, which adds further errors in our calculations. However, a III-A bulletproof vest is capable of stopping a 9x19 mm Parabellum bullet to cause fatal injuries to the target. In reality, bulletproof vests are not bulletproof, but bullet resistant. It is worth mentioning that, although bulletproof vests can prevent most fatal injuries, the target can still experience minor to moderate injuries due to the impact with the bullet.

Conclusion

We have found that a 9 mm thick III-A bulletproof vest is capable of stopping a 9x19 mm Parabellum bullet. The bullet penetrates 2 mm into the vest. Additionally, we have determined the kinetic energy of the bullet at firing to be 483 J and the velocity imparted to the target by the bullet to be 0.04 ms^{-1}. This vest can stop bullets of higher calibre and is hard to conceal under thin clothes because it is very thick. We conclude that this vest would be more suitable for military use rather than police because policemen need lighter vests, which are easier to hide and do not complicate movement.

References

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