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A5_6 Protective Panning

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Abstract

In the video game 'PlayerUnknowns's Battlegrounds' a cast iron pan is able to ricochet incoming bullets to protect the wearer from harm. We identified the critical incident angle as 45.39° using a Beretta 92S pistol using 9 mm Parabellum ammunition with any incident angle less than this causing complete ricochet.

Introduction

The video game 'PlayerUnknowns's Battlegrounds' (PUBG) pits 100 players in a fight to become the last person alive on an otherwise deserted island. Players spawn with nothing and over the course of the game scavenge for items which may assist in victory. One such item is the frying pan, which at first glance could be overlooked as a melee weapon of little use. The frying pan is actually one of the most valued items despite its uselessness offensively due to the pans unique ability to deflect bullets. We investigated the impact properties required for a cast iron frying pan to actually be able to cause ricochets. Modelling the bullet on impact as a hydraulic press using shear stress to achieve penetration [1] a critical angle for ricochets can be obtained. It is assumed the pan in-game is cast iron.

Theory

Any projectile that bounces off a surface is said to ricochet. Ricochets occur when the angle of incidence is sufficiently low that on contact with the surface the projectile is significantly deflected from the initial trajectory while maintaining projectile structural integrity [2]. Structural integrity assumes the projectile remains as a single object and doesn't fracture or splinter.

Stress expresses how much internal force the material can withstand before slippage along the plane parallel to induced stress. Figure 1 details how the shear stress can cause a fracture in the material allowing penetration of a projectile.

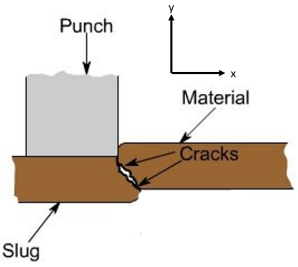

Figure 1: The punch in the diagram is the bullet with cracks appearing in the surface of the material due to uneven force distribution causing shear stress fractures [1]. The slug is the volume of the pan fractured by the bullet (punch).

The force required for penetration is found via (1). Where F_{Pen} is the force required for penetration, L is the perimeter of the bullets impact, T is the thickness of the material and P_{Shear} is the shear strength of the material.

$$F_{Pen} = LTP_{Shear} \tag{1}$$

When the projectile impacts off the material force is applied in both the x and y axis dependant on the angle of incidence as shown in figure 2.

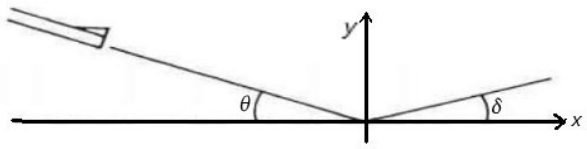

Figure 2: The incident angle is denoted by θ and the ricochet angle by δ [3]. The surface runs along the x axis with the impact at the intersection of x and y.

The force of bullet in the y axis, the plane perpendicular to the material, is found by Newtons second law (2). Where $\vec{F}_{net}$ is the net force in the direction of the plane, m is the mass of the projectile and $\vec{a}$ is the acceleration of the projectile.

$$\vec{F}_{net} = m\vec{a} = ma\sin(\theta) \tag{2}$$

We assumed at impact the acceleration change to be instantaneous, as we are only interested in the directional change at impact, in reality there would also be deceleration. We can make this assumption as real bullets would dent the pan, whereas we are looking at binary penetration or deflection. We also assumed the acceleration of the bullet at the pan is the same as the acceleration the bullet has when it leaves the barrel, as acceleration would decrease with distance due to air resistance which we've assumed as negligible. The bullet's acceleration on impact with the pan can be calculated using the kinematic equation (3), where V is the final velocity of the projectile, V_0 is the initial velocity and s is the barrel length. Air resistance is assumed to be negligible and thus the velocity upon leaving the muzzle is the same velocity upon impact.

$$a = \frac{V^2 - V_0^2}{2s} \tag{3}$$

By substituting (3) into (2) and setting $\vec{F}_{net}$ equal to F_{Pen} and rearranging for θ as seen in (4), we can find the critical angle at which penetration can occur. All angles smaller than θ_{crit} will ricochet. The perimeter created by the impacting projectile is assumed to be constant even with a changing angle.

$$\theta_{crit} = \arcsin\left(\frac{2sLTP_{Shear}}{m(V^2 - V_0^2)}\right) \tag{4}$$

Discussion

One firearm within the game is the Beretta 92S, a standard US Army issue pistol. The 9 mm Parabellum bullet begins at rest, has a muzzle velocity of 335 ms^{-1}, a barrel length of 127 mm [4][5] and a bullet weight of 8.04 g with a diameter of 9.01 mm [7]. The shear strength of cast iron is 21600 psi [8], the standard top of the range cast iron pan is 0.6 mm thick [6]. Computing all the information into (4) gives a θ_{crit} of 45.39°. Any incident angle smaller than this under these conditions would trigger a ricochet.

Conclusion

We found the critical angle under which ricochets occur against a cast iron pan when fired at by a Beretta 92S using 9 mm Parabellum ammunition were in line with the results found in [2], where the .38 revolver created ricochets even at high incident angles against steel plating with no penetration. Our results do not take into account that higher velocity targets are often destroyed during the ricochet process due to instability tearing the round apart [2], nor do they take into account air resistance slowing down the bullet before it hits the pan which would increase the incident angle ricochets could be achieved at.

References

[1] `https://bit.ly/2YhpQTK`[Accessed 20 Nov. 2019]

[2] `https://bit.ly/3618ixV`[Accessed 20 Nov. 2019]

[3] `https://bit.ly/2Pb6onQ`[Accessed 20 Nov. 2019]

[4] `https://bit.ly/2PfJbRv`[Accessed 20 Nov. 2019]

[5] Myatt, F. (1981). An illustrated guide to pistols and revolvers. London: Salamander.

[6] `https://bit.ly/2Yd4V4s`[Accessed 20 Nov. 2019]

[7] `https://bit.ly/2rcBaEM`[Accessed 20 Nov. 2019]

[8] `https://bit.ly/363igit`[Accessed 20 Nov. 2019]