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P4_5 Bending Bullets

Brewster. N, Adams. N, Kerr. T, Smith. J.

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH.

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Abstract

This article investigates how the Coriolis force affects the flight of a bullet. For this investigation, the distance of the shot is taken to be equal to the longest recorded kill, 2.48km [1], with an average flight velocity of 450ms^{-1}. Using these figures, it is found that there is a lateral displacement of 1m, therefore the sniper could easily miss the target if the Coriolis force is not considered. It is also found that with the equipment discussed, any shot beyond 1300m could be affected enough by the Coriolis force to miss the target.

Introduction

The longest confirmed kill by a sniper is clocked at 1.54 miles (or 2.48km) using an Accuracy International L115A3 long-range rifle [1]. This paper investigates whether such a shot would have to consider the rotation of the Earth and compensate for it. The force in question is the Coriolis force which acts to push moving objects to the right in the northern hemisphere and to the left in the southern hemisphere.

Analysis

The Coriolis force is defined as

$$\boldsymbol{F} = -2m\boldsymbol{\omega} \times \boldsymbol{v}, \qquad (1)$$

where m is the mass of the moving object, ω is the angular velocity of the rotating body and v is the velocity of the moving object [2]. This is most commonly used to describe weather systems, since it is the Coriolis Effect that causes them to spiral. This can be written as an acceleration by replacing the force with $F = ma$, where F is the force acting on the bullet, m is the mass of the bullet and a is the acceleration experienced by the bullet. Substituting this means masses cancel leaving only the vector product. This can also be removed by considering only the magnitude when the angle between the two vectors is aligned to create a maximum, which is when they are perpendicular. This leaves

$$a = -2\omega v. \qquad (2)$$

By using this condition, the shot is assumed to be fired due south (or north) in the northern hemisphere (since the force always acts to the right in the northern hemisphere, as can be seen in equation 1).

The angular velocity of the Earth can easily be calculated by dividing 2π by the number of seconds in 1 day, however the velocity of the bullet varies in flight, so an average must be taken (figure 1).

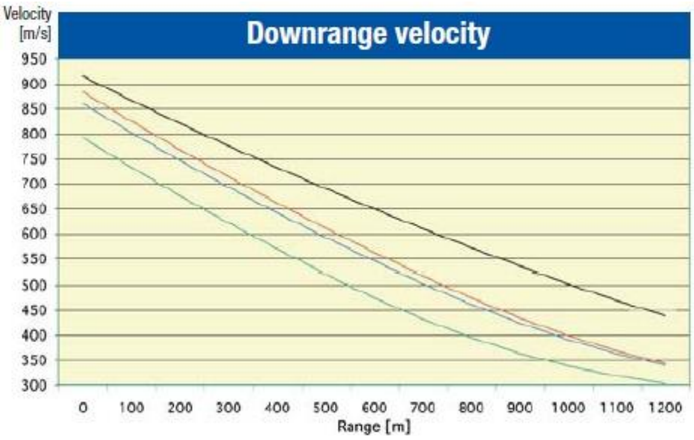

Figure 1: *Velocity variation of several bullets manufactured by Lapua [3]. The black line shows the velocity curve for the .338 Lapua Magnum round, which was used for the longest corfirmed kill.*

Clearly this only extends to 1200m, with the longest shot being around a further 1300m. The line shows a gradual exponential decay therefore it is possible to extrapolate the graph to 2500m, at which point the velocity will be around 250ms^{-1}. Due to the exponential decay, the mid-point of the bullets flight can be taken to be the average velocity, which is around 450ms^{-1}. The

Coriolis acceleration can then be calculated from equation (2) as $0.065ms^{-2}$ (the negative sign can be ignored as this only determines direction). Then using the equation

$$s = ut + \frac{1}{2}at^2, \quad (3)$$

where *s* is the displacement, *u* is the initial velocity, *t* is the time and *a* is the acceleration, the lateral displacement due to the Coriolis force was found. Since this is only considering the lateral movement, *u* is set to zero, then *a* is the Coriolis acceleration and *t* was found from the distance the bullet travelled divided by the average velocity, which is 5.5 seconds. Substituting these values gives a displacement of 0.99m. In the context of a 2.5km journey, this displacement is minimal, however, when considering the target is at most 0.5m wide, this means the shooter could easily miss the target.

Clearly the case above is an exceptional circumstance. The same process was done in reverse to try to find the minimum distance at which the shooter might miss the target. To do this, an average chest width was taken as 35cm, therefore if aiming in the middle of the chest, a deviation of 17.5cm would constitute a miss. Since the average velocity, and thus the Coriolis acceleration, is dependent on distance there was some trial and error involved in the calculation. As such, it was necessary to simply choose a distance and using the same method as above, determine whether a shot at that distance would hit or miss. Doing this for a few distances, a cut-off point of around 1300m was found whereby within this range the bullet should still hit the target but beyond this it will miss (when aimed in the middle of the target).

Conclusion

These calculations show that when considering a shot equivalent to that of the longest ever recorded, the Coriolis Effect must be considered and therefore compensated for. In addition, it is found that using a system similar to the equipment considered here (the Accuracy International L115A3 rifle firing the .338 Lapua Magnum), any shot beyond 1300m could be deflected enough to mean the shooter misses the target.

References

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