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A3_7: Babylon Gun Revisited

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Abstract

This paper investigates the Iraqi supergun that was under construction in 1988. The gun was never completed so its performance will be investigated using a model constructed from information about the gun. The maximum range of the gun fired at 33 degrees to the horizontal was investigated and found to be 1406km. Its impact angle was found to be 61 degrees and its impact velocity 2640m/s.

Introduction

In our previous paper, 'Babylon Gun' [1], we investigated the performance of the Iraqi supergun that was under construction in 1988 firing vertically. In fact two of these devices were planned the second of which would have been built on an embankment angled at 33 degrees [1][2]. This follow on paper will use the same model presented previously to look at the same projectile fired at 33 degrees and calculate its maximum range impact angle and impact velocity.

Theory

The same chemical explosive has been selected namely TNT the chemical compound is [1][3][4],

$$C_6H_2(NO_2)_3CH_3,$$

and contains upon detonation around 4184 kJ/kg via decomposing in the manner shown in our previous paper [1]. As before this will provide the impulse to the projectile.

The gun has been modelled exactly as previously stated, as a special type of piston engine and its efficiency has been estimated at around 33% due to the degrees of freedom of the gas. With 4 recoil cylinders that would bleed off gas to prevent damage to the gun during firing and a recoil spring to prevent damage to the breach and firing assembly [2]. This setup would take 50% of the useful energy of the explosion and dissipate it harmlessly. Internal friction from the barrel has been ignored as this is dependent on the projectile and the bore tolerances.

As previously shown with these assumptions it is calculated that 9 tonnes of TNT would impart $1.40\text{x}10^{10}$J of energy to the projectile. Assuming this energy is converted into kinetic energy and using the equation below [5],

$$KE = \frac{1}{2}mv^2. \quad (1)$$

The mass of the projectile *m*, is 600kg. The release velocity *v* of the projectile can be calculated to be 4320m/s.

Big Babylon could also fire (on a 2nd gun, not by manoeuvring the previous device) at 33 degrees from the horizontal. Taking the previously calculated velocity, and separating the vertical (y) component and the horizontal (x) component using [5],

$$v_x = v_0 cos\alpha, \quad (2)$$
$$v_y = v_0 sin\alpha, \quad (3)$$

where α is the angle from the horizontal, and v_0 is the initial velocity previously calculated. Component forms can be found for kinetic energy by combining (1) and (2) or (3). The vertical component was found to be 2353m/s and the horizontal component 3623m/s. The vertical component is subject to the same forces as before whereas the horizontal component will only experience the drag force. The horizontal equation of motion will be,

$$m\frac{dv}{dt} = -\frac{1}{2}C_d \rho \pi R^2 v^2, \quad (4)$$

The mass of the projectile is still *m.* The radius of the projectile *R* was 0.5m. The drag coefficient C_d was estimated as a cone with a cylinder attached and a boat-tail giving a value of 0.2. The density of air *ρ,* is 1.2kg/m^{3}at sea level. Both of these quantities will vary throughout the flight regime so will be modelled using a iterative computer process as before. The vertical component will again be subject to the following quadratic drag equation [5][6]:

$$m\frac{dv}{dt} = -(m - m^*)g - \frac{1}{2}C_d \rho \pi R^2 v^2, \quad (5)$$

where symbols take their previous definitions. The mass of the displaced medium m^* is ρ *x (volume of projectile)* and the volume of the projectile was estimated from the density of steel to be 74.5m^3. *R* is still radius of the projectile. 0.2. Rearranging and substituting apparent gravity g^* which was calculated to be 8.35, which is *g* minus *g* multiplied by the ratio of the displaced medium mass to the mass of the projectile, (which accounts for the buoyant force), and putting all constants as a single constant γ, we get the following equation for the upward acceleration.

$$\frac{dv}{dt} = -g^*(1+\gamma^2 v^2). (6)$$

Integrating this and applying the condition that $v(0)=v_0$, we get the upwards velocity as a function of time:

$$v(t) = \frac{1}{\gamma}\tan\left(-\gamma g^* t + \arctan(\gamma v_0)\right). (7)$$

The height that the projectile reaches is the integral of the velocity with respect to time.

$$h(t) = \int v(t)dt. \quad (8)$$

Performing this integral and setting the condition that $h(0)=0$ we get the height as a function of time for the upwards path and the integration constant.

$$h(t) = \frac{1}{\gamma}\frac{1}{\gamma g^*}\ln(\cos(-\gamma g^* t + \arctan(\gamma v_0))) + C$$

$$C = \frac{1}{\gamma^2 g^*}\ln\sqrt{(1+(\gamma v_0)^2}. \quad (9)$$

The integration constant *C*, is in fact the maximum height that the projectile will reach. However direct calculation using a static C_d and ρ will give an incorrect value as the drag coefficient is not constant from mach 12 to below mach 1, and the air density varies exponentially with height [7][8].

$$C_d = \mathrm{e}^{\left(-1.7066-0.33\mathrm{M}+0.00366\mathrm{M}^2\right)} \quad (10)$$

$$\rho = \rho_0 e^{\frac{z}{H}}. \quad (11)$$

Where M is the mach number, z is the height and H is the scale height taken as 8km. This equation for the drag coefficient is empirically derived.

Using formulas (3)(5)(10)(11), and a computer iterative process, the flight time was calculated from the vertical component in the same manner as our previous paper and was found to be 479s with a final velocity of -2347m/s and a height of 241km. The horizontal component was then modelled using (2)(4) and the height data from the vertical component to vary the density of air with altitude. It was found that the projectile would travel 1406km in this time and its impact velocity would be 1280m/s.

Taking these two components and again using equations (2)(3), the impact angle can be calculated to be 61 degrees, and the total velocity in this direction is 2640m/s. At this velocity its kinetic energy is 20.9 x 10^{8}J.

Conclusion

In conclusion the predicted range is again found to exceed Bull's original claims of over 1000km range. However even calculating in the rotation of the earth and assuming it would fire in to this rotation, which was the direction it had been intending to face, the projectile would not stay in orbit without further acceleration provided by a booster of some form. Used as a weapon however the gun was capable of hitting targets out to 1406km at 2640m/s with 20.9 x 10^{8}J of kinetic energy on top of whatever payload was carried. The inability to move the gun or target it however would be a serious limitation.

References

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