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A3_4: Babylon Gun

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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 height of a projectile fired from the gun was calculated and compared to the project leaders original claims of the weapon. It was found that the projectile would rise to a height of 1046km, which was very close to the 1000km originally predicted.

Introduction

In 1988 Iraq embarked upon a secret project to build a supergun. The project was led by Gerald Bull and based upon work he had done in the 1960s Project HARP[1]. This report will test whether the biggest of these devices, 'Big Babylon' would have lived up to the initial claims made by Bull. Big Babylon was 1m in diameter (bore) and 156m long and would have used 9 tonnes of chemical propellant to launch a 600kg projectile to ranges over 1000km [2]. Big Babylon was designed to fire in two modes, one was to launch vertically up into the high stratosphere which was how HARP had tested re-entry vehicles, the second mode was to launch at 33 degrees to send an object into low earth orbit. The vertical launch mode will be investigated here.

Theory

The problem was approached by first looking at the amount of energy available in 9 tonnes of propellant. The propellant chosen was TNT (Trinitrotoluene) which has the chemical composition [3][4],

$$C_6H_2(NO_2)_3CH_3$$

and contains upon detonation around 4184 kJ/kg which is far less than its heat of combustion due to oxygen deprivation. 1kg of TNT which has a molecular weight of 227g/mol is approximately 4.4 mol of TNT and will decompose to 22 mol of gas shown below.

$$3N_2 + 5H_2O + 7CO + 7C$$

or

$$3N_2 + 5H_2 + 12CO + 2C$$

This will provide the impulse to the projectile.

The gun has been modelled 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. The gun also has 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.

Using these assumptions it can be shown that 9 tonnes of TNT would impart 1.40×10^{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 was designed to shoot directly upwards as a cheap alternative to rockets for putting objects in to low orbit. This technique had been used by HARP to test re-entry vehicle shapes. Taking the previously calculated velocity, the projectile motion was then modelled using quadratic drag equation [5][6]:

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

The mass of the projectile is still *m*. 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. 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. Rearranging and substituting apparent gravity g^* which was calculated to be 8.35, for the mass minus the displaced medium mass (which accounts for the buoyant force), and putting all constants as a single constant γ, we get the following equation for the upward acceleration.

$$\frac{dv}{dt} = -g^*(1+\gamma^2 v^2) \quad (3)$$

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

$$v(t) = \frac{1}{\gamma}\tan\left(-\gamma g^* t + \arctan(\gamma v_0)\right) \quad (4)$$

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

$$h(t) = \int v(t)dt \quad (5)$$

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.

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

$$C = \frac{1}{\gamma^2 g^*}\ln\sqrt{(1+(\gamma v_0)^2} \quad (6)$$

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].

$$C_d = \mathrm{e}^{(-1.7066-0.33\mathrm{M}+0.00366\mathrm{M}^2)} \quad (7)$$

$$\rho = \rho_0 e^{\frac{z}{H}} \quad (8)$$

Where M is the mach number, z is the height and H is the scale height taken as 8km.

Using formula's (3)(5)(7)(8) and the information already calculated and iterating the small change in velocity within a small time increment the maximum height that the projectile would reach is found to be 1046km. This model includes the reduction in drag due to the reduction in density of the atmosphere with altitude [8], and also models the variation of the drag coefficient from mach 12 to mach 0 using experimental data from hypersonic studies [7].

Conclusion

In conclusion Bull's original assessment of the guns performance seems realistic. His original statement was for 9 tonnes of his specialised supergun propellant which have been modelled here using TNT. Some thought was given to using RDX which is a higher power explosive and one that Iraq had a known stockpile of, but there were worries about the power of this explosive (and in particular the velocity of the shockwave which is 8.75kms^{-1}) and the integrity of the gun, so TNT was selected.

These distances could be increased by reducing the drag of the projectile using bleed effects or using rocket propelled projectiles of which Bull was also well renowned [9]. This may explain why he was later assassinated as there were rumours of him redesigning the scud missile nose cone. In conclusion, had the gun ever fired properly it is likely it would have been capable of putting small payloads into low earth orbit firing from 33 degrees, or as shown over 1000km vertically upwards. Combined with a sophisticated targeting system and steering system for the projectile this could have had a anti satellite capability.

References

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