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DESIGN AND DEVELOPMENT OF WATER ROCKET

Mr. Ramjan R. Pathan

Mr. Anaekh Dheepak

Mr. Sagar Tijare

LIGHTNING DRONES, INDIA

ABSTRACT

Rocket technology dates back to the 1st century BC, when the Hero of Alexandria came up with an engine which works on steam. Right from that period there have been numerous improvements in the rocket technology. Understanding of actual rocket and its performance can be carried out with water rocket, which is easy, safe and less expensive. This paper deals with the design and development of water rocket and its parachute. Water rocket works on the principle of Newton's Third Law, where water is used as its reaction mass. The compressed gas forces out the water creating an equal and opposite reaction. In this paper a conceptual design methodology is followed to design parachute and water rocket using a 2 L bottle having a diameter of 8.5 cm to find out different performance parameters. The calculated velocity, thrust and range are 26.24 m/s, 31.72 kg and 181.44 m respectively. To achieve 2 m/s terminal velocity of descending rocket, parachute has been designed of 50 cm in diameter. On basis of designed parameters various rockets has been developed and tested successfully for different percentage of water and internal pressure. This paper gives a design and development methodology for any such water rocket with parachute, which can be adopted for further usage.

INTRODUCTION

Humanity has always looked to the moon and stars, and dreamed of traveling to reach them. But it is only in the latter half of the twentieth century, however, that humans have actually left the Earth and set foot on the Moon or sent robotic spacecraft throughout the solar system. The vehicle that has made such travel possible is the rocket!
Rocket does not have Air Breathing Engine, therefore it works better in space

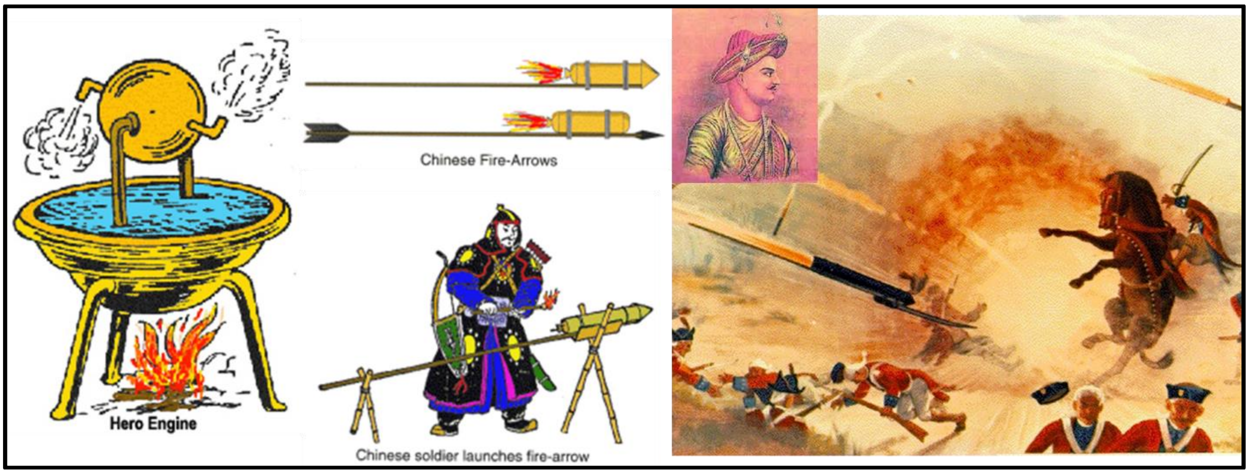

Fig. 1. History of Rockets

Today's rockets are remarkable collections of human ingenuity that have their roots in the science and technology of the past. They are natural outgrowths of literally thousands of years of experimentation and research on rockets and rocket propulsion.
Rocket engines have been tried from several centuries and first engine worked on this principles with steam is recorded by Hero of Alexandria as Hero Engine in 1st century BC. Chinese were claimed to use fire arrows in wars as showed in figure. But the Indian Man, king of Mysore, Tipu Sultan developed rockets with metal casing

first time in history. British had reverse engineered rockets seized in Mysore war and used against French coast later.

Today Missiles, Satellite Launch Vehicles and Spaceships are most successful examples of rockets being used. But experiments have been done on several aircrafts, cars and bikes. Concepts of super humans travelling with rocket jets like Ironman has been fetched enough publicity too.

Fig. 2(a) Space Shuttle **Fig. 2(b) GSLV** **Fig. 2(c) Missiles**

WATER ROCKET

A water rocket is a type of model rocket using water as its reaction mass. The water is forced out by a pressurized gas, typically compressed air. Water rockets are being used in schools and colleges to help students to understand the principles of aeronautics and rocketry. The Science Olympiads and National Physics Labs provide challenges of bottle rocket design and flight, including altitudes and distances reached. Many interesting designs and additional information on bottle rockets can be found with a simple web search.

Students can be introduced to several concepts with Water Rockets like Rocket, Launcher, Parachute, Pressured Chamber etc. One can understand physics behind and learn Inertia, Gravity, Acceleration, Air Resistance, Newton's laws of motion, relationships between Work and Energy or Impulse and Momentum, Projectile Motion and Free fall etc. Performance parameters of rockets like Range, Height, and Apogee can be taught with water rockets. Most importantly learner will follow the design methodology and the practice of true engineering.

2.1. BASIC COMPONENTS OF WATER ROCKET:

NOSE CONE: An extension of the bottle that comes in a variety of shapes and is used to improve the aerodynamics of the rocket

PAYLOAD SECTION: This is an optional section can carry parachute or payload if any

BODY: A water bottler that serve as the propulsion compartment or engine of water rocket

NOZZLE: A part that fits into the bottle opening to help in propulsion of the rocket and provides a mounting point for launchers

FINS: A part that helps to stabilize the water rocket though out its flight

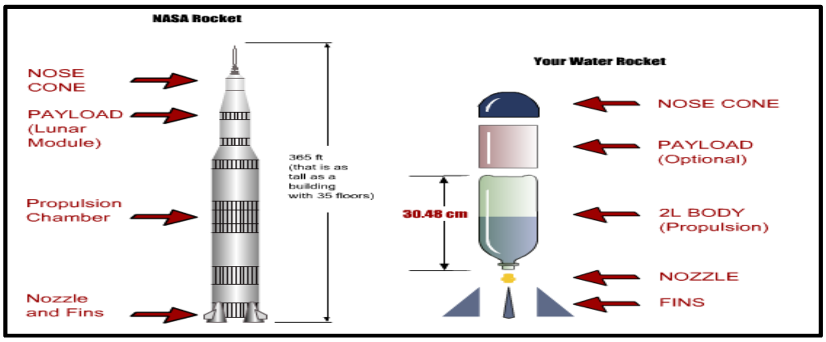

Fig. 3.Comparison of Water Rocket with NASA Rocket

DESIGN OF WATER ROCKET

3.1. CALCULATION OF MAS FLOW RATE

$$\dot{m} = A^* \sqrt{2 * \rho * (P_i\text{-}Pa)}$$ ……………….Equation 1.

Where, $\dot{m}$ = mass flow rate in kg/s
A = area of nozzle (bottle opening) = π/4*D^2 = **4.52*10^ -4m^2**
ρ = density of water = **1000 kg/m^3**
Pi = Inside Pressure = 50 psi = **344737.87Pa** Gauge Pressure (Showed in Pressure Gauge)
Pa = Outside Pressure = 101325 Pa – Absolute Pressure = 0 Pa – Gauge Pressure

Therefore, $\dot{m}$ **= 11.86 kg/s**

But by continuity equation, $\dot{m}$ = ρ*A*Ve ……………….Equation 2.
Where, Ve = Nozzle Exit Velocity = 11.86/(1000*4.52*10^-4) = **26.2389 m/s**

Now Thrust force generated by rocket = T = $\dot{m}$ ***Ve = 311.1938 N = 31.722 kg**
This is more than enough to lift up ~ 1 kg of water bottle and generate lot of accelerations too!

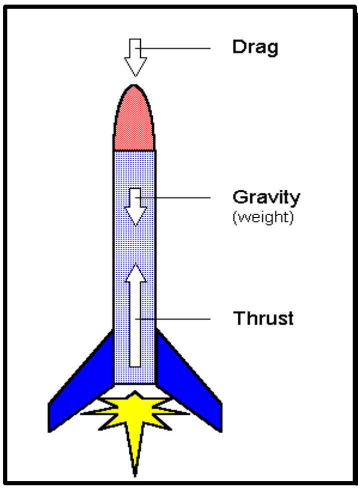

Fig. 4(a) Forces on Rocket

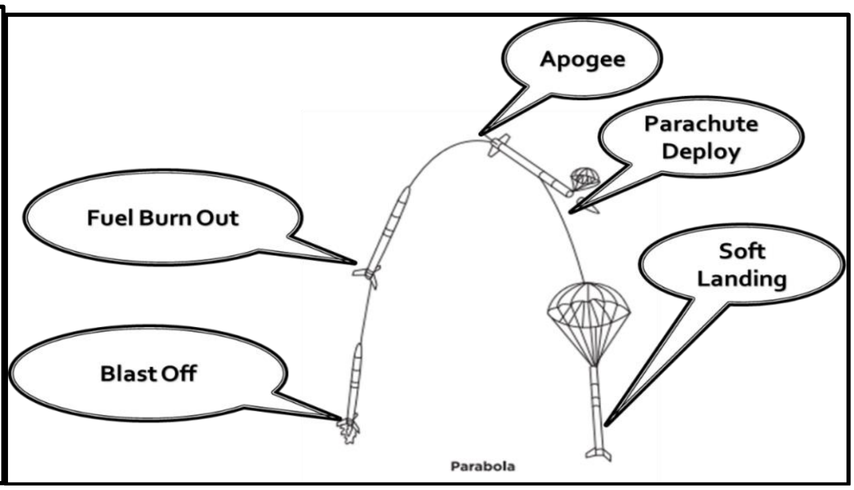

Fig. 4(b) Rocket Flight

3.2. CALCULATIONS OF WEIGHT

Overall Weight of Rocket = Empty weight of Rocket including cap + Parachute Weight + Water Weight
Wo = We + Wp + Ww = 0.08 + .02 + 0.9 = 1 kg = 9.81 N
Net Force in Upward Direction = Thrust – Weight – Drag
F = T – W – D = m * a
where a = acceleration of rocket
D = Drag, which is considered to be negligible at basic calculations
As we are considering the acceleration is constant throughout the climb we need to consider half of water weight, so average weight of rocket,
Wavg = 0.08 + 0.02 + 0.9/2 = 0.55 kg = **5.4 N**
Therefore, F = 311.1938 – 5.4 – 0 = **305.8 N** = Mavg * a
Hence a = 305.8/0.55 = **556 m/s^2 ---------------------------------- Ohh My God!!! :O**

Now time to reach burn out point = t = mass of water / mass flow rate = m / $\dot{m}$

Therefore t = 0.9/11.86 = 0.0759 s

Maximum velocity achieved = Vmax = a * t = 556*0.0759 = 42.19 m/s

Now, Range of bottle in m = R = V^2*(sin2Ө)/g ………………Equation 3.

Therefore R = 42.19^2*(sin (2*45)/9.81 = 181.44 m

This is maximum distance that rocket can cover at given conditions of inside pressure, percentage of water and with no drag!!

PARACHUTE

Fig. 5. Types of Parachutes and their Applications

Parachute is a device used to slow down the motion of an object through an atmosphere by creating aerodynamic drag. There is a special type of parachute Ram-Air Parachutes with airfoil cross section works on aerodynamic lift, this is most advanced and popular skydivers parachute being used in forces.
Parachutes are being used in rockets to give soft landing to reusable rocket shells, designers may consider more than one parachutes on failsafe and for minimal opening time. Such parachutes are being used by space agencies to slow down space capsules and for dropping cargo at required remote places by military forces.

4.1 DESIGN OF PARACHUTE

The most critical parameter in parabolic parachute design is its diameter. Thereforearea of the parachute is important to obtained, consider fully deployed parachute in air,

At equilibrium Drag = Weight

$\mathbf{D} = \rho * v^2 * \Pi * d^2 * C_d / 8 = \mathbf{W} = m * g$

ρ = density of air = 1.225 kg/m3

v = safe descent speed i.e. the speed we want to impact on ground = 2 m/s

d = diameter of parachute

Cd = drag coefficient = 1.75 (typically)

m = mass of empty rocket = 80 g = 0.08 kg

Therefore

$$d = \sqrt{\frac{8*m*g}{\rho * v^2 * \Pi * Cd}} \quad \mathbf{\sim 50\ cm}$$ ………Equation 4.

DEVELOPMENT OF WATER ROCKET

On basis of above calculations and conceptual design of water rocket, team Lightning Drones has been developed several water rockets, their launchers and parachutes. After experimenting with various parameters like size of bottle, percentage of water, pressure difference and parachute diameters team optimized the water rocket assembly as shown in figure below.

Fig. 6(a) Launching of Water Rocket

Fig. 6(b) Parachute Deployed

CONCLUSIONS

1. Design and development procedure for water rocket their important components have been established and cab be used further for any such design
2. New designer can vary parameters like size of water bottle, weight,water content, nozzle diameter and decent velocity to design different water rockets and parachutes
3. Team Lightning Drones had been tested and experimented several rockets and parachutes with above parameters for best system
4. On basis of material availability and easy accessibility dimensions of water rocket, launcher assembly and its parachute have been optimized and tested successfully

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