Design and Manufacturing of Cloud Seeding Rocket

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Abstract— Rain deficiency and waterfall shortage is an environmental issue in India and especially in Maharashtra. Even 5% shortfall of rain causes deficiency of water for drinking and irrigation. I final year mechanical student considered this problem for my industrial research project to work on latest Artificial Rain Technology to create artificial rain by seeding the clouds by introducing cloud condensation nuclei (CCN) particles (silver iodide). Rocket is propelled with solid propellant sugar. The Rocket is designed to achieve a maximum apogee of 4.5kms to 5kms. This paper describes the methodology to manufacture the cloud seeding rocket and its modification. It does not explain anything detail information about the chemical used for cloud seeding purpose. Main Objective of this project is to design and manufacture a rocket which will achieve apogee of 4.5kms to 5kms with the payload of 0.6-0.8kg and it will be used for cloud seeding purpose.

Key words: CCN, Cloud Seeding Rocket

I. Introduction

In the design of the Rocket which was tested and operational zed in 2015 cloud seeding operation by the company Engenious Aerospace Ltd our work contribution involves improvement in terms of its performance parameters of Altitude, (4.5km from 3 km) using more light and high strength aluminum alloy(Aluminum T6-6061), increase the production rate for minimum production batch of 1000 units and efficiency with accuracy of the seeding process by minimizing the eliminating the trajectory dispersion effects emanating from the Aero-Elastic behavior of the rocket fins.

In order to improve efficiency of the rocket with higher flight performance, the team has been making dedicated study to make performance parametric studies, production process improvement, aero-elastic study of the rocket fins in flight to minimize the trajectory dispersion and precision entrance of the rocket's Silver Iodide (AgI) aerosol particles in the super cooled region of the cloud.

II. Problem Statement

Design and Manufacturing of cloud seeding rocket based on previous designs to carry payload of 0.6-0.8kg to an altitude of 4.5kms-5kms with reducing weight using Aluminum T6-6061.

III. Rocket Parts & Its Function

A. Nose Cone

The term nose cone is used to refer to the forward most section of a rocket, guided missile. The cone is shaped to offer minimum aerodynamic resistance. Nose cones are also designed for travel in and under water and in high-speed land vehicles.

B. Parachute and Payload

The descent rate of any body (such as a rocket) equipped with a parachute is dependent upon the drag force that the parachute develops, to counteract the gravitational force resulting from the payload's mass. The drag force is dependent upon:

1) The dynamic pressure created by moving air striking the parachute canopy (and which keeps the parachute inflated).
2) The diameter of the parachute, which determines the area over which the dynamic pressure acts.
3) The drag coefficient, Cd, of the parachute.

C. Nozzle

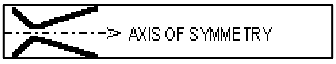

Fig. 1: Nozzle

The rocket nozzle can surely be described as the epitome of elegant simplicity. The primary function of a nozzle is to channel and accelerate the combustion products produced by the burning propellant in such as way as to maximize the velocity of the exhaust at the exit, to supersonic velocity. The familiar rocket nozzle, also known as deLaval nozzle, accomplishes this remarkable feat by simple geometry. In other words, it does this by varying the cross-sectional area (or diameter) in an exacting form. The analysis of a rocket nozzle involves the concept of "steady, one-dimensional compressible fluid flow of an ideal gas".

D. Fins

The purpose of putting fins on a rocket is to provide stability during flight, that is, to allow the rocket to maintain its orientation and intended flight path. If a typical amateur rocket was launched without fins, it would soon begin to tumble after leaving the launcher, due to the way that aerodynamic and other forces (such as wind) act upon the rocket, in relation to the forces that are exerted upon the rocket by the motor and by gravity. The problem here is that the rocket's centre of pressure (CP) would be forward of its centre of gravity (CG).

IV. Propellent

Sugar-based rocket propellant comprised of a fused mixture of Potassium Nitrate serving as the oxidizer, and Sucrose (table sugar) serving as the fuel and binder.

For convenience, acronym KNSU in reference to the contemporary formulation of this propellant, which is 65% Potassium Nitrate and 35% Sucrose? Although not a high performance propellant, KNSU delivers a fair specific impulse. Its main advantage over many other amateur formulations is the relative case and safety of preparation and usage. Another factor that makes this propellant popular is the ingredients, both of which are commonly available.

The propellant described is heat cast, using a melting technique, to form the propellant body, or grain.

A. Formulation

As mentioned earlier, the standard ratio of constituents is 65% Potassium Nitrate and 35% Sucrose, by mass. This ratio has proven to give the best overall performance combined with acceptable casting qualities. Theoretically, the highest specific impulse is delivered at a 66/34 ratio, although the standard 65/35 ratio tends to be used by most experimentalists. There are three reasons for this:

1) The propellant characterization data has been obtained mainly for the 60/40 ratio.
2) The performance difference is slight (about 1%).
3) The combustion temperature rises sharply with increased O/F ratio. At the 65/35 ratio, steel nozzles suffer no erosion, as there is an adequate margin between the theoretical flame temperature (1450C) and the melting point of steel (approx. 1500C).

B. Chemical Reaction

For the KN-sucrose propellant, with an oxidizer-fuel (O/F) ratio of 65/35, the theoretical combustion equation is as follows:

$C_{12}H_{22}O_{11}$ + 6.288 KNO_3 --> 3.796 CO_2 + 5.205 CO + 7.794 H_2O + 3.065 H_2 + 3.143 N_2 + 2.998 K_2CO_3 + 0.274 KOH

At a pressure of 68 atmospheres and where the following compounds are symbolized as:

Sucrose	Solid	$C_{12}H_{22}O_{11}$
Potassium Nitrate	Solid	KNO_3
Carbon Dioxide	Gas	CO_2
Carbon Monoxide	Gas	CO
Steam	Gas	H_2O
Hydrogen	Gas	H_2
Nitrogen	Gas	N_2
Potassium Carbonate	Liquid	K_2CO_3
Potassium Hydroxide	Gas	KOH

Table 1: Propellant Terms

V. DESIGN OF NOZZLE

Material Selected=M.S.

A. Rocket Motor Thrust and the Thrust Coefficient

The thrust *that* a rocket motor generates is the most fundamental yardstick of performance. Thrust is generated by the expelling of mass (the exhaust) flowing through the nozzle at high velocity. The expression for thrust is given by

$$F = \int P\,dA = \dot{m} V_e + (P_e - P_a) A_e \quad (1)$$

Where the left hand term in the equation represents the resultant acting on the chamber and nozzle, projected on a plane normal to the nozzle axis of symmetry, as shown in the figure

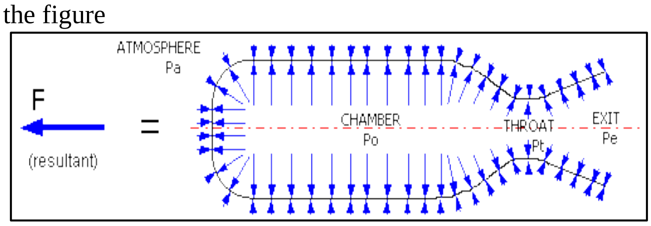

Fig. 2: Combustion Chamber

Also,

$$F = A^* P_o \sqrt{\frac{2k^2}{k-1}\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}\left[1-\left(\frac{P_e}{P_o}\right)^{\frac{k-1}{k}}\right]} + (P_e - P_a) A_e$$

Also

F = Isp*g* ṁ

From experiments it is clear that to achieve height of 4 to 5 km, having payload of approximately 1 kg thrust force required is around 1870 N.

From the property of sugar propellant it is clear that Isp 120 sec

Therefore,

1870 = 130*9.81* ṁ

Mass flow rate ṁ =1.466 kg/s

For choking of flow through the nozzle

ṁ= A*P0(k/RT0)0.5(2/(k+1))(k+1)/[2(k-1)]

ṁ=1.466kg/s

P=1000 psi

K=1.15

R=198J/kg k

Solving,

Area of throat=188.85 mm ^2

At = π* Dt2 /4

Dt=15.5 mm

Nozzle Exit to Throat Area Ratio

Area Ratio = $\frac{Ae}{At}$

Ratios shown in Table are those required to achieve an exit pressure (Pe) Equal to atmospheric pressure (14.7 psia)

Chamber Pressure	K = 1.15	K = 1.2	K = 1.25	K = 1.3	K = 1.4
600 psia	6.8 to 1	6.0 to 1	5.6 to 1	5.2 to 1	4.5 to 1
700 psia	7.6 to 1	6.8 to 1	6.3 to 1	5.8 to 1	5.0 to 1
800 psia	8.4 to 1	7.6 to 1	6.8 to 1	6.4 to 1	5.4 to 1
900 psia	9.2 to 1	8.2 to 1	7.4 to 1	6.8 to 1	5.8 to 1
1000 psia	10.0 to 1	8.8 to 1	7.4 to 1	6.8 to 1	5.8 to 1
1100 psia	10.9 to 1	9.5 to 1	8.2 to 1	7.4 to 1	6.2 to 1
1200 psia	11.6 to 1	10.2 to 1	9.3 to 1	8.4 to 1	7.0 to 1
1300 psia	12.4 to 1	10.8 to 1	9.8 to 1	8.9 to 1	7.4 to 1
1400 psia	13.0 to 1	11.5 to 1	10.4 to 1	9.4 to 1	7.7 to 1

Table 2: Area Ratios

For k= 1.15 and 1000Psi pressure

Ratio =10

Therefore Area at exit =1888.5 mm^2

Ae = π* De^2 /4

1888.5= π*(X) ^2/4

De=45.78 mm

Similarly Di = 57.74 mm.

From the experimental data it is clear that Divergence angle should be 12 degree and Convergence angle should be 30 degree for minimum energy loss.

VI. ROCKET ASSEMBLY & SIMULATIONS

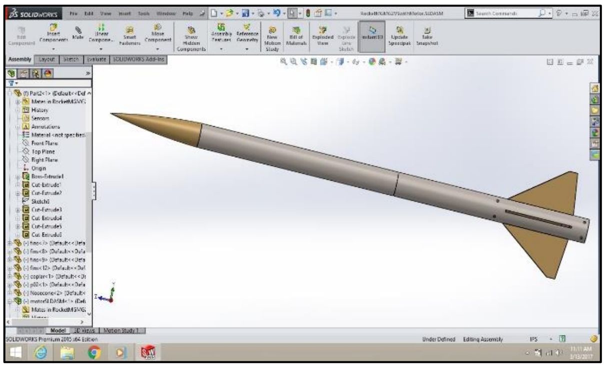

Fig. 3: Rocket Assembly on SolidWorks15

The simulations of the rocket are the study of launching parameters of the rocket before it actually launched. The parametric study of the basic parameters like rocket stability, recovery simulations and altitude is important to before the launch. Simulations of this rocket are done on software SpaceCad-5.

A. Rocket Stability

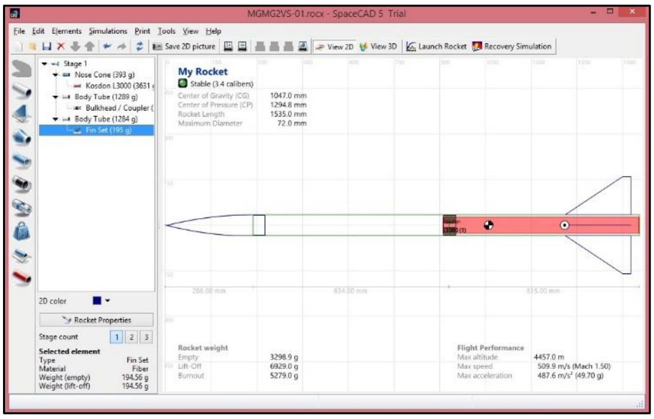

Fig. 4: Stability Test on SpaceCad-5

This test results as the good stability and height achieved as 4.45kms which is approximately equal to our objective.

B. Trajectory Path

Fig. 5: Trajectory path on SpaceCad-5

The result shows that the rocket will fly with the maximum of velocity to 509.94m/s. and the acceleration of 487.5 m^2/s.

C. Recovery Simulation

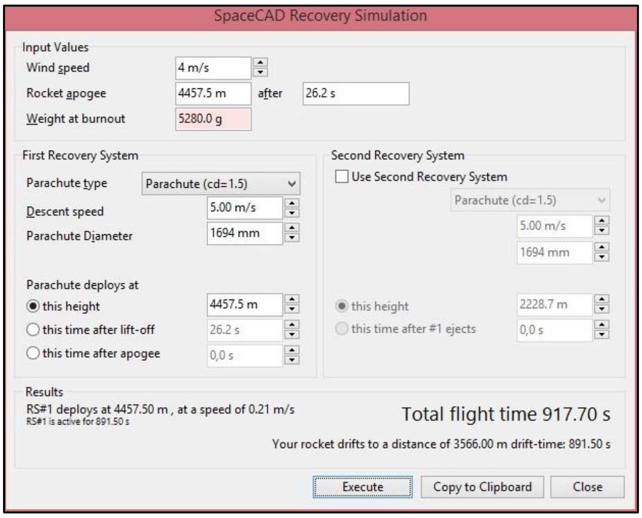

Fig. 6: Recovery Simulation on SpaceCad-5

VII. LAUNCHING METHODOLOGY

A. Launch Preparation

Site inspection is the important factor at the time of rocket launching to avoid site accidents. After selection of the appropriate site soil digging, launcher fixing and launch rod fixing etc. is to be done.

B. Rocket Preparation to Launch

Finding the Center of Gravity of the rocket and fixing the launch lug at the C.G of the rocket. The launch lug is nothing but the tube of length 70-80mm in length with inner diameter equal or slightly greater than the launch rod.

C. Ignition Methodology

The battery of 12-15 Volts with the wire length of 6-7 fits and Heating Coils filled with sugar propellant is basically required in this type of rocket launch. The ignition coil (Heating Coil) is connected to the battery with the help of wire and switches and it is placed in the rocket nozzle. As the switch is on the heating coil is gets heated and there is a blast of ignition coil is takes place because of the propellant filled in it and this starts the combustion of rocket fuel.

VIII. RESULTS AND CONCLUSIONS

In this project we had achieved our main objective as reducing the overall weight of the rocket by using light weight and cost effective material ie aluminum T6-6061. In Aerospace industries weight is the important factor and our aim was to work on it.

Also, we had redesigned the rocket for maximum altitude of 4-4.5kms on changing the thrust area of the rocket nozzle. On Simulating the Rocket on SpaceCad5 we come to the performance parameters as the rocket altitude 4457meters and the velocity as 509 m/s.

Successfully Launching of our rocket using sugar propellant is done on April 22, 2017 – April 23, 2017

At Saphale, Maharashtra, India.

REFERENCES

[1] Richard Naka website
[2] Military Handbook Design of Free Rockets, U.S.A, 17 July1990.
[3] MagnusMarGundersons072205.Characterization of Potassium Nitrate – Sugar Alcohol Based Solid Rocket Propellants, Department of Chemistry, Technical University of Denmark, August 2010.
[4] Darin Partum, Jeffrey D. Kazak, Robert J. Barrowman, and A Custom Launch System for satellite smaller than 1 kg, Rochester Institute of Technology, 79 Lomb Memorial Drive, Rochester, NY 14623-5603.
[5] Jack N. Nielson. Missile Aerodynamics, VIDYA Inc. Stanford Industrial Park, Plato alto, California, USA, McGraw Hill Publication 1960.
[6] Design, Development And Flight Test Of The Super Loki Stable Booster Rocket Systems, Bruce Bollermann, et al Space Data Corporation, Phoenix, Arizona, 30 June 1973.