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ANALYSIS OF DIFFERENT FINS STRUCTURE AND CONCEPTUAL DESIGN OF SINGLE STAGE SOUNDING ROCKET

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ABSTRACT : The design for single stage sounding rocket have been proposed. Modern techniques and methods has been used to optimise the performance of rocket with less weight. The structure of rocket have been designed on the basis of earlier works and theories that were produced by the immense analysis and experiments by different organisations. The aim of the paper is to develop a single stage sounding rocket with overall length constrained less than 1 meter. The structure of rocket have been designed by applying certain constraints such as the payload mass is less than 1000 g and the haack series design is used for the nose cone section for optimum performance. The analysis of different types of fins including clipped fin, trapezoidal fin, tapered fin have been studied rigorously.

I. INTRODUCTION

Sounding rocket have become a integral part of space related experiments and it is getting extensively used for different kinds of space research and for probing the upper atmospheric regions. Since sounding rockets are very affordable and easier to manufacture so they are also used for testing various kinds of prototypes of new components or subsystems intended for use in launch vehicles and satellites.

Sounding rocket are lightweight and require less propellant to launch and they can be easily restored for new projects.

I have created a one stage sounding rocket that is very efficient and very light in weight. The rocket can lift the payload of weight equal to 410 and can significantly provide a altitude of more than 1600 ft. The design of the rocket is highly advanced and it significantly provides a amazing performance with reduced drag forces. It have very low drag and due to its fin design, the rocket is highly stable. The use of 3 fins have decreased the size of rocket and have efficiently balanced the stability caliber. The modified design of fins provides more thrust and also reduces the drag which helps the rocket to achieve extra height. The rocket is highly stable as its vertical orientation does not change much with time and it provides the rocket more stable flight. The g class motor is used which is easily available and can provide the desired performance with controlled velocity. The G12RC-P motor is used which is having thrust of 10.8 NS and provides the controlled velocity with greater stability.

Since the polymer is extensively getting used in industries due to its properties like heat resistance ,durability and thermal insulation so carbon fiber reinforced polymer can increase the performance of rocket and can provide a shielding to the rocket from heat exposure.

II. METHODOLOGY

The rigorous study on different design models of rockets helps to create the rocket design to optimise its performance. The payload for the rocket has been setup to 0.5kg and the mass of required propellent has been calculated. With the help of empirical formula ,the structural ratio and payload ratio have been calculated and it is found out to be 0.79 and 0.65 respectively.

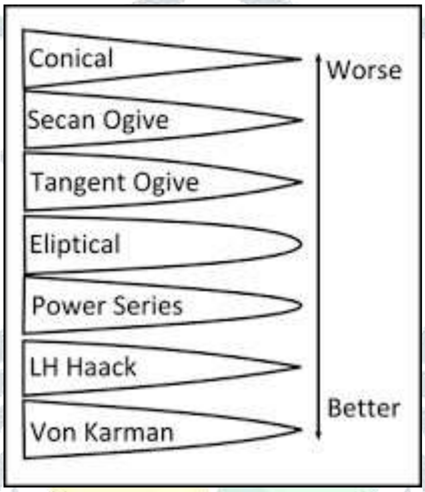
The mass for the propellant is chosen to be 0.7 kg as the rocket is very light in weight and highly efficient. According to the study of Adam Okninskia (2017) use of ammonia perchlorate with aluminium powder and HTPB provides a effective composite propellant . So the solid propellant for the design of rocket have been used and it is a composite mixture of Ammonium Perchlorate,aluminium and HTPB.

2.1 Nose Cone

The aerodynamic shape of the nose cone helps rocket to counter the air from slowing the rocket.The oxidizer and fuel are burned together to launch the rocket off the ground. Rocket experiences the four major forces while it is in air and they are weight, thrust, and the two aerodynamic forces, lift and drag. Nose cone play a significant role in performance of rocket. It is responsible for the drag and aerodynamic forces at the front of rocket. So it has to be carefully made with proper dimensions. The rounded curve is the best shape for nose cone section part of rocket when the speed of rocket is less than the speed of sound (1200 km/h in air at sea level). At higher speed or supersonic speeds (faster than the speed of sound), the best shape is a sharper point and narrow.The amount of air resistance that opposes a rocket's motion depends mainly on the shape of the nose cone, the diameter of the rocket and the speed of the rocket so in order to get the optimum performance, the design of nose cone becomes major concern. The study of lucas de Almeida Sabino Carvalho et.al (2019) showed the shape of the nose cone plays a critical role in reducing the aerodynamic drag of the sounding rocket. Different shapes of the nose cone for the rocket were analysed on ANSYS Fluent with an objective to achieve minimum aerodynamic drag for a medium range Mach number 0.05 to 0.62 approximately. The study predicted use of ellipsoid shape as it produces 4.93% less drag compared to parabolic shaped nose cones. To further optimize the results, the paper suggests von Karman shape and Haach series can be used to optimize the performance of nose cones [1].

Nose cone is the first part that meets the air at the front end of rocket so it should be highly aerodynamically stable in order to get less drag. Rockets that have a greater diameter experience more drag because there is more air being pushed out of the way. Drag generally depends on the cross-sectional area of the object pushing through the air that means if the cross sectional area of the object is more then the drag force will be more. A rocket should be made as narrow as possible in order to reduce the drag.

Speed of rocket also matters a lot as the speed of a rocket through the air doubles, drag increases four times as much.
According to the study on nose cone for various shapes including conical, elliptical, power series and others, the von karman and hack series showed the best performance in countering the drag



Since the hack series have the best shape in nose cone of the rocket , so the nose cone has been designed with the haack series and it provides the required stability to the rocket which eventually enhance the performance of rocket. The dimension of nose cone is 10 cm in length and 3.7 cm in diameter .

2.2 Body Tube

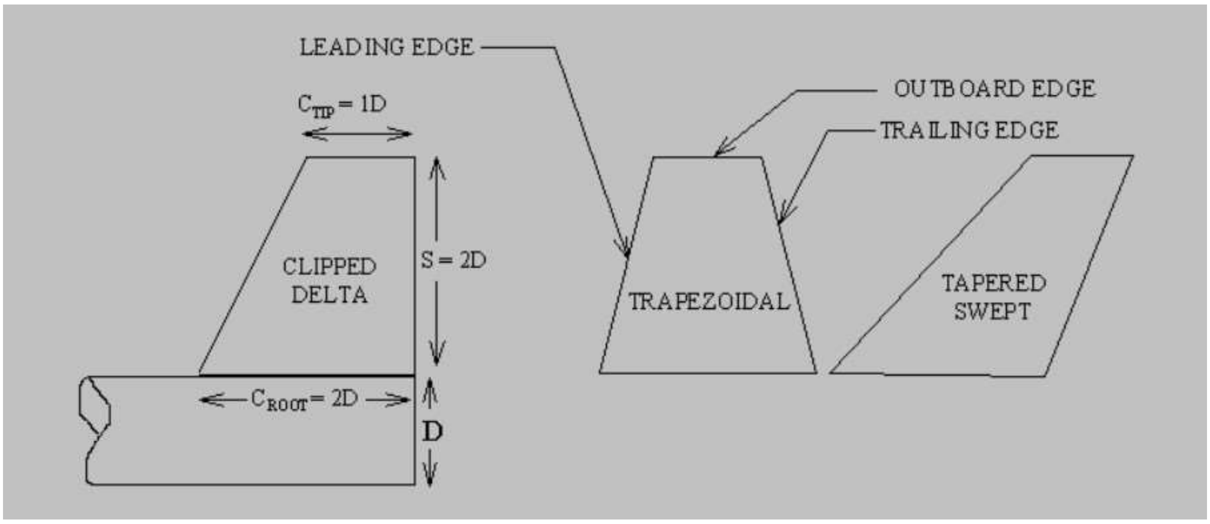
The body tube section of the rocket is really important as it forms the main body of the model rocket. It holds the nose cone (the tip of the rocket) in place. The rocket fins at the bottom of the rocket provide stability during flight by decreasing the drag and providing more aerodymic stability. A launch lug is attached to the body tube near the center of gravity for the rocket in order to get better static margin and stability caliber.
The body tube dimension in the rocket is 40 cm in length and 3.7 cm in diameter. The body tube of the rocket is quite stable due to its overall center of gravity.

2.3 Fins

The purpose of fins on a rocket is to provide stability and lift during flight, to keep the rocket on the intended course through inducing rotation. This rotation is created by the lifting forces that are generated by each fin . Since fins have a vital role in stability and lift of rocket so the rocket have used three fins in order to get much lift and altitude with great stability and less fuel.

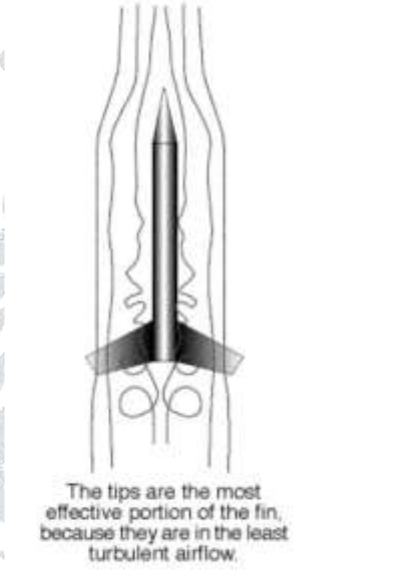
The shape of the fins for a rocket is highly important as it decreases the drag and provides the stability to the rocket. The fins should have low thickness with comparatively large chord length and larger taper ratio to minimize fluttering. Comparative fin analysis of FalconLaunch V, FalconLaunch VI, Doe Low, Doe High was studied by Simmons, Joseph R. III and found that the flutter velocity decreases with decline in volume of the fin. The study recommends use of compact fins to reduce flutter [2].
Generally any kind of fin can do the job , as long as the required Center of pressure-Center of Gravity relationship is maintained, and the span length is sufficient to generate good restoring lift force. The fin span in the rockets is more effective than fin length. According to the study, the best shapes for fins are either the trapezoidal(which is really a clipped delta with a forward swept trailing edge) or the clipped delta . There is one great advantage of the trapezoidal planform. The advantage for having the trailing edge in forward of the end of the body tube, the fins are somewhat protected from impact damage such as bending while the rocket touches down. The parachute reduces the descent rate

significantly but many rockets ended up with bent fins when using either of the other two planforms, as it is the fin trailing edges that initially make contact with the ground so in order to avoid such incidents ,the trapezoidal is the best one.



fin planforms

Since the best design for fins of any rocket is trapezoidal or clipped delta , so the rocket have designed using the trapezoidal fin design for better performance with some modification which eventually increased the performance and stability of rocket. The thickness of the fins is 0.8 and the chord length is 2 cm in order to decrease the fluttering and which provides the better performance.

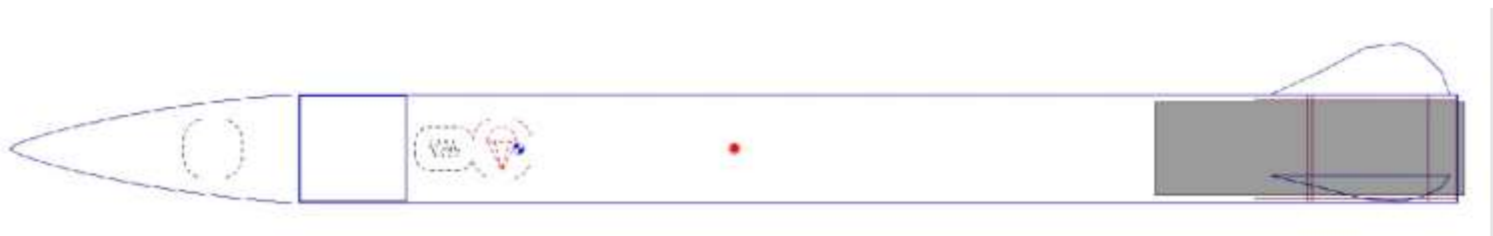


flow at the fins of rocket

In order to counter the force near to the tip of fin, some modification has been done, which increased the vertical stability as well as efficiency of rocket.

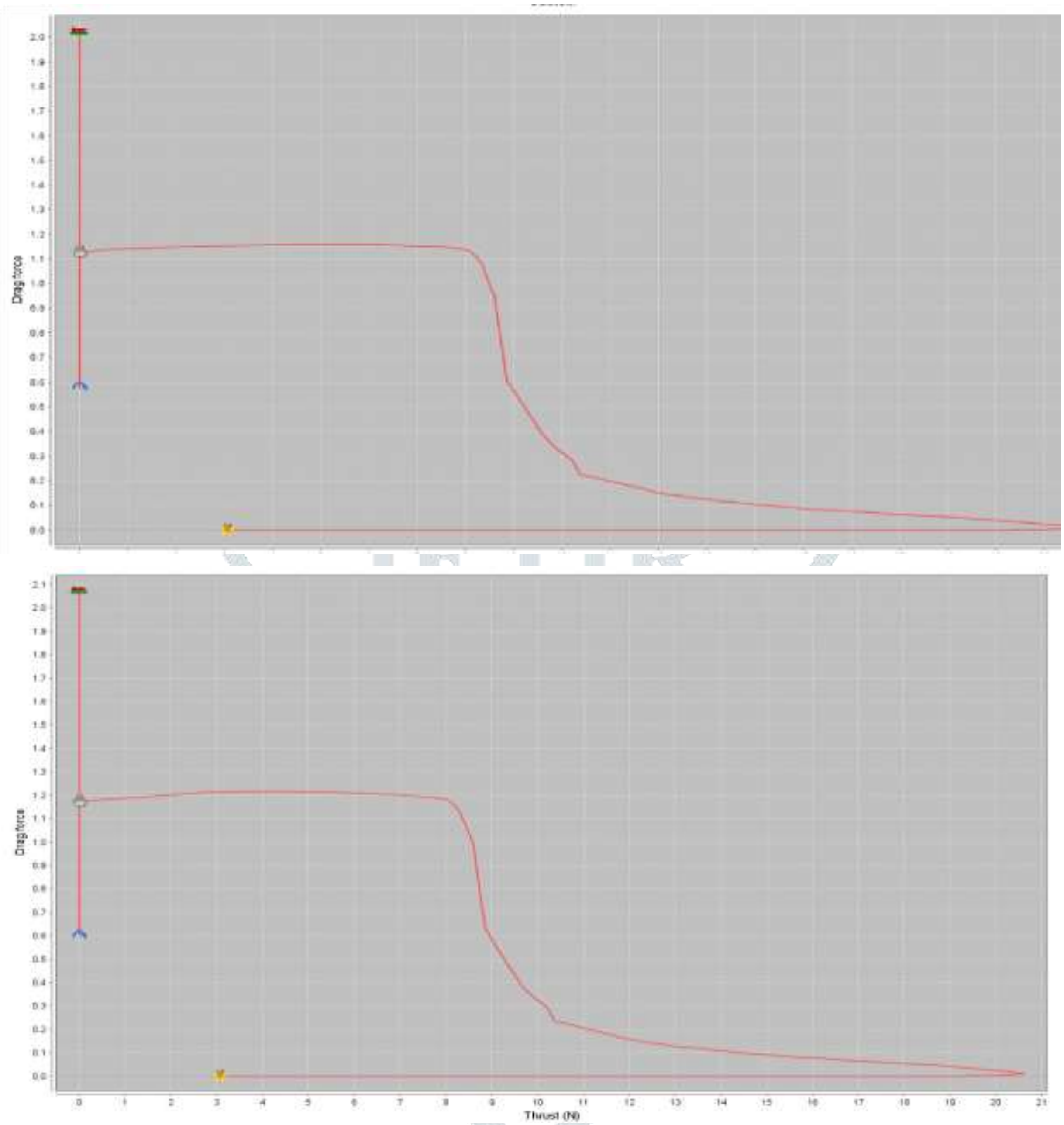
2.4 G12RC-P motor

Rocket engines are basically reaction engines that produce the thrust by ejection of mass rearward, in accordance with Newton's third law. space vehicles or rockets carry their own oxidizer, unlike most combustion engines, so that rocket engines can be used in a vacuum to propel spacecraft and ballistic missiles.

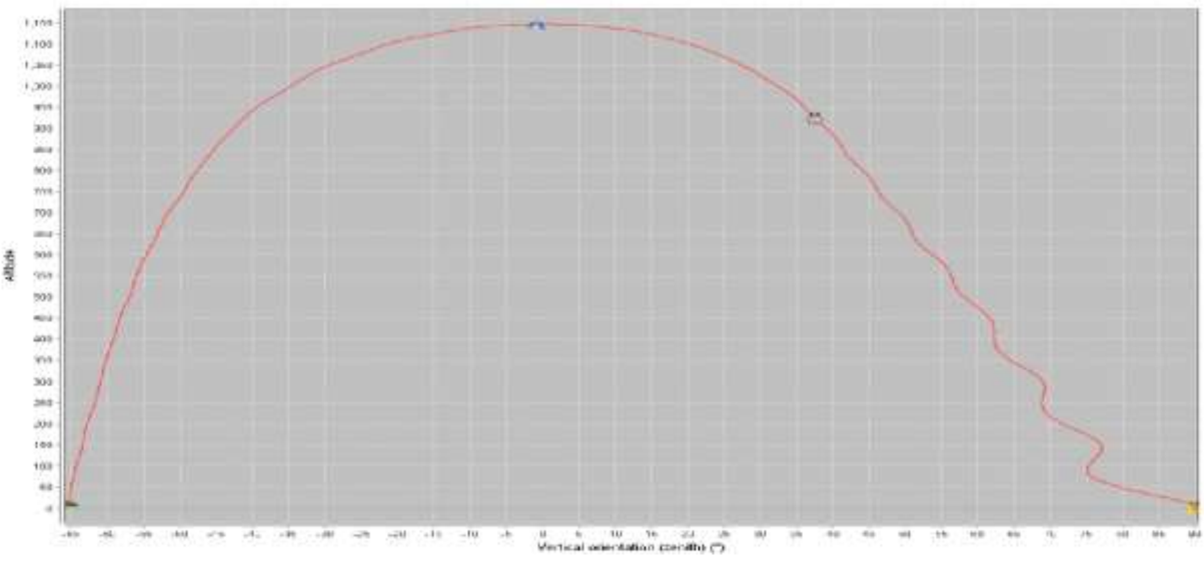


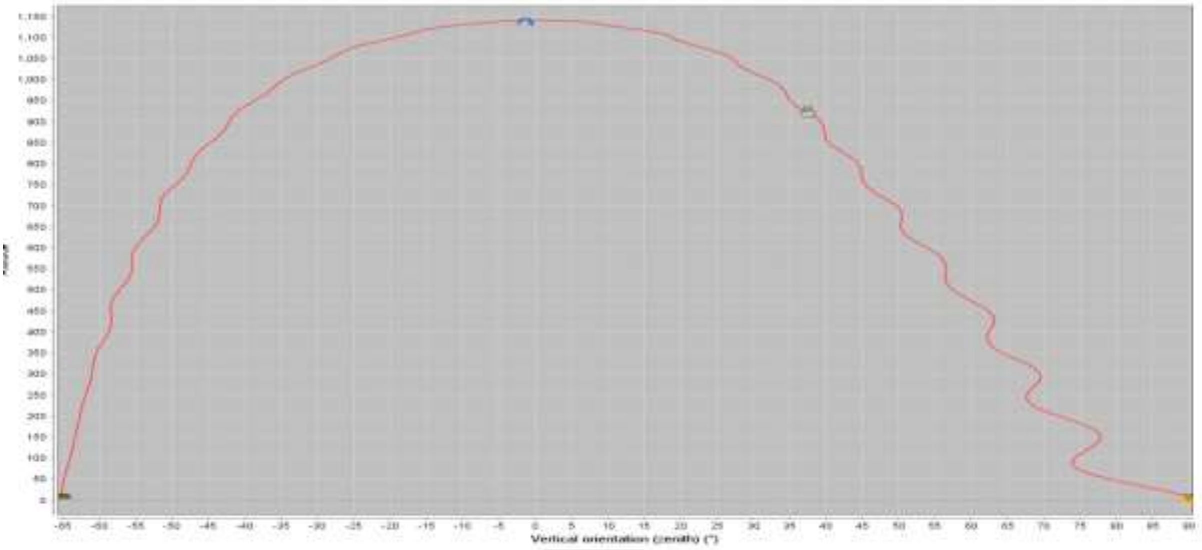
The G12RC-P motor have very low average thrust which helps in maintaining the speed of rocket and also improves the stability of rocket. The value for average thrust in this motor is 10 Ns. Due to its low average thrust , we get the desired velocity of rocket.the launch mass of the rocket is 131 g and empty mass is 80 g.

III. RESULTS AND DISCUSSION

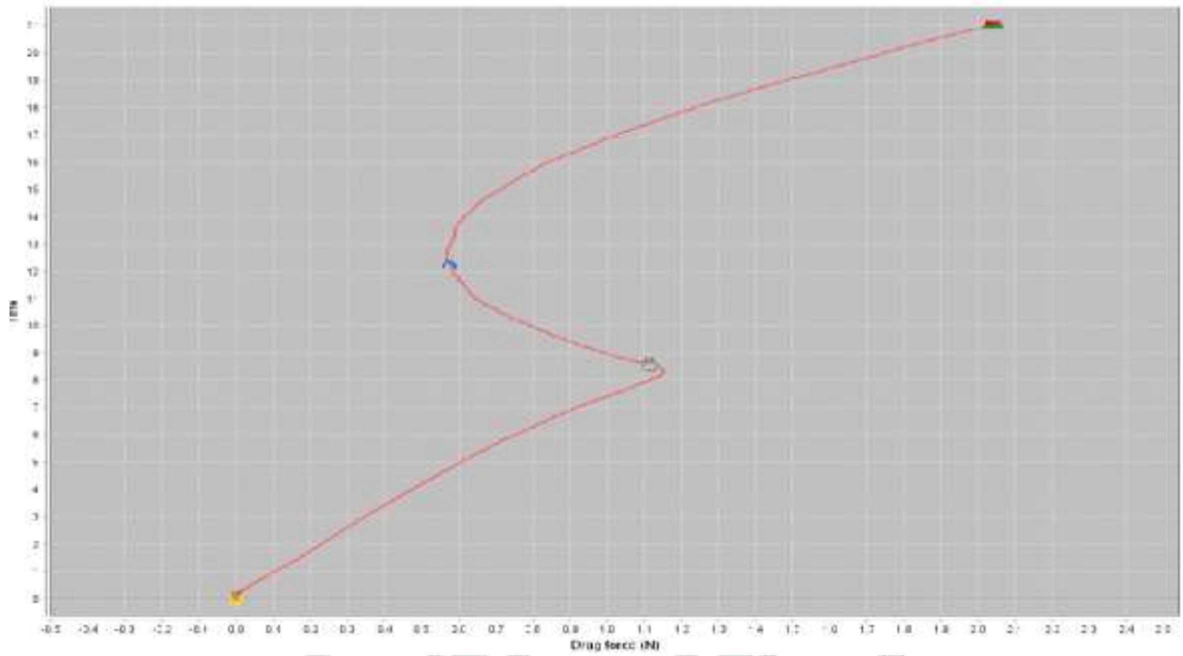


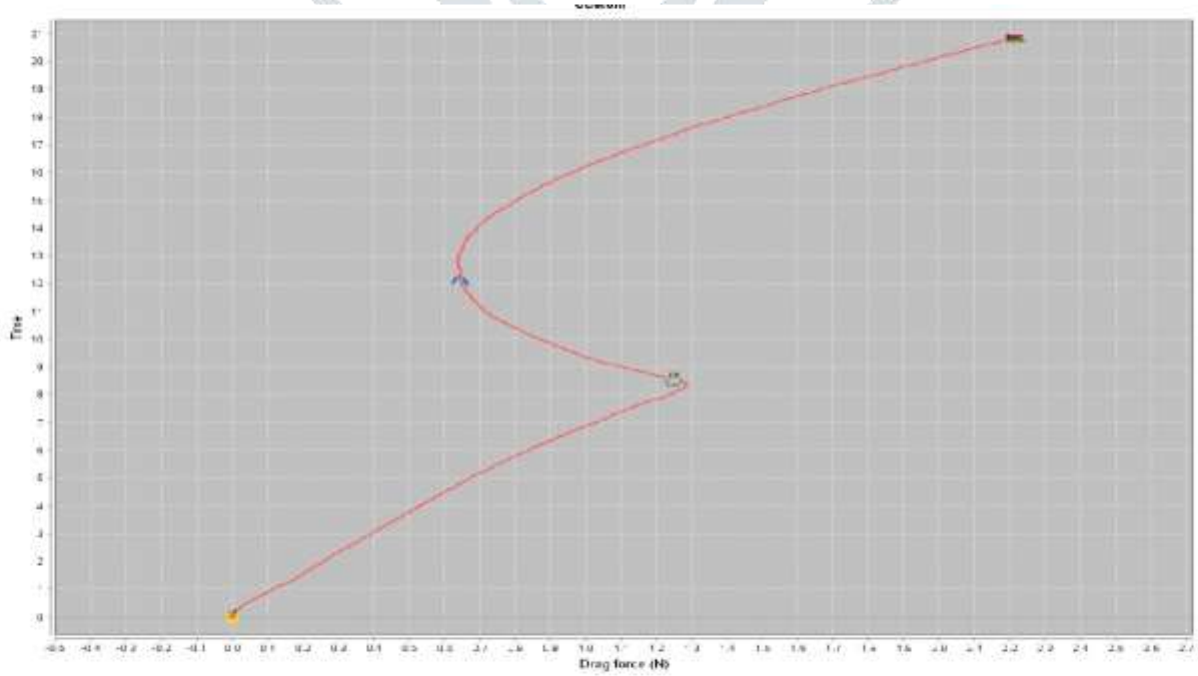
graph between the drag force on y axis and thrust on x- axis (1) tapered fin, (2) clipped fin





altitude on y axis and vertical orientation on x axis (1) tapered fin,(2) clipped fin





Graph between drag force on x axis and time on y axis (1) tapered fin, (2) clipped fin

IV. CONCLUSION

The rocket can significantly attain the altitude of more than 1650 ft with very less propellant weight. The modified shape of fins provides the better stability and also improves the lift generation of rocket. The G12RC-P motor has been used in order to get controlled and desired velocity of rocket. The rocket shows the stable orientation with altitude and time. The rocket can carry the payload more than 800 g with altitude of more than 1200 ft. The rocket is very cheap and easy to manufacture, in addition it is highly heat resistive that makes the rocket more safe and efficient. The modified design of fins provides the less drag and greater stability.

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