DESIGNING OF MODEL ROCKET WITH THRUST VECTOR CONTROL CONCEPT AND PROPELLANT TESTING

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Abstract: *Our project deals about the Thrust vector control concept and designing of model rocket in connection with Avionic components. Our aim is to build the model rocket and TVC component model designed by using Open Rocket Software and CATIA, 3D printed machine respectively. Then, we are making the connection between TVC setup and Sensors where testing shows the movement of TVC with respect to rocket movement, behind the process called Thrust vector control by Gimbal mechanism. In addition to that we encounter propellant cooking process and make the solid propellant as a motor. Finally we tested the TVC with sensor and getting the update result on Arduino program. We are experimentally experiencing and tested the complete concept and get the results.*

***Keywords*: Thrust vector control, Gimbal Mechanism, Propellant cooking, Solid motor**

1. INTRODUCTION

Thrust vectoring, also known as thrust vector control (TVC), is the ability of an aircraft, rocket, or other vehicle to manipulate the direction of the thrust from its engine(s) or motor(s) to control the attitude or angular velocity of the vehicle. In rocketry and ballistic missiles that fly outside the atmosphere, aerodynamic control surfaces are ineffective, so thrust vectoring is the primary means of attitude control.In rocketry and ballistic missiles that fly outside the atmosphere, aerodynamic control surfaces are ineffective, so thrust vectoring is the primary means of attitude control.For aircraft, the method was originally envisaged to provide upward vertical thrust as a means to give aircraft vertical (VTOL) or short (STOL) takeoff and landing ability. Subsequently, it was realized that using vectored thrust in combat situations enabled aircraft to perform various maneuvers not available to conventional-engined planes. To perform turns, aircraft that use no thrust vectoring must rely on aerodynamic control surfaces only, such as ailerons or elevator; aircraft with vectoring must still use control surfaces, but to a lesser extent.

1.1 How to make Mini Sugar Rocket

A sugar rocket is a simple home project that uses potassium nitrate (KNO_3) and powdered sugar as fuel. While it's easy to make a sugar rocket, it's also very dangerous, so use caution throughout your project. To build your rocket, you'll need to make a rocket body out of heavy paper. Then, you'll mix up rocket fuel and pack it into your rocket. During the entire process, stay away from heat sources and open flames.

1.2 Introduction of Open Rocket Sowtware

Open Rocket is an open source model rocket simulation software application. It was originally developed by Sampo Niskanen in 2009 as part of his master thesis at what was then Helsinki University of Technology. If you want to have a look at his thesis you can download it from Open Rocket's technical documentation page. Written entirely in Java, Open Rocket is fully cross-platform. Have a look at the next section if you need information about how to open the program on your computer.

Open Rocket is intended to be used by rocketeers who want to test the performance of a model rocket before actually building and flying it. The software accurately computes the aerodynamic properties of rockets and simulates their flight, returning a wide range of technical results.

The program can be roughly divided into two sections:

- Rocket design, where you can design the model rocket you intend to build, choosing from a wide range of body components, trapezoidal, elliptical and free-form fins, inner components, and mass objects. During this phase you will see a 2D representation of the rocket you are building and various technical information (size, mass, apogee, max.velocity, max.acceleration, stability, centre of gravity (CG), centre of pressure (CP)) about your rocket, so you can have already a good idea of its performance even before running any simulation.
- Flight simulation, where you can run one or more simulations of your rocket's flight, choosing from one or more motor configurations. Each simulation (calculated using the Runge - Kutta 4 simulator) returns a wide range of data about the rocket's flight. Unfortunately, for the moment a graphical visualization of the rocket's flight is not available

1.3 PROCEDURES FOR MAKING SUGAR ROCKET MOTOR:

- Primarily we have to take KNO3 and DEXTROSE in the proportion of 65:35 respectively.
- And then mix these two substance in the fine manner.
- Gently heat the mixture of potassium nitrate and dextrose until it becomes viscous syrup.

NOTE: Dry heating does not actually melt the KNO3, but it melts the sugar and then the KNO3 grains become suspended in the sugar. Metal oxides have been found to increase the burn rate of sugar propellants.

- Pour the melted mixture in to the container we chose for making the motor.
- After pouring we have to strongly pack the Propellent by dumping.
- After the completion of dumping make the hole for making ignition easier.

2. Methodology

2.1 Project Mission

In this methodology, we are going to design the Rocket software, then we have to set up the TVC with Gimbal mechanism by 3d print model, we have to interface the sensor with Arduino and TVC then, solid motor ignition making and testing, in addition to that we have to make the model rocket from PLA, Cardboard, PVC and finally we have to assemble the rocket with TVC and propellant.

2.2 Software used

Open Rocket (To design the Model Rocket)

- **Cura Software** (3D Printed Models)
- **CATIA V5 Software**
- **Arduino Code** (Arduino IDE Software Used to Programming the Arduino Controller Board)

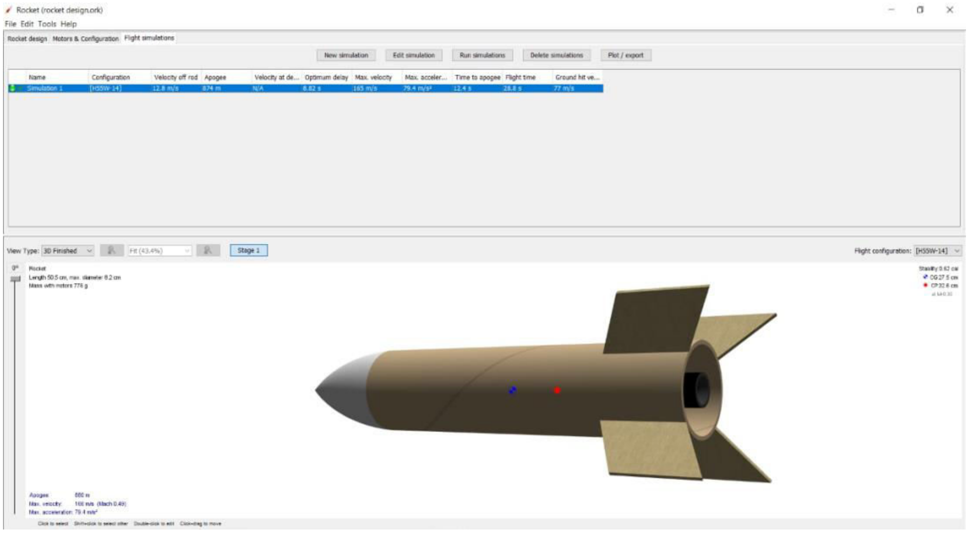


Fig.1. model rocket design

Flight Configuration

Stability	**0.52 cm**
CG	**27.5 cm**
CP	**32.5 cm**
Maximum Velocity	**165 m/s**
Maximum Acceleration	**79.4 m/s^2**
Apogee	**880 m**
Length	**50.5 cm**
Diameter	**8.2 cm**
Mass with Motors	**775 grams**

3. Modelling and Analysing

CATIA SOFTWARE as used for designing the parts such as Nose Cone, TVC Model like Motor Casing, Outer Gimbal, Inner Gimbal. 3D Printing has been carried out in CURA Software

3.1 CAD Models of TVC

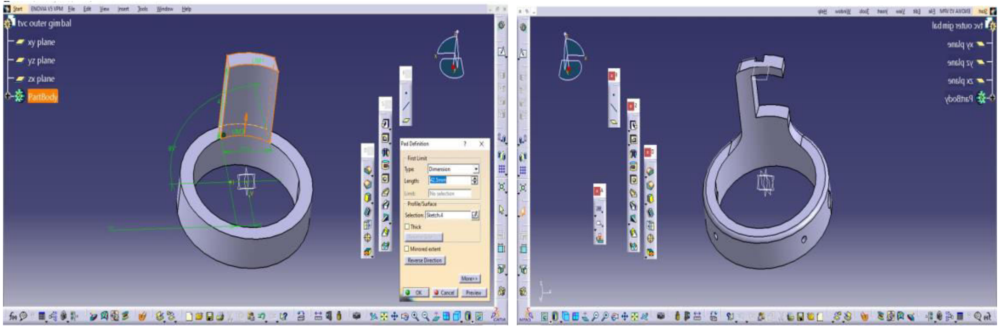


Fig. 2. CAD model of Outer Gimbal

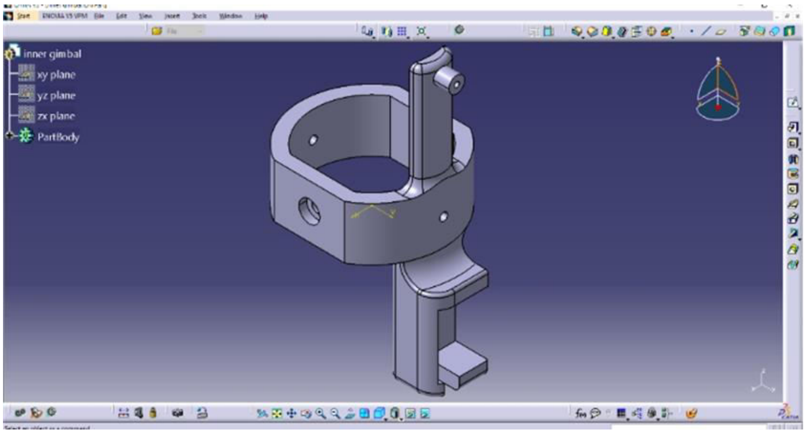


Fig. 3. CAD model of Inner Gimbal

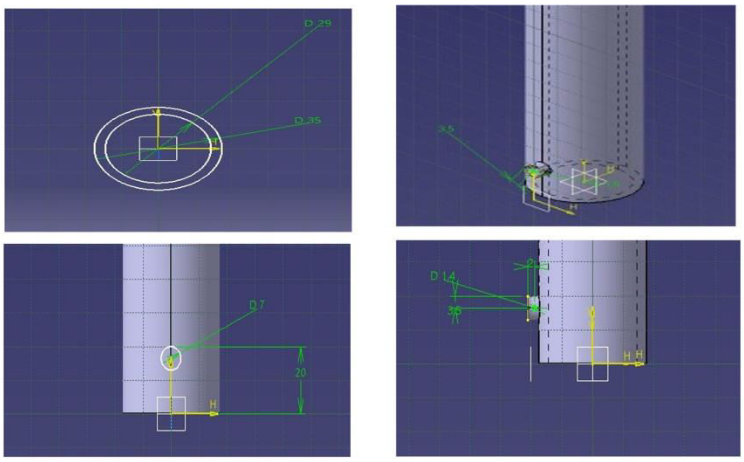


Fig.4 CAD model of Motor Casing

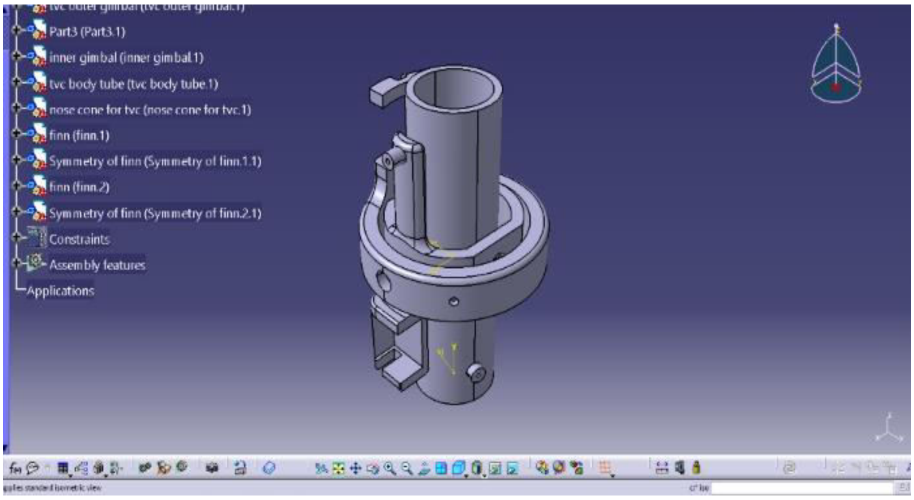


Fig.5 CAD model of Assembled TVC

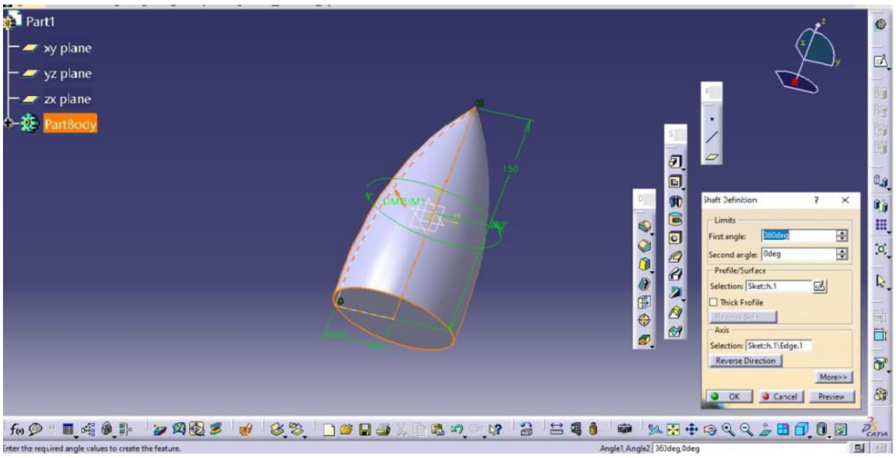


Fig.6 CAD model of Nose Cone

3.2 3D Printed Models

Fig.7. 3D printing of TVC

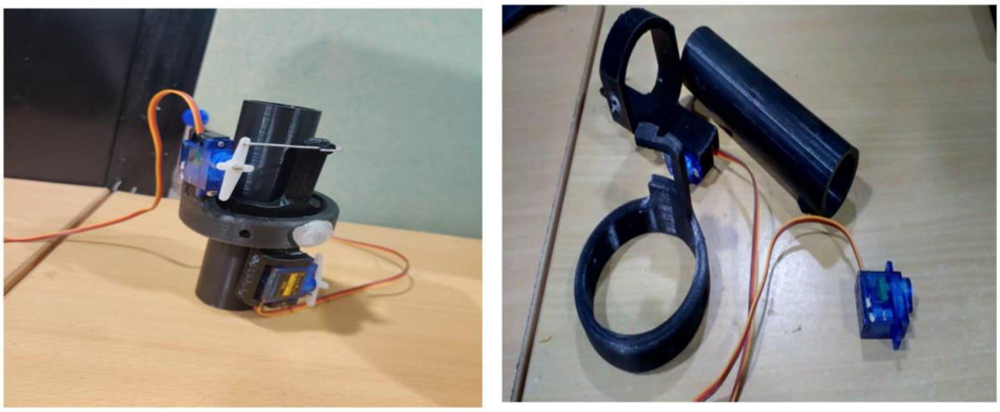
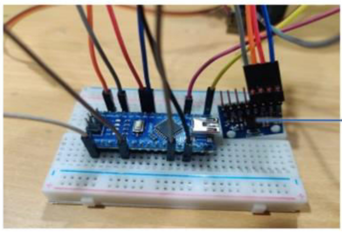


Fig.8. 3D printing of Assembled TVC

3.3 Avionics Components And System

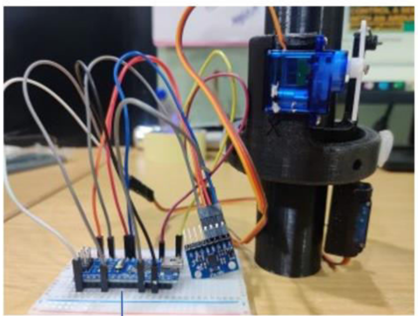


MPU 6050 Sensor

❑ The MPU6050 is a Micro Electro-Mechanical Systems (**MEMS**) which consists of a 3-axis Accelerometer and 3-axis Gyroscope inside it. This helps us to measure acceleration, velocity, orientation, displacement and many other motion related parameter of a system or object.

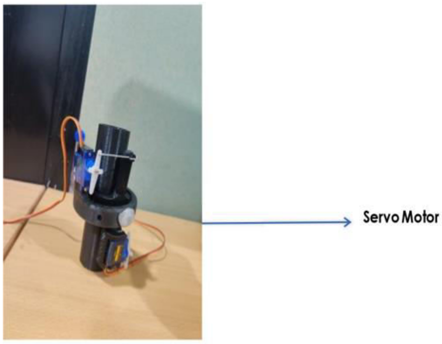
BMP 180 Sensor

❑ **BMP180** is one of sensor of BMP XXX series. They are all designed to **measure Barometric Pressure** or **Atmospheric pressure**. BMP180 is a high precision sensor designed for consumer applications.



Arduino Nano

❑ The Arduino Nano is equipped with 30 male I/O headers, in a dip-30 like configuration, which can be programmed using the Arduino Software integrated development environment (IDE), which is common to all Arduino boards and running both online and offline. The board can be powered through a type-b micro-USB cable. or through a 9V battery.



Servo Motor Specifications

- Model : SG90
- Weight : 9 Gram
- Operating Voltage : 3.0 V – 7.2 V
- Servo Plug : JR
- Stall Torque : 4.8 Volt : 1.2kg cm

4.Testing

4.1 Testing of TVC

- Initially by using Bread Board Connected Servo Motors with sensors then SD Card Module with Laptop.
- Once Connected, we just tested that if we moves sensor X,Y,Z direction , response of the Servo Motor is viewed and at the same time Temperature, Pressure Values are displayed in Laptop.
- At last, model rocket assembly and insert the TVC Model into it, it has been tested by the Movement of TVC at 180 degree with the response of Rocket because Sensor placed in the Nose cone of the Rocket.

4.2 Testing and Evaluation of a Rocket Motor

Calibration of Thrust stand

The thrust stand is used to restrain the test article and provide for measurement of the forces generated by the test article. Its reading is recorded in a computer by a special Arduino programmed board. It gives us live measurement of forces during testing for our calculations. Its needs to be calibrated before testing. We purposely give some known loads and then measure the forces which is recorded by the computer and after taking this value we match the recorded values with known values. Finally, the thrust stand is successfully calibrated with no point of error.

Fig 9.Thrust stand calibration

4.3 Motor Ignition Test

After calibration of the thrust stand, we set up our Rocket motor on the thrust stand. After that we ignited the propellent using Nichrome wire. When electric current is passed through Nichrome ire its temperature increases abundantly, which is enough to ignite our propellent.As burning of propellent progresses, the thrust produced by the motor is measured b the thrust stand and the readings are noted

```
18:06:29.611 -> Weight: 0.220 kg
18:06:29.705 -> Weight: 0.233 kg
18:06:29.798 -> Weight: 0.251 kg
18:06:29.908 -> Weight: 0.272 kg
18:06:29.954 -> Weight: 0.306 kg
18:06:30.048 -> Weight: 0.355 kg
18:06:30.142 -> Weight: 0.443 kg
18:06:30.236 -> Weight: 0.583 kg
18:06:30.345 -> Weight: 0.709 kg
18:06:30.392 -> Weight: 0.789 kg
18:06:30.486 -> Weight: 0.867 kg
18:06:30.580 -> Weight: 0.963 kg
18:06:30.673 -> Weight: 1.079 kg
18:06:30.751 -> Weight: 1.185 kg
18:06:30.845 -> Weight: 1.293 kg
18:06:30.939 -> Weight: 1.452 kg
18:06:31.033 -> Weight: 1.634 kg
18:06:31.126 -> Weight: 1.829 kg
18:06:31.220 -> Weight: 2.062 kg
18:06:31.314 -> Weight: 2.358 kg
18:06:31.408 -> Weight: 2.794 kg
18:06:31.454 -> Weight: 3.308 kg
18:06:31.548 -> Weight: 3.809 kg
18:06:31.642 -> Weight: 4.447 kg
18:06:31.736 -> Weight: 5.124 kg
18:06:31.829 -> Weight: 5.712 kg
18:06:31.923 -> Weight: 6.256 kg
18:06:32.017 -> Weight: 6.783 kg
18:06:32.111 -> Weight: 7.453 kg
18:06:32.158 -> Weight: 8.133 kg
18:06:32.251 -> Weight: 8.722 kg
18:06:32.346 -> Weight: 8.962 kg
18:06:32.440 -> Weight: 8.477 kg
18:06:32.533 -> Weight: 6.480 kg
18:06:32.626 -> Weight: 3.572 kg
18:06:32.720 -> Weight: 1.456 kg
18:06:32.814 -> Weight: 0.609 kg
18:06:32.908 -> Weight: 0.262 kg
18:06:32.955 -> Weight: 0.106 kg
18:06:33.048 -> Weight: 0.033 kg
18:06:33.142 -> Weight: -0.014 kg
18:06:33.236 -> Weight: -0.049 kg
18:06:33.330 -> Weight: -0.076 kg
18:06:33.439 -> Weight: -0.095 kg
18:06:33.486 -> Weight: -0.108 kg
18:06:33.579 -> Weight: -0.115 kg
```

Fig 10. Weight and time Recording

4.4 ROCKET MOTOR PERFORMANCE CALCULATIONS:

We take the readings which is given by thrust stand and the we do some mathematical calculations in excel workbook. And then we calculate the rocket performance characteristics which is following below

BURN TIME	7.6 s
FUEL BURNT	150 g
MASS FLOW RATE	0.019737kg/s
AVERAGE THRUST	13.3566 N
MAXIMUM THRUST	88.982 N
TOTAL IMPULSE	101.5101 Ns
SPECIFIC IMPULSE	676.7342 N.kg/s

Table 1. Rocket Performance

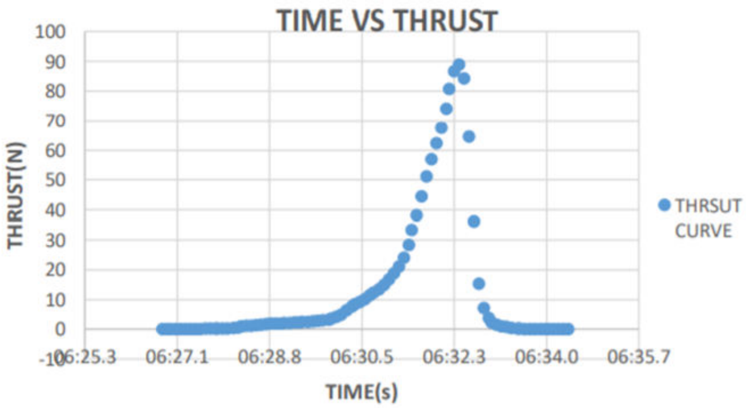


Fig 11. Thrust vs Time

5. Fabrication of Rocket Body

5.1 Conceptual Designing

The conceptual design phase results in a description of the proposed system in terms of a set of integrated ideas about what it should do, how it should behave, and what it should look like. Visualizing your product is an important aspect of verifying the complete design intent. We primarily make a cad model of rocket before fabrication for getting better understanding of our rocket model.

5.2 Making Rocket Models

After the completion of conceptual design we start making real model using materials such as PLA, Cardboard for Nose cone, Fins, Rocket Body respectively.

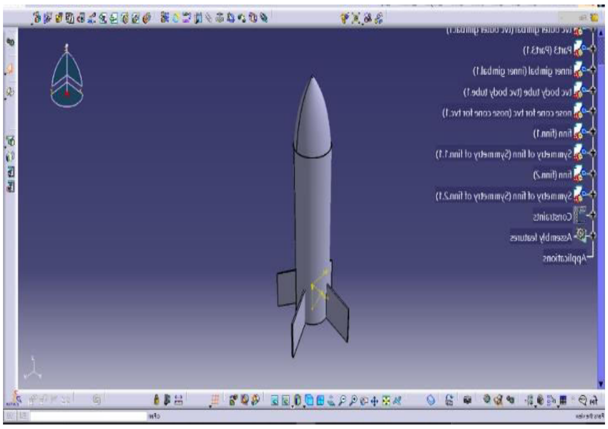


Fig 12.CAD Model of Rocket

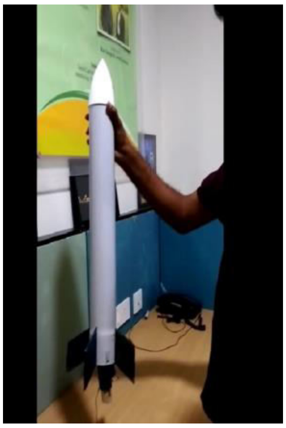


Fig.13 Real Model of Rocket

6. .Results and Discussion

In our project our main aim is to design Thurst vector control mechanism called gimbal components embedded with Avionic system. Since we are successfully getting good results in our work, we were made so many iteration and tested the TVC with Avionic system. Once, rocket has any movement inside the component called detection sensor (gyroscope), Connecting with the programme where data has been recorded constantly. In addition to that, we are making propellant and successfully tested with the load cell testing machine which is used to calculating the Thurst, in addition to that by having 150grams of propellant we achieved maximum Thrust of 88.98N, meanwhile weight of the propellant data has been displayed and recorded in the laptop screen. At the same time we make the video of the movement of TVC with respect to rocket movement. So we conclude that this propellant is enough to producing required Thurst to launch model rocket.

Finally we are concluded that our experimental setup gives an amazing response and has been successfully recorded.

7. Conculsion

As we encountered about TVC Mechanism is embedded with Avionic System, Study of Model Rocket and Making the Solid Motor as well as testing. Finally we conclude that our project comprehensively discussed the mechanism behind TVC and Electrical Components. We successfully build the Model Rocket and Testing the Propellant as much as we can.

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