Perspectives in Communication, Embedded-Systems and Signal-Processing (PiCES) – An International Journal
ISSN: 2566-932X, Vol. 4, Issue 5, August 2020
Part of the Proceedings of the 1st All India Paper writing Competition on Emerging Research - PaCER 2020

Flying Rover

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Abstract: Flying rover is a rover which is been modified with the attachment of a drone having a H-axis morphing mechanism for the purpose of landing the rover and to fly it through the valleys and peaks, even through the narrow gaps in the mars and titan surface, that are having similar atmosphere conditions like earth. The objective of this flying rover is to overcome the problems in the landing of rover in other planets and satellites and to assist the rover through its entire research period. It is been designed by using CATIA software and fabricated using 3-D printing method. And the structural analysis is been carried out and resultants are plotted by using ANSYS software. By carrying out instrumentation, interface and flight testing of the scaled prototype of flying rover, the paper concludes the landing of rover using this method is simple to operate and can land the rover safely on mars and titan's surface even in slope surface, valleys or peaks having a major advantage compared to other techniques existing in landing the rovers in the martin's surface. Combined performance of both drone and rover gives a greater step-over than other landing techniques.

Keywords: Flying-rover; Landing-technique; Space; Drone; CATIA; Morphing; Rover; ANSYS

I. INTRODUCTION

A. *Types Of Landing Methods Used In Other Planets And Satellites*

The widely used landing techniques to land the rover in foreign planets and satellites are,

- Conventional landing
- Sky crane assisted parachute landing

a) *Conventional landing:*

Conventional landings are mainly used in the satellites where there is no gravity i.e., mainly preferred for landing the lander which carries rover in the moon's surface. This landing technique uses a rocket engine, quad landing gears and fuel and oxidizer tanks for propulsion purpose.

In this landing the probe consisting of lander and rover gets separated from the interplanetary orbiter and enters into the satellite or planet's atmosphere.

And then, the lander lands on that planet or satellite's surface using its rocket engine and with the help of its landing gears. After lander lands successfully, then the rover is been deployed from the lander over the satellite or planet's surface.

This method was mainly considered for its simple operating procedure and has reduced operational cost compared to other techniques.

For reference, let us discuss an overview on the conventional landing of Vikram lander of CHANDRAYAAN II mission, which carried Pragyan rover to the lunar south-pole i.e., moon's south-pole.

The mass of the Pragyan rover was about 27 kg, which had a dimension of 0.9m*0.75m*0.85m that was powered by solar panels that produced the required power supply of 50W.

While, the mass of the Vikram lander was 1471 kg at wet condition and 626 kg at dry condition with a power requirement of 650W for its operation. The combined mass of the mission including the orbiter which requires a power of 1KW weighs about 3850 kg at wet condition and 1308 kg at dry condition was launched using GSLV Mark III M1.

In this mission, conventional landing was the technique used to land the Vikram lander in the lunar south-pole surface. This Vikram lander used a single rocket engine for landing with the help of quad landing gears on which the rover's chamber was mounted. Yet, the lander was failed for a successful landing, considering from the point of simulation that was done before the mission launch – the rover will be deployed only after the lander has landed successfully on the lunar south-pole surface.

b) Sky Crane assisted Parachute Landing Technique:

Sky Crane Parachute Landing Technique is widely used to land the rovers in Martin surface i.e.., mars. This technique is mainly considered to land the rover even in steep slopes, which cannot be performed using conventional landing technique. Since, Mars has 1/3rd gravity of earth's gravity and the Mars atmosphere is 99% thinner than the Earth's atmosphere the parachute assisted crane landing is been successful in landing the rovers in Martin's surface.

This technique consists of a chute used to descend the rover into the atmosphere from the probe and a sky crane that is operated to lower the rover on the mars surface and thrusters that are used to hover the crane over the surface until the rover is successfully landed.

This technique has greater advantages over conventional landing by eliminating the landing gear, the velocity of lowering the rover can be controlled and can also be land in steep slopes or also in valleys and ridges.

Using this technique, NASA has successfully landed rovers like OPPORTUNITY rover and CURIOSITY rover on the mars surface.

For reference let us consider the landing of Curiosity rover over the martin surface using this Sky Crane assisted parachute technique.

The Curiosity rover weighed a combined mass of 899 kg, where 80 kg of scientific instruments combined with the rover's 819 kg. This Curiosity rover was powered by using plutonium based RTG's (i.e.., Radio Thermal Generators) to move even into the dark parts of the mars. The dimensions of the rover were about 2.9m of length with 2.7m of width having a height of 2.2m.

A chute weighing 45 kg which is 1/7th of rover's weight generates a force of 27,200 kg is used to descend the rover and sky crane from the orbiter probe. Then, Rover jettison technique is used to separate lower heat shield from the rover's bottom. After that, the crane is operated at a speed of 2.7 km/hr or 1.7 mil/hr to lower the rover on the martin surface. The sky crane is kept hovering at a stable position in mars atmosphere with the help of thrusters until the rover is successfully landed in the mars surface.

B. Problem Statement

The above used techniques may have various advantages, yet they suffer from some serious disadvantages like,

In Conventional landing technique,

i. In conventional landing technique, the rover will be deployed only if the lander successfully lands on the corresponding planet or satellite's surface.

ii. If the landing of the lander on that planet or satellite surface is not succeeded, then the rover will not deployed and the entire mission will be considered to a failure.

In Sky Crane assisted Parachute landing technique,

iii. In sky crane assisted parachute landing, the operational risk is too high.

iv. The rolling of rover upside down may occur in the sky crane assisted parachute landing, which may lead the mission to a failure.

Problems faced by rovers after landing,

v. After the landing process in both of the above techniques, the rover is required to move on its own across the valleys and hills that cannot be climbed or passed through by normal rovers like Curiosity rover, Opportunity rover and Pragyan rovers.

vi. They are all required to travel an additional distance to come across them by finding an alternative way or else withdrawing from that place at rare instants.

C. Idea Overview

To overcome the above disadvantages, we came up with a project idea called "Flying rover" i.e.., a rover which is attached with a drone. In this technique, the drone is fixed to rover permanently. The upper heat shield of the probe is fixed to the drone and the lower heat shield is fixed to the rover's base. After entering the planet or satellite's atmosphere, the lower heat shield gets separated and the drone rover gets detached from the probe's upper heat shield at a minimum altitude of 2km above the ground surface of either planet or satellite. And then, the drone gets activated and lands the rover on the surface. After that, the drone gets shut down and the rover is been activated and also the drone's arms are been constrained into h axis to reduce the narrow size of the rover and also to fly the drone through the narrow ways.

The major advantage is that we can operate drone not only for the purpose of landing and can also be operated in such a conditions where rover cannot be operated like valleys and peaks, that can be passed through by flying rover with the help of operating drone.

This flying rover can be used for landing rover and operate it in various conditions in the planets and satellites like Mars, Titan and Lunar (Moon). The flying rover is focused to use in the Mars planet and Titan i.e.., satellite of Saturn, because only in this planet and satellite the atmosphere and gravity conditions are moreover like earth's atmosphere and Fig. 1 like gravity conditions. The propeller using drone can be used to propel the thrust to lift the rover and its instruments in such conditions due to the presence of moisture air in its atmosphere. Here, Fig. 1 explains that the propellers can produce lift and thrust only in the presence of atmosphere and air. Generally, the propeller motors in the earth's atmosphere works by pushing the air molecules to the downward direction in order to produce the thrust which helps in lifting the drone from the surface. Based on this, we require a propeller rpm of 10 times greater than in the earth to lift the drone rover inside the martin's atmosphere. While considering Titan the atmosphere is dense as like the earth's atmosphere is and the atmosphere is rich with nitrogen molecules which will help the propellers to produce the thrust easily inside the titan's atmosphere and also it has a surface pressure of 50 percent higher than earth's surface pressure. Titan's atmosphere is 10 times higher than the earth's, which is nearly 600 km into space and has a very high ratio of atmospheric density to surface gravity that greatly reduces the propeller span needed for the drone to maintain lift. This all considerations makes a possible gateway for the drone rover to fly inside both Martin's atmosphere and Titan's atmosphere.

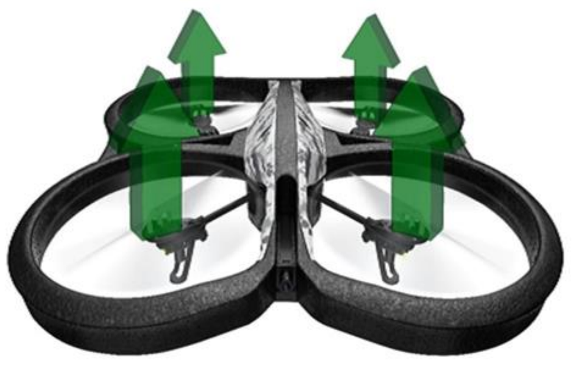
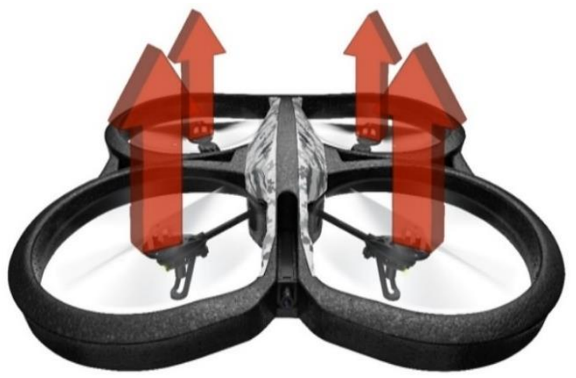


Fig 1. Propellers can produce lift and thrust only in the presence of atmosphere and air



(b)

Fig 2. Propellers cannot produce lift and thrust in the absence of atmosphere and air

We know that, the propelled drones cannot fly in the lunar atmosphere due to the absence of air molecules in it. Which has only vacuum in its space. This makes more complicated for the drone rover to fly inside the lunar's atmosphere. For this problem we have come across with a solution that using of thrusters, which are now-a-days used in the VTOL (Vertical Take-off and Landing) engines to been used replacement in the place of propeller motors in the drone rover. The red colored arrows in the Fig. 2 clearly explains that thrust and lift cannot be generated by using the propellers inside the lunar's atmosphere.

D. Project Objectives

1. To overcome the problems faced by the landing techniques like Conventional landing and Sky Crane assisted Parachute landing used for landing rovers on other planets and satellites and the difficulties faced by rover during its period of research in that planets and satellites, while crossing through the valleys and hills, etc. using a modified flying rover.
2. To design the flying rover using CATIA software, where the design section is divided into two, i.e., drone designing and rover designing.
3. To fabricate the drone frame and drone arm using 3D printing technology using the material named PLA (polymer lactic acid) and the rover plate using wooden cardboard.
4. To fabricate the rover plate using wooden cardboard and the rover wheels using general plastics.
5. To perform load estimation and configuration of morphing mechanism from X-axis to H-axis.
6. To perform structural analysis for the drone frame and arm applying point loads and uniform load over the frame.
7. To perform assemble of drone frame, drone arm, rover plate and rover wheels.
8. To perform instrumentation and interfacing of drone rover's receiver to the remote controller or transmitter.
9. To perform flight testing of drone like yaw, pitch and rpm of the motors and axis movement testing of servo motors and the rover movement and control testing after instrumentation and interfacing.

II. METHODOLOGY

1. Design and Structural analysis
2. Designing of drone frame, drone arm and rover plate
3. Fabrication of drone frame, drone arm and rover plate (i.e.., PLA – Poly Lactic Acid is the material used for the fabrication purpose)
4. Assembly and Instrumentation
5. Interface and testing

III. DESIGN AND FABRICATION

A. CATIA Modelling

Both the 2-D and 3-D designs of the drone frame, arm and rover are been designed by using commercially available CATIA software.

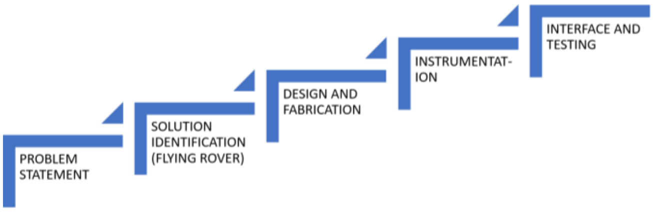


Fig 3. Flow chart

a) Frame Designing

Drone Frame designing is been designed using CATIA software, and Fig.4 represents the two dimensional diagram of the drone frame. The design was carried out based on the analysis and reference of various existing quad-copters and their dimension.

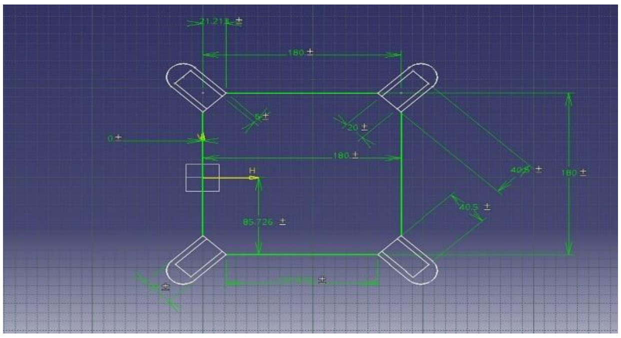


Fig 4. 2D Frame design

Based on them, we have designed the quad-copter frame with a dimension of 180mm of length and 180mm of width with a height of 36.1mm with a cavity of 26.1mm in the center of the frame body which is used as instrument carrier section and also to reduce the weight of drone, which will increase the efficiency of the quad-copter at flight conditions. Also, there are FTHE cavities in the drone frame, each cavity is at the end of the drone frame where the arm is to be mounted. The purpose of the cavity is to fix servos that is used to move the drone arm from X-axis to H-axis during both in-flight and after flight conditions. Each cavity has a similar dimension of 40.5mm of length and 20mm of width with a height of 40.5mm. Similarly, Fig.5 represents the three dimensional diagram of the drone frame, which was also designed by using CATIA software.

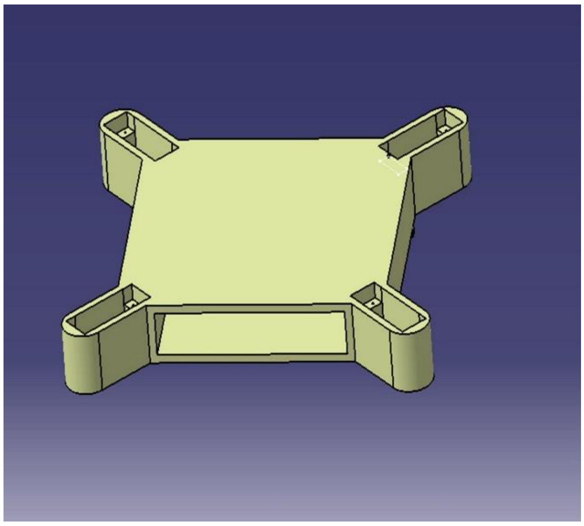


Fig 5. 3D design of frame

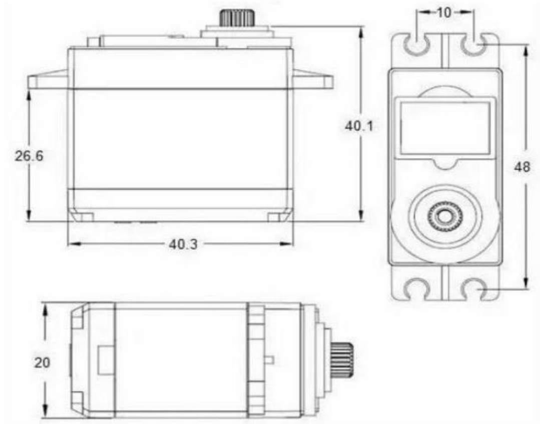


Fig 6. Servo data sheet

Here, Fig.6 represents the geometrical dimensions of the selected servo motor MG995 i.e.., has an 180deg rotational. Also, it is the design consideration that was used to design the servo motor cavity in the FTHE corners of the drone frame to fix the motor in it.

b) Arm Designing

Drone Arm designing is been carried out by using CATIA software. Fig.7 represents the three dimensional diagram of the drone arm, which is designed by referring the existing quad-copter arms in the dimensions of arm length 145mm and an extended width of 25mm that is designed based on the truss design with a base of diameter 40mm for fixing the brushless motor with the drone arm. Also a hole of 1mm is introduced in another side of the arm, through which the arm is fixed to the servo motor that is already attached to the drone frame. Here, Fig.8 represents the three dimensional arm supporter which is fixed below the drone arm to reduce the vibration and to act as a support to the arm to increase its strength. This L supporter is been designed by using CATIA software in three dimensional. This arm supporter has two holes which is used to connect the arm connector with the drone arm.

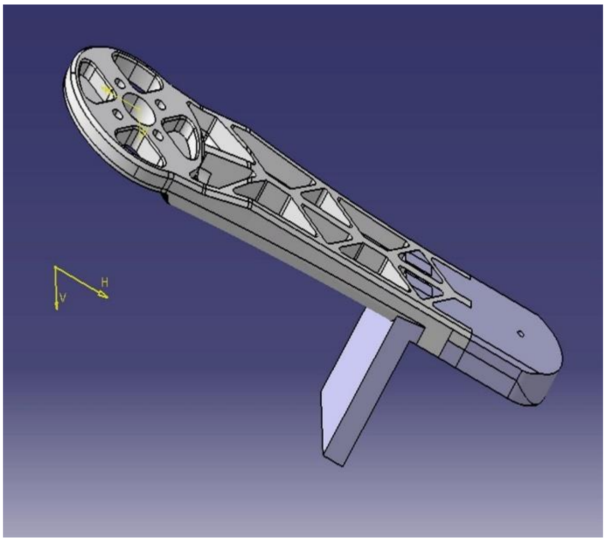


Fig 7. 3D Design of arm

The gear size of the servo motor MG995 and the base dimensions of the A2212/6T brushless dc motor are been considered as the design factors for carrying out the 2 dimensional and 3 dimensional diagram of the drone arm in CATIA software. The servo motors gear size is been considered from the Fig.6 and the BLDC motor base dimensions are considered from the Fig.9 that represents the geometrical diagram of the A2212/6T motor that can produce a thrust about 2200Kv.

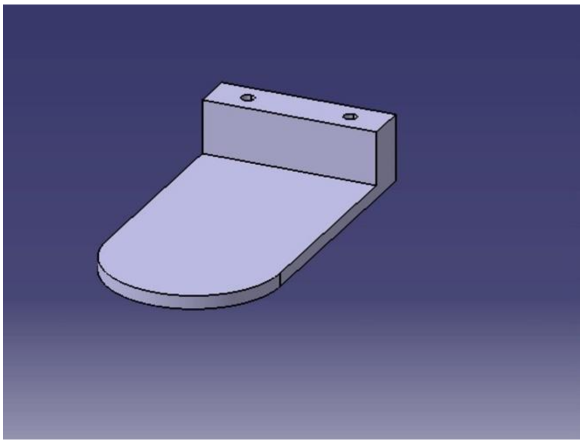


Fig 8. Arm lower

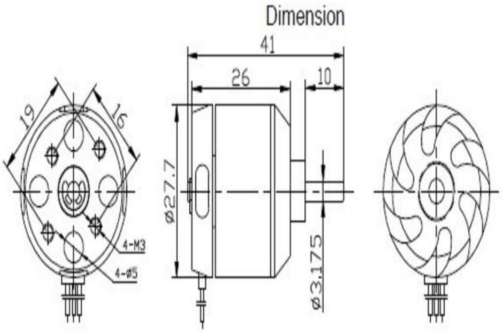


Fig 9. BLDC Data sheet

c) Rover Plate Designing

The rover plate connects the drone frame to the motors that operates the wheels. Based on its purpose, the rover plate is been designed in the dimension of 180mm of length and 180mm of width with a thickness of 3mm.

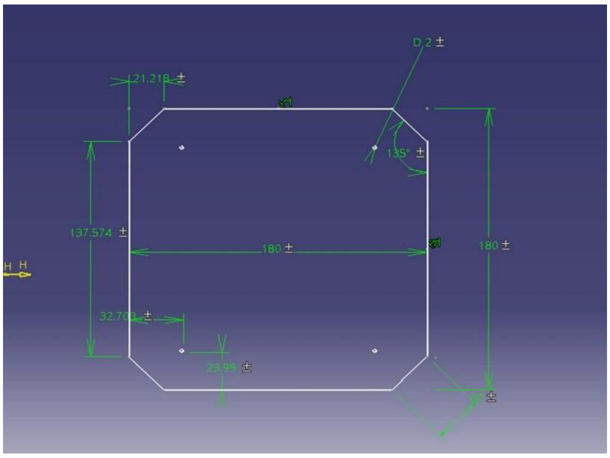


Fig 10. 2D Design of rover plate

And FTHE holes are introduced at similar distance, which is used to attach the rover plate with the drone frame. Fig.10 represents the two dimensional diagram of the rover plate that is been drawn using CATIA software.

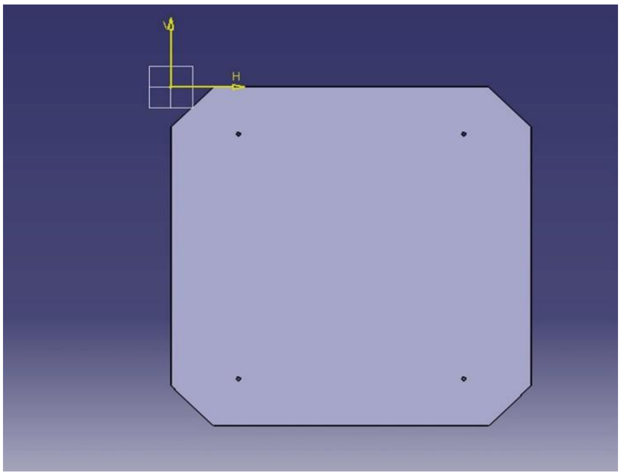


Fig 11. 3D Design of rover plate

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Here, Fig.11 represents the three dimensional diagram of the rover plate which is also drawn using the CATIA software.

B. Fabrication of Drone Rover

The designed drone frame, drone arm, arm supporter and the rover plate are been fabricated.

a) Fabrication Drone Frame and Arms

The designed three dimensional drone frame, drone arms and arm supporters are fabricated into real-time component using 3-D printing method. In this method a 3-D printing machine of size 300mm*300mm of dimension with a height of 500mm. The material used for 3-D printing is PLA (Poly Lactic Acid) material i.e.., chemical formula as ($C3H4O2$)n with square spacing inside the drone frame and arm components.

PLA is a crystalline polymer which is biodegradable, and bio active polyester made up of lactic acid as building blocks. The major consideration for using PLA for fabrication is because that the material has a melting point of 150 to 160deg-C with an injection molding temperature of 178 to 240deg-C. The density of the material is about 1.210 to 1.430 g.cm-3. Also the material has higher strength with a tensile modulus of 2.7 to 16GPa with a glass transition temperature of 60 to 65deg-C. Also this material can perform solvent welding using dichloromethane.

Fig 12. PLA

Fig.12 represents the PLA orange filament which is used to 3-D print the drone arm and arm supporters. The PLA ribbon filament roll is been attached to the 3-D printing machine and the machine is been operated at a temperature of 150-160deg-C.

Then the STP file of the 3-D modeled drone frame is installed inside the machine and the weight of the drone frame is determined as 332g and the spacing is selected as square spacing and then the white filament PLA is attached to the machine and the printing HTHES for the drone frame is been estimated as 29 HTHES for the regarding 3-D printing machine that is been used. Similarly, the drone arm file is installed and determined to have a weight of 20g per each printed using orange PLA filament with an estimated printing time of 2 HTHES per each arm. After that the arm supporter file is been installed with a determined weight of 3g per each with a printing period of 9 minutes per each printed using orange filament PLA using square spacing inside them to reduce the weight of the body.

Fig 13. 3D part of arm and frame

Fig. 13 represents the fabricated drone frame and drone arms i.e.., the drone frame is been fabricated using white ribbon PLA and the drone arm and the arm supporter are been fabricated using orange ribbon PLA.

S. No	Component	Quantity	Weight
1	Drone Frame	1	332g
2	Drone Arm	4	80g
3	Arm Supporter	4	12g
4	Total	9	424g

Table 1. 3D parts list

Table 1 represents the number of drone parts, weight of the each part in grams with a cumulative weight of 424g of drone frame, drone arms and arm supporter and the 3-D printing HTHES for each component with a total period of 35 HTHES and 37 minutes at a maximum melting temperature of 160deg-celsius.

b) Fabrication of Rover Plate

The fabrication of rover plate is been carried out using a hardwood plywood material. The main factor for considering this hardwood plywood for rover plate fabrication is to reduce the cost of the scaled prototype and also this plywood has increased in strength to weight ratio compared to other plywood materials. The material is also easy to handle and eco-friendly. The selected plywood is in the dimensions of 180*180mm and weighs about 40g with a thickness of 3mm.

IV. CONFIGURATION OF MORPGHING MECHANISM

Morphing mechanism in a quad-copter is been performed by adaptive morphing mechanism, which is used to further increase the versatility for a fully autonomous quad-copter. The adaptive morphology in drones are generally proposed to perform varies tasks such as negotiation of narrow gaps, close inspection of vertical surfaces, object grasping and transportation. For the flying rover we have carried out the H-axis adaptive morphing mechanism to fly and move the rover even through narrow gaps. In this morphing mechanism the drone arm's X-axis position can be changed into H-axis position moving for an angle of 40deg from the actual position of the drone arm. This adaptive morphing mechanism is been performed in the flying rover using an 180deg rotational servo motor which is been fixed in the FTHE modified edges of the drone frame firmly.

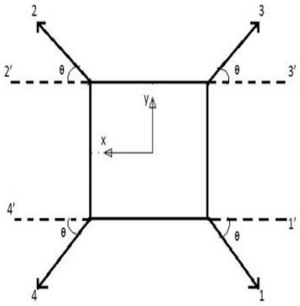

Fig 14. Morphing Mechanism

And then, the drone arm is been attached to the servo motors metal gear. When the servo motor is been operated to perform a rotational angle of 40deg and the drone arm moves from the actual X-axis position to the modified H-axis position. This adaptive morphing can be performed only during the stable maneuvering of the flying rover, because during flight conditions the H-axis morphing mechanism can lead to the damage or even breakage of the drone arms from the motor's gear. Also this morphing can be performed at the surface level to reduce the ground coverage of the flying rover during movement. This adaptive morphing greatly helps the flying rover to move through even narrow and congested paths.

V. LOAD,THRUST AND POWER ESTIMATION

A. *Load Estimation of Flying Rover:*

Load estimation of the flying rover is been determined by using the general equation,

$$W_g = W_e + W_f + W_{pl} + W_{crew} \quad (1)$$

where,

W_g = Gross weight of flying rover

W_f = Fuel weight of flying rover

W_e = Empty weight of flying rover

W_{pl} = Payload weight of flying rover

W_{crew} = Crew weight of flying rover

Generally in drones, the fuel weight and the crew weight will be absent. So, both the fuel weight and the crew weight of this flying rover will be zero. Hence, (1) deducts into,

$$W_g = W_e + W_f \quad (2)$$

Here, the empty weight (W_e) of the flying rover includes the drone frame weight, drone arm weight and the rover plate and rover wheels weight. And, the payload weight of the flying rover includes the instruments used i.e.., FCB, BLDC motor, servo motors, battery, ESC, propellers, DC motors and receivers.

Considering the above components and instrument weight,

Total empty weight of the flying over (W_e) = 566gm

From the table.2 representing the data sheet, we obtained,

Total payload weight of the flying rover (W_{pl}) = 1384 gm

Substituting the W_e and W_{pl} in (2), we obtain the gross weight of the flying rover,

From (2), $W_g = W_e + W_f$

W_g = 566 + 1384

W_g = 1950gm

Therefore, the total Gross weight of the flying rover is 1950gm.

B. *Thrust Estimation of Flying Rover*

For thrust estimation of the flying rover, the total Gross weight of the flying rover and the thrust produced by each BLDC motor for 2200KV at 6T turns are been considered.

The thrust of each Brushless DC motor is been determined as 800gm per each motor using power analyzer setup. To find the total thrust produced by quad BLDC motors,

$$Thrust\ of\ each\ motor = \frac{Total\ thrust}{No.of\ motors} \quad (3)$$

where,

Total thrust = Thrust of each motor * no. of motors (4)

Total thrust = 800 * 4 = 3200gm

Therefore, the total thrust produced by the Brushless DC motor is 3200gm.

C. *Power Estimation of Flying Rover:*

Battery = Current * Flight time

Assume flight time = 7 mins

Servo = 2 mins

Rover = 1 mins

Note that

1S = 1Cell = 3.7 V

3S = 11.1 V

Power total = IV

I = 20amps

So, Battery that need = 3000mAh

So the actual flight time will equal = 9mins.

VI. INSTRUMENTATION

Table 2 is the datasheet of the instruments that are been used for in the instrumentation and interfacing of the flying rover. The instruments that are used are been selected based on the weight of the drone frame and arms and the rover plate including the payloads that are been used in it.

S.No	Instruments	Numbers Used	Weight
1.	Flight Control Board	1pc	82gm
2.	Brushless DC Motors	4 pcs	60gm/each
3.	Electronic Speed Controller	4 pcs	28gm/each
4.	Battery	1 pc	310gm
5.	Propeller	4 pcs	28gm/each
6.	Servo Motors	4 pcs	55gm/each
7.	RC Remote Controller	1pc	680gm
8.	Power Distribution Board	1pc	45gm
9.	Damping Plate	1pc	55gm
10.	DC Gear Motors	4pc	52gm/each

Table 2. Data sheet

A. *Flight Controller Board*

The flight controller board that we have used is ARDUPILOT APM 2.8 which has a 3-Axis Gyro meter, Accelerometer and high performance Barometer sensors are built in with having a USB port and a GPS input port. This board has 8 input channels with an equivalent output channels of 8 and also includes a telem port built in it. The processor that is built in the board is ATMEGA2560 and ATMEGA32U-2. The input voltage of the board is 12-16 VDC having a weight of 82gm with dimensions of 85*45*15 mm. The stability and reliability of this flight controller board are the main characteristics which are been considered to use this board in this flying drone.

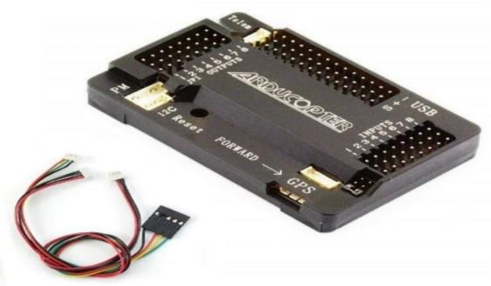

Fig 15. APM

S. No	Name	Specification
1.	Model	APM 2.8
2.	Power Supply	LP2985-3.3
3.	Ports	MUX(UARTO, UART2, mnnl2 and OSD are optional, OSD is the defaulted output)
4.	Input Voltage(V)	12-16 VDC
5.	Sensors	3-Axis Gyrometer, Accelerometer, High-Performance Barometer
6.	Processor	ATMEGA25650 and ATMEGA32U-2
7.	Dimension(mm) L*W*H	85*45*15
8.	Weight	82gm

Table 3. APM Data Sheet

B. *Brushless DC Motor*

The Brushless DC motor A2212 6T that we have used is 2200 KV with 6 turns. This BLDC motor has a maximum efficiency of 80% with a load current of 0.5A at 10V and has 4-10A of maximum current efficiency. The motor has a current handling capacity of 12A per 60S and can be powered by using 2S-3S Li-Po batteries. The shaft diameter of this BLDC motor is 3.17mm with a weight of 60gm and a length of 27mm with a width of 26mm. This BLDC motor can produce a thrust of approx.900gms by each motor. The reason for considering this 2200KV motor with 6T is that the higher KV motors than this will lack with less rpm than this motor and the lower KV motors cannot produce the required amount of thrust, despite the motor has higher rpm than this motor. And the major advantages of using brushless dc motors over normal dc motors for drones are these motors does not require brushes for producing sparks and brushless dc motors produce very less noise compared to the DC motors. Also this BLDC's have higher rpm and thrust produce when compared to the dc motors at the similar power supplies.

Fig 16. BLDC Data sheet

Table 4 represents the data sheet of the Brushless DC Motor A2212 with 6T used for the flying rover.

S. No	Name	Specification
1.	Model	A2212 6T
2.	Motor KV (rpm/V)	2200
3.	Li-Po Batteries	2S-3S
4.	Shaft Diameter(mm)	3.17
5.	Maximum Efficiency	80%
6.	Current Handling Capacity	12A/60S
7.	Load Current	0.5A @ 10V
8.	Max. Efficiency Current	4-10A
9.	Length (mm)	27
10.	Width (mm)	26
11.	Weight (gm.)	60
12.	No. of units used	4

Table 4. BLDC Data sheet

C. *Electronic Speed Controller*

Electronic speed controller is a device which is generally used to control the rotational speed of the BLDC motor and to provide a constant power supply from the battery to the motor without any flaws in the power distribution. Here, we have used ESC called E max BL Heli Series 30A model which is used because of its higher reliability and has a higher performance than the normal electronic speed controllers.

Fig 17. ESC

The burst current flow in this E max is about 40A for 10 sec and has a constant current flow of 30A. This speed controller has a power distribution capability of 5V per 2A in a circuit. The suitable batteries for this controller are 2S-4S Li-Po batteries and has a weight of 28gm with the dimensions of 52 mm of length, 26 mm of width and thickness of 7 mm.

Table 5 represents the data sheet of the E max BL Heli series 30A used in this flying rover.

S. No	Name	Specification
1.	Model	E max BL Heli Series 30A
2.	Burst Current	40A for 10 sec
3.	Constant Current	30A
4.	BEC (Battery Elimination Circuit)	5V/2A
5.	Suitable Batteries	2S-4S
6.	Color	Black
7.	Dimensions(mm) L*W*H	52*26*7
8.	Weight (gm.)	28
9.	No. of units used	4

Table 5. ESC Data Sheet

D. *Battery*

Generally, batteries are a device which are used to store and distribute the energy to the required instruments. We have used Lithium Polymer Battery of capacity 3000mah for the flying drone i.e.., Orange 3000/3S-40 which has a output voltage of 11.1V. The charge rate of this Lithium Polymer battery is 1-3C and has a discharge plug XT-60 and a balance plug called JST-XH. This lithium polymer battery weighs about 310gm and has a length of 137 mm, width of 44 mm and thickness of 37 mm. The maximum burst discharge of this battery is 80C (416.0A) and has a maximum charge rate of 5C with a maximum continuous discharge of 40C (208.0A). The major advantage of using Lithium Polymer battery instead of Lithium Ion battery is that this battery has reduced weight and has FTHE times the energy density than nickel cadmium or nickel metal hydride batteries. Lithium Polymer batteries are lightweight and pliable and also can be made to almost any shape or size. Also Lithium Polymer batteries have improved safety than the Lithium Ion batteries. Here, Fig.19 represents the electric circuit inside the battery, which has three equally powered cells in it and a balancer to balance the electric flow and to maintain constant current flow from each cell and a battery protection to avoid failure of cells.

Fig 18. Battery

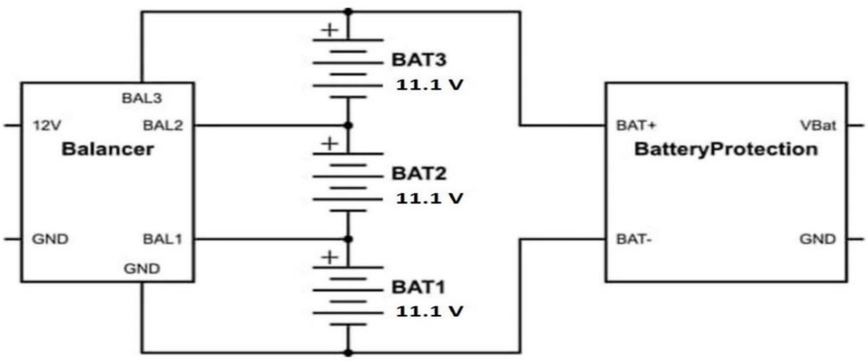

Fig 19. Fig 19. Circuit Diagram

S. No	Name	Specification
1.	Model	Orange 3000/3S-40
2.	Capacity	3000
3.	Weight (gm.)	310
4.	Output Voltage	11.1V
5.	Charge Rate	1-3C
6.	Discharge Plug	XT-60
7.	Balance Plug	JST-XH
8.	Length (mm)	137
9.	Width (mm)	44
10.	Thickness (mm)	37
11.	Maximum Burst Discharge	80C (416.0A)
12.	Maximum Charge Rate	5C
13.	Maximum Continuous Discharge	40C (208.0A)
14.	No. of units used	1

Table 6. Battery Data Sheet

E. Propellers

Propellers are aerodynamic designed component which are used to lift the drone. Based on the frame and arm length of the drone the propeller's length and pitch size varies. Depending on the propeller's length and pitch the rpm and the thrust produced by the motor can be determined and varied. Here, we have used Glass Fiber Nylon propeller of length 6 inch and pitch of 4.5 inch.

The size of the propeller is selected as 6 inch based on the size of the frame which is about 180 mm of length. The shaft diameter of the propeller is about 5mm and has a total length of 155 mm with a weight of 28gm. This Glass fiber Nylon propeller has an epoxy resin cover over it and has very light weight.

S. No	Name	Specification
1.	Model	Orange hd Propeller
2.	Material	Glass Fiber Nylon
3.	Color	Black
4.	Length (inch)	6
5.	Pitch (inch)	4.5
6.	Shaft Diameter (mm)	5
7.	Total Length (mm)	155
8.	Weight (gm.)	28
9.	No. of units used	4 (clockwise: 2; Anti-clockwise: 2)

Table 7. Propeller Data Sheet

This propeller is very strong and rigid in strength and has greater aerodynamic efficiency and also has good lifting capacity. Also the glass fiber nylon has reduced cost, when compared to other fiber propellers.

Fig 20. Propeller

F. Servo Motor

Servo motor is a device which is generally used to move the axis of an arm from one angle to another angle, where the widely used servos are of angle 180deg and 90deg. In this flying rover, the servo motors are been used for the movement of drone arm from X-axis to H-axis for an angle of 40deg. Here, we have used MG995 servo which has a movement angle of 180deg. This servo motor weighs about 55gm and can be operated at a voltage of 4.8 to 7.2V and has an operating speed of 0.20 sec per 60deg and stall torque of 10 Kg-cm at an input voltage of 4.8V.

S. No	Name	Specification
1.	Model	MG995
2.	Weight (gm.)	55
3.	Operating Voltage	4.8-7.2 V
4.	Operating Speed	0.20 sec/60 deg @4.8V 0.16 sec/60 deg @6.6V
5.	Stall Torque	10 Kg-cm @4.8V 12 Kg-cm @6.6V
6.	Operating Temperature (deg. C)	-30 to 60
7.	Dead Band Width	1 µs
8.	Gear Material	Metal
9.	Rotational Degree	180
10.	Servo Plug	JR
11.	Cable Length (mm)	30
12.	Length (mm)	40.5
13.	Width (mm)	20
14.	No. of units used	4

Table 8. Servo Data Sheet

The operating temperature of this motor is -30 to 60 deg. C with a dead band width of 1 µs. The gear material used in this servo motor is metal and has a rotational degree of 180deg with a servo plug of JR and has cable length of 150mm. The length of this servo motor is about 40.5mm and width is 20mm.

Fig 21. Servo

G. Remote Controller

Remote controller is a device which consist of a transmitter and a receiver that are generally used to control a distant device or an instrument or a vehicle using long range and short range frequency signals. The input data for the vehicle to be controlled is been transmitted from this remote controller with the help of a transmitter that transmits the input data in the form of frequency signals to the receiver that is fixed to the corresponding vehicle and also connected to its supporting instruments.

The transmitter we have used to operate this flying rover is FS-TH9X which has band range of 2.40 to 2.48 GHz and FS-IA10B receiver. The number of channels used in this transmitter is 9 with an antenna length of 100mm and the number channels used in the receiver is 10 and has dual antenna of length 26mm. This transmitter is been operated at an operating voltage of 12V DC and has a bandwidth of 500 KHz with a sensitivity of 1024. The radio frequency power in this transmitter is about less than 20dbm and the code type used in this transmitter is digital which is an advantage over other transmitters that makes the control much easier and simple. Another main advantage of this transmitter is the number of channels available in it i.e.., 9 channels. Also the accuracy of this transmitter is high.

S. No	Name	Specification
1.	Model Type	Digital Radio Trans receiver Transmitter - FS-TH9X Receiver – FS-IA10B
2.	Code Type	Digital
3.	Bandwidth	500 KHz
4.	Operating Voltage	12V DC
5.	No. of Channels	Transmitter – 9 Receiver – 10
6.	Band Range	2.40 – 2.48 GHz
7.	Sensitivity	1024
8.	RF Power	Less than 20dbm
9.	Antenna Length	Transmitter – 100mm Receiver: Dual Antenna – 26mm
10.	No. of units used	1

Table 9. Remote Controler Data Sheet

Fig 22. Remote Controller

H. Damping Plate

Damping plate is a device which is used to prevent and reduce the vibrations that act on the flight control board during flight and also during landing operations. The plate itself acts as suspension mechanism for the FCB, which contracts and retracts based on the vibrations produced in the drone frame and protects the compass in the FCB board that is highly sensitivity which can be damaged due to the continuous vibrations acting on it for a longer period of time. The usage of damping plate is highly necessary, because even a minor damage in the FCB board and its gyro system may lead to the failure in the entire flight operation of the drone.

I. DC Gear Motors

The general working principle of a DC Gear motor is to covert the input electrical energy into a mechanical energy in turn of output. In this flying rover, the DC gear motors are been used to operate the rover wheels. In this flying rover, we have used a 4 set of 6V Dual Axial TT DC motor with gears. These motors has an operating voltage of 6V with a load current of 0.5A at a rated rpm and torque of 35 rpm and 2.9kg-cm. A gear box made up of plastic material is been attached to this 6V DC motor which has a dimension of 37mm length, 18mm of width and a height of 22mm. Also the gears are made up of plastic and the gear box has dual axial connector in it.

S. No	**Name**	**Specification**
1.	Model Type	6V Dual Axial TT DC motor with Gear
2.	Operating Voltage (VDC)	6
3.	Load Current (A)	0.5
4.	Rated RPM	35
5.	Rated Torque (kg-cm)	2.9
6.	Motor Dimensions (mm)	Length: 28 Width: 20 Height: 20 Shaft diameter: 3
7.	Gear Box Dimensions (mm)	Length: 37 Width: 18 Height: 22
8.	Gear Box and Gear material	Plastic
9.	No. of Axial	2
10.	Weight (gm.)	52

Table 10. DC Motor Data Sheet

VII. ASSEMBLE

Fig 23. X- Morphing

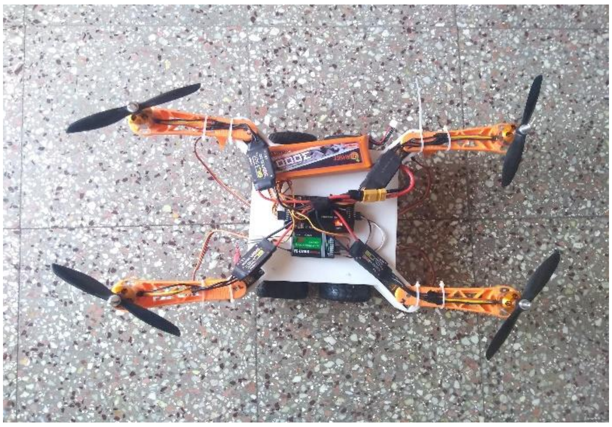

Fig 24. H- Morphing

VIII. STRUCTURAL ANALYSIS

In general, structural analysis is a process which is carried out for a 3-D model to determine its structural strength and deformations formed on the body for certain pressure or forces acting on it. Here, we have carried out the structural analysis for the drone frame for different pressure forces acting over it and determined the resulting deformation and strains graphs of the structure for the applied pressure forces.

In the below, the resultant equivalent elastic strain, equivalent or von-mises stress and total deformation for different pressure forces are been determined using static structural analysis.

A. For Applied Pressure Force *of 50kN*

The Fig.25 represents the equivalent elastic strain formed due to the applied pressure force of 50KN that is been carried out using static structural analysis. For this we obtained a minimum value of equivalent elastic strain of 1.2413e-10m and a maximum value of 1.7512e-6m. Similarly, the Fig.26 represents the equivalent (von-mises) stress obtained due to the same applied force of 50KN obtaining a minimum value of equivalent stress of 130.65Pa and a maximum value of 3.1153e5Pa.

And the Fig.27 represents the total deformation of the drone frame for the applied pressure force of 50KN with resulting maximum deformation value of 1.1669e-7m and a minimum value of 1.2965e-8m.

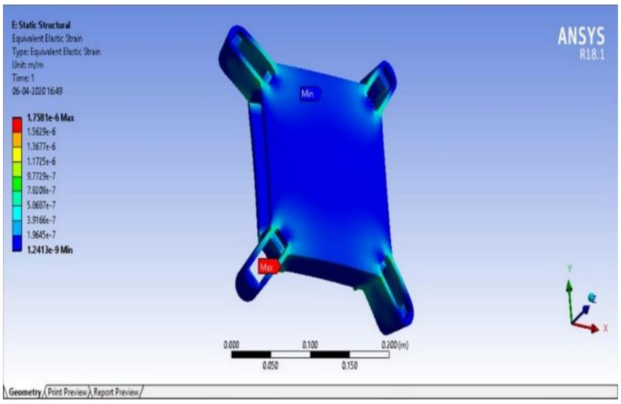

Fig 25. Equivalent elastic strain

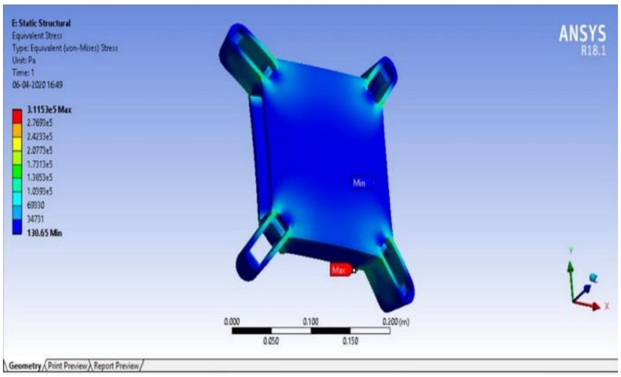

Fig 26. Equivalent (von-mises) stress

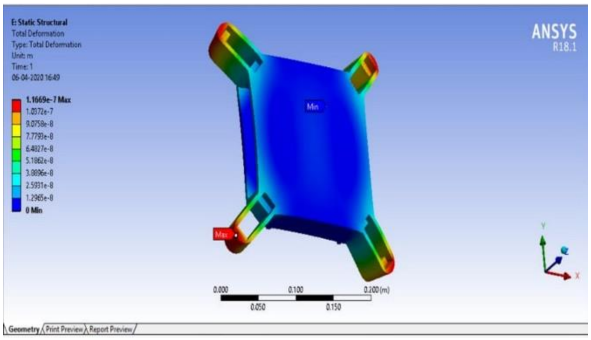

Fig 27. Total Deformation

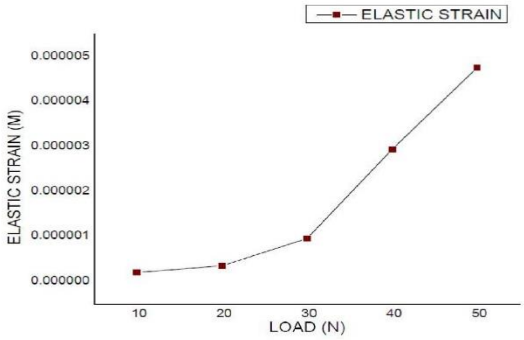

Fig 28. Equivalent elastic strain

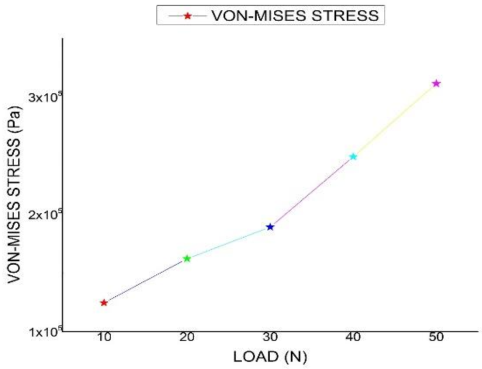

Fig 29. Equivalent (von-mises) stress

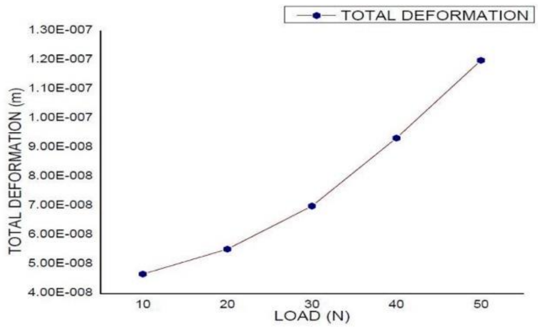

Fig 30. Total Deformation

IX. RESULTS AND DISCUSSIONS

A. Resultant Graphs

In this, Fig.28 represents the relationship between elastic strain and the applied load factor of 0KN to 50KN obtaining a peak value of elastic strain as 0.5e-5m for the applied load of 50KN. Where, Fig.29 shows that the obtained peak value for von-mises stress is 3e5Pa to the applied load of 50KN by establishing the relationship curve for equivalent or von-mises stress and for the load factor N.

Similarly, Fig.30 obtains a resultant graph by establishing the relationship between the total deformation values for each applied load N to the drone frame. This graph results the peak value of deformation as 1.20e-7m to the applied maximum load of 50KN to the drone frame.

X. CONCLUSION

This paper concludes that the flying rover having of estimated thrust of 3200N can lift its estimated load of 1950gm or 1.95kg for an estimated time of 9mins performing the operations such as flight operation, rover operation and servo operation including in the estimated time for the power of 3000mah used in it at 11.1V. From this, the flying rover proves that it can land the rover in both martin and titan's surface and it can assist the rover in its entire operational period in the rover's research mission. This flying rover also has various in-earth applications where both the applications of rover and drone are required in instant such as in building collapses, land slide, surveying in dense forest and other natural calamities.

REFERENCES

[1] Raghavendra Panchal. (May 2013), "Unmanned Aerial Vehicle-Rc Quad copter", International Jthenal of Students Research in Technology and Management Vol. 1(3).

[2] Nilesh Kumar, Sheilza Jain. (2014), "Identification, Modeling and Control of Unmanned Aerial Vehicles", International Jthenal of Advanced science and technology. vol. 67, pp. 01-10.

[3] Shlok Agarwal, Apoorva Mohan, Kamlesh kumar. (2014), "Design, Construction, and Structure Analysis of Twin rotor", International Jthenal of Instrumentation and Control Systems. Vol. 4, pp. 33-42.

[4] Anurag singh Rajpoot, Namrata gadani, Sagar kalathia. (2016), "Development of Arduino based quadcopter", International Advanced Research Jthenal in science, Engineering and Technology. pp. 252-259.

[5] J Olvander, B Lunden, H Gavel, "A Computerized Optimization framework for the Morphological matrix applied to aircraft conceptual design", Computer Aided Designing 41 (3), 187-196, 2009 – Elsevier.

[6] J. (Bob) Balram, Timothy Canham, Cthetney Ducan, 2018, "Mars Helicopter Technology Demonstrator", AIAA Atmospheric Flight Mechanics Conference.

[7] Ralph D. Lorenz, Elizabeth P. Turtle, Jason W. Barnes, John Hopkins, "A Rotorcraft Lander Concept for Scientific Exploration at Titan", APL Technical Digest, Vol. 34, no. 3 (2018).