DESIGN AND DEVELOPMENT OF HOVER BIKE

Sidhanth M Pilankar[1], Yathin Deep M M[1], Dhruva T M[1], Thoshika H[1], Prathik S Jain[2]

[1]UG student, Department of Aeronautical Engineering, Dayananda Sagar College of Engineering, Bangalore, India
[2]Assistant Professor, Department of Aeronautical Engineering, Dayananda Sagar College of Engineering, Bangalore, India

---***---

Abstract - Hover bike is a vehicle which is an improved type of air transport system which is suitable for military applications, rescue operations, and many more. It consists of two or four propellers which are powered by 2 or 4 stroke engine or electric motor. The lift is generated due to the design of the propeller which swipes the air instead of cutting it. Due to the rotation of the propeller downward air pressure is created, hence lift is generated.

In the present work a hover bike chassis is designed using Solidworks 2018 software. The design of the hover bike consists of 4 motors and 4 propellers. The ABS material is selected as the material of the hover bike chassis based on static structural analysis carried out in Ansys 18.1 for a load of 60 N. RaceStar BR 4108 600kv motor is selected based on the maximum thrust it can produce. The hover bike is equipped with four 15 inches propellers, 4 60 amps ESC and DJI NAZA M-Lite as its flight controller.

The fabrication of the hover bike chassis was done using 3D printing process. Additional requirements like battery, receiver and transmitter are also selected as per the application of the hover bike. The prototype hover bike fabricated in the present work has an estimated range of 700m, endurance of 15 mins and it could carry a payload of maximum 0.8 kg.

Key Words: 3D printing, ABS material, Hover bike

1.INTRODUCTION

A hover bike is a combination between a motorcycle and helicopter having the simplicity of a motorcycle and the freedom of a helicopter. It is easy to operate and can be applied to various purposes as it does not need a runaway and is capable of hovering from any terrain [1]. For this reason, the military has shown continued interest in hover vehicles. A hover bike is aerodynamically efficient because the lift generated by the duct can create a thrust force that is higher than the other Vertical and/or short Take-Off and Landing (VTOL) vehicles, which have no duct and therefore no hovering flight mode. The past researchers designed the prototype hover bike using SolidWorks software and the analysis of the prototype hover bike chassis is done using Ansys software [2]. A prototype hover bike with motorcycle technology, an experiment was conducted using electric energy as its power source. The RPM of the motor was recorded using Java Prop software. As a result, the data acquired was the thrust of the propeller with a 4.5-degree pitch while the motor was idling around 1400 RPM [3]. A hover bike prototype which is a one-third scaled model of a full sized manned hoverbike. A trial-and-error method was used to develop a two propellers hoverbike the propellers are electrically driven [4].

The drivetrain for unmanned aerial vehicle is usually recommended by the manufacturer. But the pre-valued set of the drivetrain are not the best possible option for unmanned aerial vehicle. As discussed in this research paper performance of different propeller for different combination of drivetrain is tested and compared [5]. A personal aerial vehicle was modeled and structurally analyzed. Which had to be light weight and strong enough to withstand the stresses of application. In this paper a scaled prototype was designed and fabricated to assist in determining the electrical components necessary and to act as a functioning example of a full-scale vehicle [6].

The hover bikes are been designed from the very beginning to replace conventional helicopters. It is inefficient and dangerous to place complex conventional helicopters in harsh working environments. Commercial hover bikes will be comparatively a cheaper product which will not only take over the existing market but also can open it for a greater number of new customers who could not afford the high cost of conventional helicopter. The fig. 1. depicts a representation of hover bike

Fig. 1. Hover bike

2. WORKING PRINCIPLE

The main principle behind the working of the hover bike is "Newton's 3rd. Law of Motion". As the propeller starts rotating, it generates a massive downdraft of air that blows the hover bike upward. If the lift is greater than the weight, the hover bike climbs; if it's lesser than the weight, the hover bike falls. When the lift and the weight are exactly equal, the hover bike hovers in mid-air. The faster the rotors spin, the greater the lift, and vice versa. The balance of flight can be achieved as like helicopters.

3. HOVER BIKE CHASSIS DESIGN

The present work accommodates 4 motors and 4 propellers which are incorporated in the design of chassis which allowed for mode flight time and more stable flight compared to the design of chassis with 2 propellers and 2 motors. The hover bike chassis is designed in Solidworks 2018. Fig. 2. shows the isometric view of the Hover Bike chassis.

Fig. 2. Isometric view of hover bike

Fig. 3. shows the side view of the hover bike.

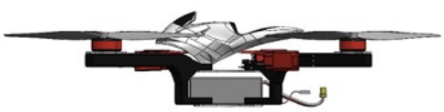

Fig. 3. Side view of hover bike

Fig. 4. shows the front view of the hover bike.

Fig. 4. Front view of hover bike

The design specifications of the hover bike for its length, height and propeller size are tabulated in Table 1.

Table 1 Design specifications of hover bike chassis

Length	Height	Propeller size
700 mm	95 mm	431.8 mm

Fig. 5. shows the dimensions of the hover bike.

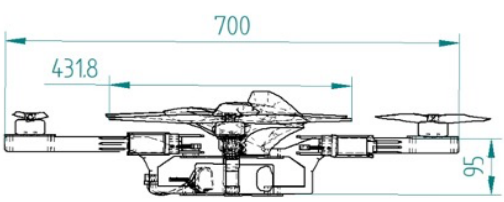

Fig. 5. Dimensions of hover bike

4. MATERIAL SELECTION

For this present work Acrylonitrile Butadiene Styrene (ABS) material is considered based on excellent impact and chemical abrasion resistance, superior stiffness and strength, easily machined, easy to paint and glue, good dimensional stability and the drawback is that the material is brittle. Analysis on the material is conducted to know the load carrying capacity of ABS material. The Table 2 shows the physical property of ABS material.

Table 2 ABS Material Properties

Material	Density (g/cm^3)	Young's Modulus (GPa)	Tensile Strength (Mpa)	Poisson's Ratio
ABS	1.02 – 1.21	1.19 – 2.9	27.6 – 55.2	0.35

A. Static Structural Analysis

Static structural analysis is conducted on the chassis of the hover bike with ABS as the material. It is very essential to perform structural analysis on the chassis of the hover bike. The chassis of the hover bike will be subjected to multiple loads. Since this is the main frame of the hover bike. Structural analysis gives information like total deformation, total stress and total strain. These parameters help during the fabrication of the hover bike chassis. ANSYS 18.1 software was used to perform the analysis.

Meshing

Meshing is a process in which the chassis of the hover bike is divided in thousand or more number of elements. These elements help in defining the geometry of the hover bike chassis. The mesh is done on the surface of the object. The analysis is performed on each element. There are 2 types of mesh structured and unstructured mesh. In structured mesh all the elements are of a fix shape and size but in an unstructured mesh the shape and size of the mesh are not fixed. Since the load acting on the chassis of the hover bike is not very large an unstructured mesh is used. In this project work an autogenerated body fitted fine mesh is applied to the hover bike chassis as shown in Fig. 6. The meshing properties are tabulated in Table 3

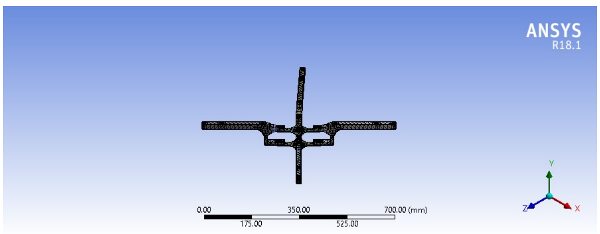

Fig. 6. Meshed hover bike chassis

Table 3 Meshing properties

Mesh type	Number of nodes	Number of elements
Fine mesh	55925	28236

Load Application

Load application is used to determine the behavior of the hover bike chassis. The load application helps determine the maximum load carrying capacity that the chassis can sustain. It also helps to estimate the structural failure of the hover bike chassis. A load of 60 N was applied on the top surface of the hover bike chassis as shown in fig. 7. The bottom plate of the chassis was fixed as shown in fig. 8.

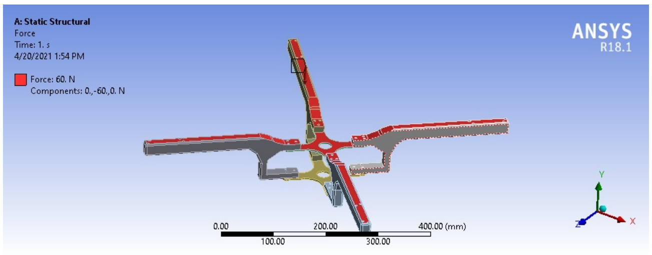

Fig. 7. Application of load on hover bike chassis

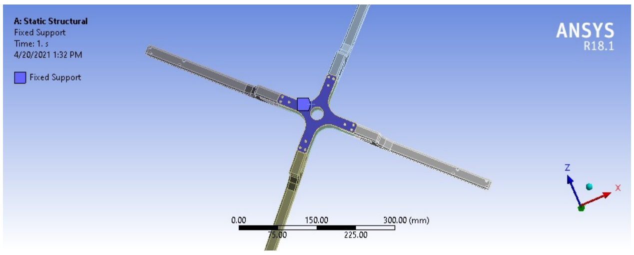

Fig. 8. Fixing the base of hover bike chassis

5. RESULT AND DISCUSSION OF ANALYSIS

The Table 4 shows the result of static structural analysis conducted on the hover bike chassis for 60N.

Table 4 Result of analysis

Material	Total Deformation (mm)	Equivalent Stress (Mpa)	Equivalent Strain (mm/mm)
ABS	0.31405	1.3797	0.00078468

The results shows that ABS undergoes very less total deformation. ABS lies within the factor of safety and can be used for the fabrication of the hover bike chassis. ABS material is the most common material used for 3D printing. ABS material is also capable of sustaining the loads required for the fabrication of the hover bike. Fig. 9. shows a maximum deformation of 0.31405 mm and minimum deformation of 0 mm.

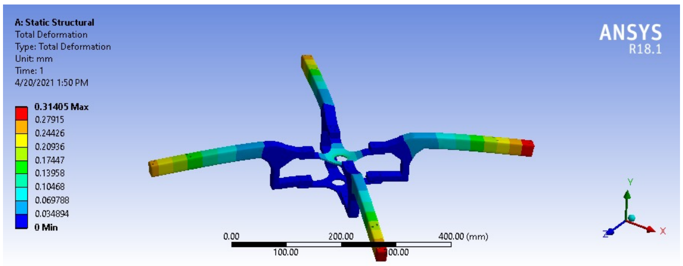

Fig. 9. Total deformation on hover bike chassis

Fig. 10. shows a maximum stress of 1.3797 Mpa and minimum stress of 1.0856x10^-5 Mpa.

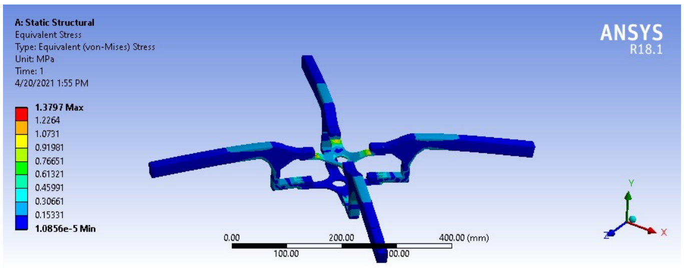

Fig. 10. Equivalent stress on hover bike chassis

Fig. 11. shows a maximum strain of 0.00078468 mm/mm and minimum strain of 6.2481x10^-9 mm/mm.

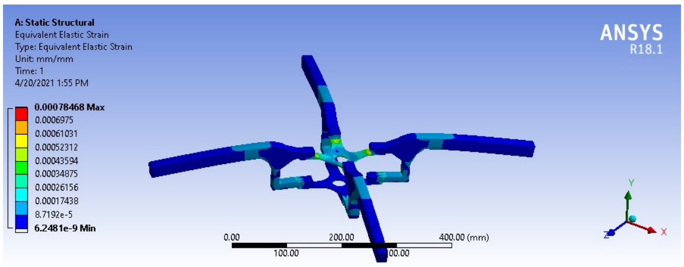

Fig. 11. Equivalent strain on hover bike chassis

6. MOTOR SELECTION

Factors considered for motor selection are high speed operation , quick acceleration, high reliability and ability to generate high thrust. Comparison of the maximum and minimum thrust produced on the following electric motor was conducted:

1. EMAX MT 3110 480 kv
2. EMAX MT 3110 700 kv
3. RaceStar BR 4108 600 kv

Calculation of maximum and minimum thrust produced by each motor

Power (P) = Voltage(V) x Current (I) (1)

$Thrust\ (T) =\ ⟦(\pi/2 \times D\text{^}2 \times \rho \times P\text{^}2)⟧\text{^}(1/3)$ [6] (2)

Here,

T = Thrust in N

D = Diameter of Propeller in m = 0.38m

$\boldsymbol{\rho}$ = Density of air [1.225 kg/$\boldsymbol{m\text{^}3}$]

P = Power in watts

The specification of RaceStar BR 4108 600kv motor is tabulated in Table 5

Table 5 Motor Specification

Motor kv	600 kv
Length	30 mm
Width	36.2 mm
Weight	92 g
Shaft diameter	4 mm
Propeller compatibility	12” – 17”
Voltage	11.1 V – 14.8 V
Current	12 A – 14.2 A

Calculation for minimum and maximum thrust by RaceStar BR 4108 600kv with 15-inch propeller

$Power\ (P) = Voltage\ (V) \times\ Current\ (I)$ (1)

$Thrust\ (T) =\ ⟦(\pi/2 \times D\text{^}2 \times \rho \times P\text{^}2)⟧\text{^}(1/3)$ (2)

$Here, T = Thrust\ in\ N$
$D = Diameter\ of\ Propeller\ in\ m = 0.38\ m$
$\rho = Density\ of\ air\ [1.225\ kg\ /\ m^3]$
$P = Power\ in\ watts$

Case 1: V = 11.1 V and I = 17.2 A
P = 11.1 x 17.2 = 190.92 watts

$$T = [(\pi/2 \times [0.38]^2 \times 1.225 \times [190.92]^2)]^{(1/3)}$$

T = 21.635 N (Minimum thrust generated by 1 motor)

Case 2: V = 14.8 V and I = 23.0 A
P = 14.8 x 23.0 = 509.4 watts

$$T = [(\pi/2 \times [0.38]^2 \times 1.225 \times [509.4]^2)]^{(1/3)}$$

T = 41.621 N (Maximum thrust generated by 1 motor)

The Table 6 shows the comparison of thrust by each motor Therefore it can be concluded that RaceStar Br 4108 600 kv motor is selected since it produces the maximum thrust.

Table 6 Thrust comparison of each motor

Motor	Thrust	Thrust (N) by 1 motor	Thrust (N) by 1 motor
EMAX MT 3110 480 kv	Minimum Thrust	15.734 N	1.60 kg
	Maximum Thrust	29.511 N	3 kg
EMAX MT 3110 700 kv	Minimum Thrust	17.019 N	1.7 kg
	Maximum Thrust	23.066 N	2.35 kg
RaceStar BR 4108 600 kv	Minimum Thrust	21.635 N	2.2 kg
	Maximum Thrust	41.621 N	4.24 kg

7. SELECTION OF PROPELLER AND ELECTRONIC DEVICES

A. Selection of Propeller

The propeller are the devices used to generate lift. When the propellers rotate at high speeds a lift force is generated. Number of Propeller Blades selected are 4 Four. The Material of the propeller is carbon nylon. The size of the propeller is 15-inch x 5 inch (15 inches long with pitch of 5 inches). Propeller is selected based on the compatibility of the motor. The GemFan 15" propeller is depicted in fig. 12.

Fig. 12. GemFan 15 inches propeller

B. Selection of Battery

LIPO stands for lithium-ion polymer battery or Lithium polymer battery. This battery is a rechargeable battery. They are used in applications where weight is a critical feature, like mobile devices and radio-controlled drones and aircraft. The battery is selected based on: battery capacity, discharge rate, battery size, battery voltage and the application of the battery.

Battery selected is 3300 mah 90c 6s LiPo. This Battery is selected due to its light weight, better discharge rate and the battery capacity. The battery is shown in fig. 13.

Fig. 13. 3300 mah 90c 6s LiPo battery

C. Selection of Electronic Speed Controller

Electronic Speed Controller (ESC) is a device which receives the throttle signals from the flight controller and run the brushless motor at its desired speed. There are number of factors that are considered while selecting the ESC and they are as, current rating, input voltage rating, weight and size. Therefore 60 amps ESC is selected. The Skywalker 60 amps ESC is shown in fig. 14.

Fig. 14. Skywalker 60 amps ESC

D. Selection of Transmitter

Radio transmitter, the electronic communication device that makes use of radio signals to transmit instructions wirelessly using a predefined radio frequency over to the radio receiver. This is connected to the flight controller of the hover bike which is being remotely controlled. This is used to increase/decrease the altitude, increase/decrease throttle and to maneuver the hover bike. These are the factors considered for selection of the transmitter. Frequency, number of channels, range, cost, compatibility with the Flight Controller and battery life. Flysky FS-i6S 2.4GHz 10CH AFHDS 2A RC Transmitter With FS-iA10B 10CH Receiver is selected for the Hover Bike application. The fig. 15. shows the Flysky FS-i6s transmitter with its receiver.

Fig. 15. Flysky FS-i6S transmitter and receiver

E. Selection of Flight Controller

A flight controller is the most essential component of the hover bike. It sends input signals to each motor which modulates the RPM. A command sent from the transmitter is processed by the flight controller, which regulates the maneuvering of the hover bike accordingly. GPS is utilized for fail-safe purposes auto-pilot. In this project work DJI NAZA-M Lite was selected as the flight controller based on compatibility with the transmitter, features, cost and its application. DJI Naza-M Lite Features are:

All-in-one design, advanced attitude stabilize algorithm, multiple flight control mode/intelligent switching, GPS module available/accurate position hold, failsafe mode, low voltage protection, motor arm and motor dis-arm, supported multi-rotor types, built-in gimbal stabilization function and remote adjustment. The fig. 16. shows the DJI NAZA-M Lite flight controller with the GPS connecter.

Fig. 16. DJI NAZA M-Lite flight controller with GPS

Table 7 tabulates the devices used and their specification.

Table 7 Devices and their specification

Sl. No.	Parts	Quantity	Specification
1.	Brushless DC motor	4	RaceStar BR 4108 600 kv
2.	Propeller	4	15*5 inches GemFan propeller
3.	Flight controller	1	DJI NAZA M-Lite
4.	Battery	1	3300 mah 90c 6s LiPo
5.	ESC	4	60 amps Skywalker ESC
6.	Transmitter	1	Flysky FS-i6s 10 channel

8. FABRICATION & ASSEMBLY OF HOVER BIKE

A. Fabrication of Hover Bike Chassis

In this project work 3D printing method was used to fabricate the chassis of the hover bike using ABS as the material of the chassis. 3D printing is a process of manufacturing three dimensional solid objects from a computer aided design. The fabrication of a 3D printed article is accomplished using additive processes. In an additive process an object is fabricated by laying down continuous layers of material until the object is produced. Each of these layers can be seen as a thinly sliced cross-section of the object. 3D printing enables to fabricate complex shapes using less material compared to the traditional manufacturing methods. The benefits of 3D printing are as follows.

- Customization - the product to be 3D printed can be of any shape and size
- Complexity - any shape can be 3D printed
- Tool-less - only a 3D printer is requiring to fabricate the product additional tools are not required
- Environmentally Friendly - 3D printing is an energy-efficient manufacturing process

The fig. 17 shows the process of 3D printing for fabrication of the hover bike chassis and other components

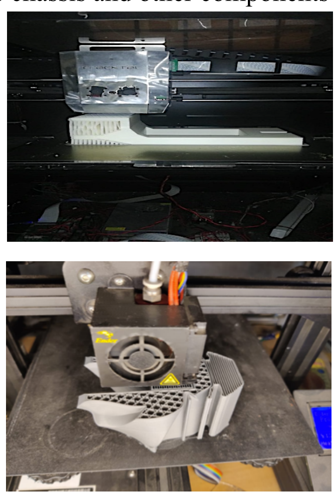

Fig. 17. 3D printing of hover bike chassis

The fig. 18 shows the final 3D printed arms of the hover bike chassis.

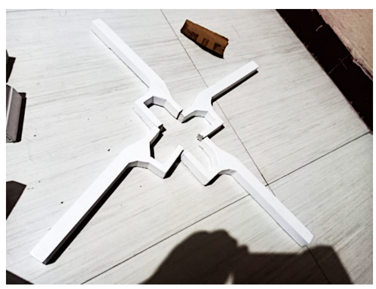

Fig. 18. Final 3D printed arms of hover bike chassis

The fig. 19. shows the final 3D printed bike structure to mount on the hover bike chassis.

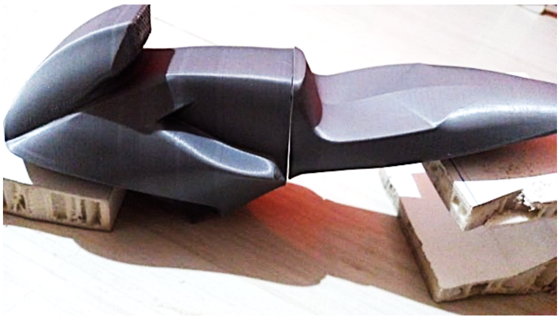

Fig. 19. Final 3D printed bike structure for the hover bike

The fig. 20. shows the final 3D printed base which is used to mount the motor on to the arm of the hover bike

Fig. 20. Final 3D printed motor mounts

B. Assembly of Hover Bike

The process of compiling all the components to form a completed product is known as assembly. The arms of the hover bike are attached using screws and adhesive to the center plate. The motor mounts are attached to the arms using adhesives. The motors, flight controller, propellers and the receiver are attached using fasteners. The ESC is attached using zip ties. The fig. 21. shows the final assembled hover bike.

Fig. 21. Final assembled hover bike

9. PROGRAMING OF FLIGHT CONTROLLER

A. Wiring of Electronics

The wiring/circuit diagrams is used to depict the physical arrangement of the wires and other components. This diagram assists in understanding the layout and wiring of all the components. The wiring diagram of all the electronics and the avionic components is shown in fig. 22. The fight controller must be mounted on the center of the hover bike chassis. The arrow printed on the flight controller must face towards the front/nose of the hover bike chassis.

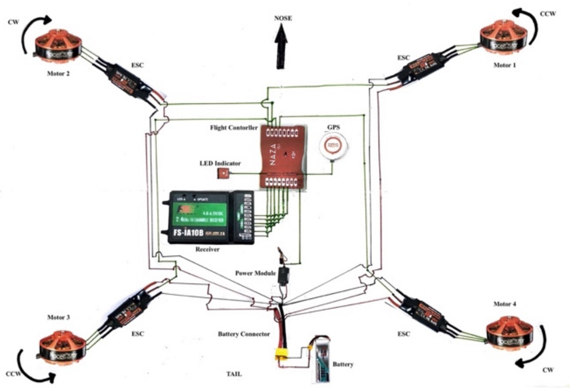

Fig. 22. Wiring diagram for hover bike electronics

B. Programming of the Flight Controller

1. Install the DJI NAZA assistant and driver on a windows computer.
2. Connect the battery of the hover bike and turn ON the hover bike.
3. Connect the USB wire to the computer on one end and the other end to the LED indicator.
4. Open the DJI NAZA assistant and select the "basic" menu and select "aircraft" tab. Select "Quad-Rotor X" as the type of motor configuration.
5. Select the "mounting" tab under the "basic" menu and enter the values of X,Y,Z in cm for the position of the GPS module from the center point of the flight controller.
6. Select the "RC" tab under the "basic" menu. Under the RC tab select "receiver type" as "traditional". Under "command sticks calibration" click start calibration and rotate the control sticks on the transmitter in clockwise direction. The control sticks must be pushed to their extreme position. Under "control mode switch" set the 3-way switch on the transmitter to different flight modes. Set mode 1 as GPS, mode 2 as failsafe and mode 3 as altitude holding mode.
7. Under the "advanced" menu and select " motor" tab. Set "motor idle speed" to "RECOMMENDED" and "cut off type" to "intelligent".
8. Select "F/S" tab and select "go-home and landing". This feature enables the hover bike to go the home point and to gain/drop altitude to 20 m and land the hover bike safely.
9. Select "voltage" tab and turn ON the "protection switch". Then under battery tab input the measured voltage of the battery and select the battery type to "6s" and press the calibrate button.
10. This completes the procedure to program the flight controller.

C. Set up of GPS

1. Connect the battery of the hover bike and turn ON the hover bike.
2. Turn on the transmitter and connect it to the hover bike. The LED indicator will flash red color. Shuffle the mode switch on the transmitter until the LED

turns to solid orange color.
3. Once the LED turns to solid orange color rotate the hover bike in 360° about the vertical axis. After one rotation the LED will turn to solid green color.
4. Point the nose of the hover bike towards the ground and the tail of the hover bike towards the sky. Rotate the hover bike in 360° about the vertical axis. On completing one rotation the LED will flash orange light.
5. This completes the procedure of setting up the GPS module of the hover bike.

10. FLIGHT TESTING

1. Check if all the electronic components are attached to the hover bike chassis properly.
2. Check if the propellers are mounted in the right orientation and are attached firmly.
3. Connect the battery of the hover bike and turn ON the hover bike.
4. Turn ON the transmitter. Shuffle the mode switch till the light on the LED indicator turns to solid orange color. After few seconds the LED indicator will flash green light. This indicates that hover bike is setup properly.
5. Arm the hover bike by getting both the control sticks on the transmitter closer to each other. These steps turn ON the motors of the hover bike.
6. Set the throttle stick to 50% throttle. Once the motors run at 50% throttle a lift will be generated and the hover bike lifts above the ground.
7. Once the hover bike is lifted above the ground different maneuver are performed using both the control sticks of the transmitter.
8. In case of loss of signal of the transmitter, low voltage of the battery or turbulent flying conditions the hover bike can be automatically landed safely using the failsafe mode. This feature enables the hover bike to go the home point and to gain/drop altitude to 20 m and land the hover bike safely.

Fig. 23. shows the hover bike preparing for take-off. Fig. 24. shows hover bike hovering above the ground. Fig. 25. shows hover bike performing maneuver and fig. 26. shows the hover bike preparing for landing.

Fig. 23. Hover bike preparing for take-off

Fig. 26. Hover bike preparing for landing

The fig. 27 shows the payload box attached to the hover bike. The fig. 28 shows the hover bike performing maneuver with the payload box.

Fig. 27. Hover bike with payload box

Fig. 28. Hover bike maneuvering with payload box

11. CONCLUSION

A 3D model of the hover bike chassis was designed using Solidworks 2018 software. ABS undergoes very less total deformation and is best suited for 3D printing of the chassis. On comparing the results, it is observed that RaceStar BR 4108 600 kv produces more thrust compared to EMAX MT 3110 480 kv and EMAX MT 3110 700 kv. Therefore RaceStar BR 4108 600 kv is selected as the motor for the hover bike. GemFan 15” x 5” propeller was selected based on the motor compatibility and design of the hover bike. Skywalker 60 amps ESC, 3300 mah LiPo battery, DJI NAZA-M Lite flight controller and Flysky Fs-i6S transmitter was selected for the design of the hover bike. 3D printing process is used for the fabrication of hover bike chassis and other components. The assembly process of the fabricated hover bike was completed along with the wiring of the electronic components. The setting up of the GPS module is completed along with the programming of the flight controller to ensure a safe flight. The hover bike could successfully achieve lift and stability during flight. The hover bike has a range of 700 m which lies within the range of radio transmitter and receiver. The payload carrying capacity of the present hover bike was upto 0.8 kg with endurance time of 15 mins. The fabricated hover bike is suitable for military surveillance and agricultural purpose.

REFERENCES

1. Abhay Naware, " Study of Construction and Working of Hoverbike", IRJET Vol. 5, Issue 5, May 2018, ISSN: 2395-0056 (PN: 4287 – 4293)
2. Ninad R. Patil, Ashish A. Ramugade, "Design Analysis of Hoverbike Prototype" IJSRD Vol. 5, Issue 2, 2017 ISSN: 2321-0613 (PN: 1061-1065)
3. B. Lokesh, Chava Navyasree, Karthik D C, Momon Singha, Dr. E. Madhusudhan, "Designing and Development of Prototype Hover Bike", IJIRSET, Vol. 4, Issue 5, 2015, ISSN: 2319 – 8753. (PN: 3549-3555)
4. Swaraj D. Lewis, Noel D. Shiri, Vikesh K., Sonali C. Olivera, Vishram Konde, Prakash C. Dsouza, "Fabrication and Testing of Scaled Prototype of Hoverbike", Journal of Mechanical Engineering and Automation 2016, 6(5A) (PN:71-74)
5. Parvathy Rajendran, Howard Smith, Khairul Yahaya, Nurul Mazlan, "Electric Propulsion System Sizing for Small Solar-Powered Electric Unmanned Aerial Vehicle", International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11, Number 18 (2016) (PN: 9419-9423)
6. Lepine, Matthew David. "Design of a Personal Aerial Vehicle." PhD diss., WORCESTER POLYTECHNIC INSTITUTE, 2017.