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Micro-Air Vehicle for Surveillance

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ABSTRACT: *This paper includes a design of MAV (Micro Aerial Vehicle) named, 'SARAS-THE CRAZY-M' which can be used for surveillance. With technologies for MAVs improving at a rapid rate, the interest in MAVs has grown significantly in recent years. It is of very small area having wing span about 450 mm with a cruise speed of 17 m/s flying with an endurance of about 30 min having attachable module structure. This report include a preliminary design process and complete analysis over a designed model by using design software such as CATIA,XFLR5& ANSYS along with analytical calculation. The objective for designing such MAV is to fulfill the basic requirements for MAV for military missions relate to surveillance operations due to their small size and video transmission capabilities. This motto is accomplished by incorporating autopilot system in our design. This paper also includes implementation of Autopilot system on small MAV. This MAV can be carry anywhere with easy handling and can be assembled and disassembled within 30 sec.*

Keywords: *MAV, SARAS-THE CRAZY M, Autopilot, Flight dynamics, CFD Analysis*

I. INTRODUCTION

"Micro aerial vehicles are very small, having the aspect ratio of 1 to 1.5, and operate at relatively low Reynolds numbers [1].There are three types of MAV recognized today are fixed wing, flapping wing (ornithopter) and rotary wing. The current concept suggests that reconnaissance MAVs need to range out to possibly 10 km, remain aloft for up to an hour, reach speeds of up to 17 m/s, and be capable of real time day/night imagery. In these instances, the MAV would relocate to a suitable vantage point and serve as a fixed, unattended surface sensor with capabilities ranging from imagery to seismic detection.

With technologies for MAVs improving at a rapid rate, the interest in MAVs has grown significantly in recent years. The potential customers for MAV are research companies such as Honeywell, M Avionics GmbH and General Atomics, Defence and Police Forces. They are looking for technology that will increase individual soldier safety and situational awareness on a platoon level by providing urban and over the hill reconnaissance, and communication protocol [2].

II. CONCEPTUAL DESIGN AND ANALYSIS

1	• **Specification** • **Airfoil Selection**
2	• **Performance Analysis** • **Aerodynamic and Stability Analysis**
3	• **Component Selection** • **Flight Test**

Specification

The basic requirements for our MAV 'Crazy M' are to fulfil the military missions. Since, the main driving force behind all the research and development effort is based on the mission to build the MAV which should have the following characteristics:
High image resolution 2) Lightweight 3) Expandable or easy to repair 4) Rapid and secure electronic connectivity

Mission Profile

The mission profile for Crazy M is given below:
1) Take-off 2) Climb 3) Loiter for up to 20MIN 4) Land within 100 meters of take-off point

Crazy-M Configurations:

Table 1: Crazy M design configuration

Wing	450mm
Weight	250 g

Velocity	17 m/s
A.R.	1.5
Chord	300 mm
Endurance	30 min

Airfoil Selection

The importance of selecting an appropriate wing airfoil for MAV is to improve the performance and stability characteristics at low Reynolds number. Crazy-M wing design has flying wing concept which requires reflex airfoil for better stability. According to total weight requirement at cruise, we have selected ESA 40 (Fig 1) as airfoil for wing. Crazy-M fly in low Reynolds numbers usually in the range below Reynolds no of 6,00,000. The selected software to do the analysis is Xfoil, as it was designed especially for low Reynolds number and proved to be more efficient and reliable for airfoil analysis. First we gathered a data base of suitable airfoils for cruise flight regime and analyse it.

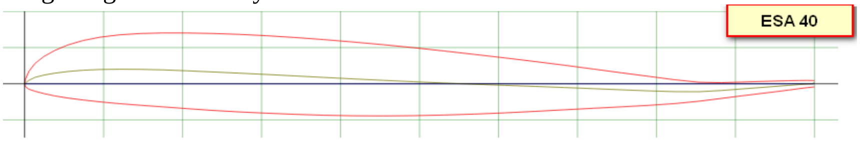


Fig 1: selected Airfoil ESA 40

Performance Calculation

Hereby, we will show the calculation of lift and drag coefficient required at design cruise velocity 17m/s.

Lift Coefficient

$L=\frac{1}{2}\rho v^2 s\, C_L$ and $L=W$,

$$\mathbf{0.250 \times 9.81 = \frac{1}{2} \times 1.05 \times 17^2 \times 0.45 \times 0.3 \times C_L}$$

$\boldsymbol{C_L(airfoil) = 0.119}$, and $\boldsymbol{C_L(wing) = 0.90 * 0.119 = 0.107}$

The require lift coefficient produced by airfoil at 0 deg. angle of attack is 0.119. Obviously, the lift coefficient requirement of wing is lower than airfoil due to 3-dimentional effect.

Drag Coefficient

$C_{D(wing)} = C_{DO} + \frac{\mathbf{C_L^2\ (at\ 2\ deg\ incidence)}}{\mathbf{\pi eAR}}$, $C_D = 0.04 + \frac{\mathbf{0.04^2}}{\boldsymbol{\pi \times 0.8 \times 1.5}}$, CD (at 2 deg. incidence) =0.0404

Min drag is required to have better glide and min power to propeller the MAV for longer time. If we build lighter MAV's, it will produce less drag as both the quantities are directly proportional to each other.

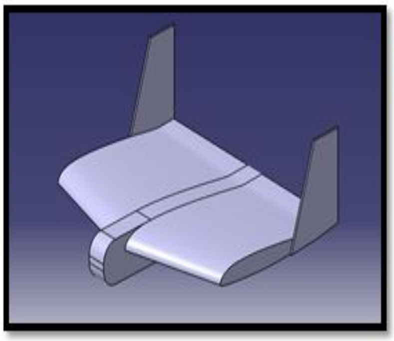
Power Calculation:

$$\boldsymbol{P_R = \frac{W}{CL/CD} \times V_\infty,\ P_R = \frac{0.250 \times 9.81}{0.107/0.0404} \times 17,\quad P_R = 15.74\ Nm/s}$$

This is the power require during the cruise flight. While selecting the power plant (i.e. selecting Motor), we have to consider power greater than power obtained from above calculation.

Aerodynamic analysis using CFD

In this project, we have performed the CFD analysis on CRAZY MAV using ANSYS CFX software. Firstly, we have designed the model in CATIA as shown in Fig 2. The mesh has been generated using meshing tool ICEM CFD in Ansys. The pre-processing and solving is performed in CFX 14. The CL and CM plots obtained from CFD analysis are shown in Fig 3. Fig 3 shows the negative slope of CM curve which mean that aircraft is stable in longitudinal direction.



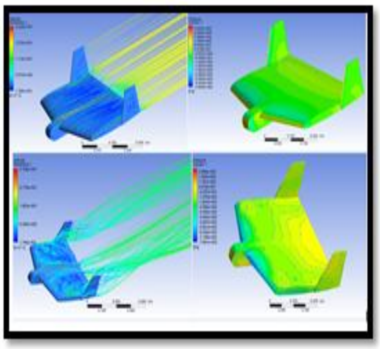


Fig 2: CATIA modelling and CFD analysis for Crazy-M

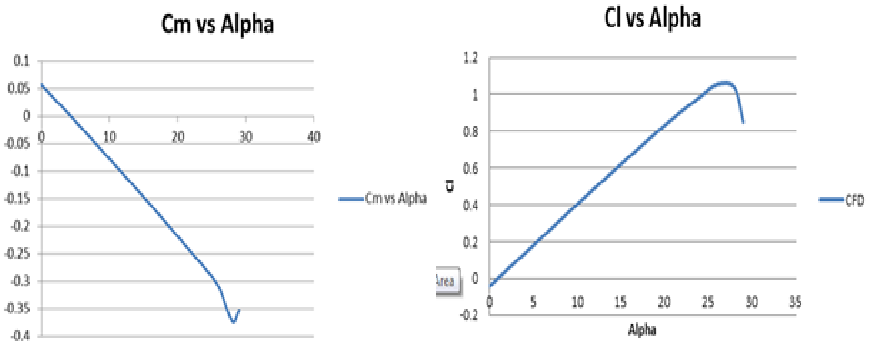


Fig 3: C_M and C_L curve from CFD analysis in ANSYS CFX

Stability analysis using XFLR 5

Stability calculation is performed using XFLR5 software [3]which is based on lifting line theory. Longitudinal and lateral stability is calculated using XFLR5. The Roots for longitudinal and lateral modes are specified below:

Longitudinal mode: Short period oscillation:-28.1013±i4.08163, Phugoid:-0.01179±i0.163179

Lateral Mode:Pure Roll: -5.2097, Spiral: 0.012116, Dutch roll: -2.54819±i1.90826

This analysis represents that Crazy-M has a stable flight in both longitudinal and lateral direction. The Eigen value placement on the complex plane and dynamic simulation for the model is shown in figure. The dynamic simulations for velocity (v), Roll rate (p), yaw rate (r), and roll angle (phi) shows the damping tendency in time.

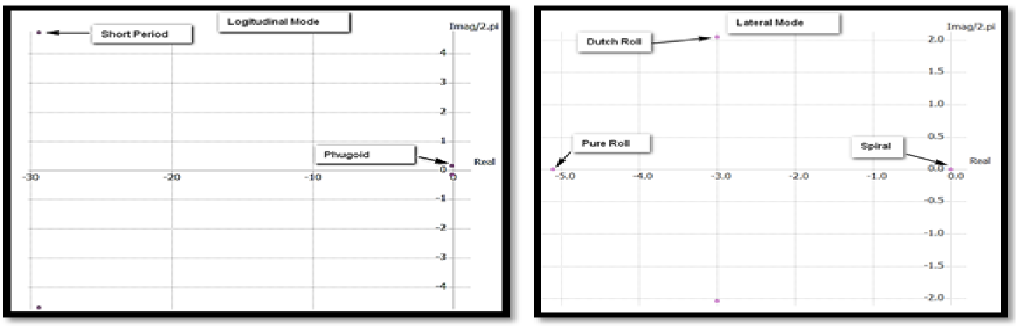


Fig 4: Longitudinal and lateral Modes of Crazy M

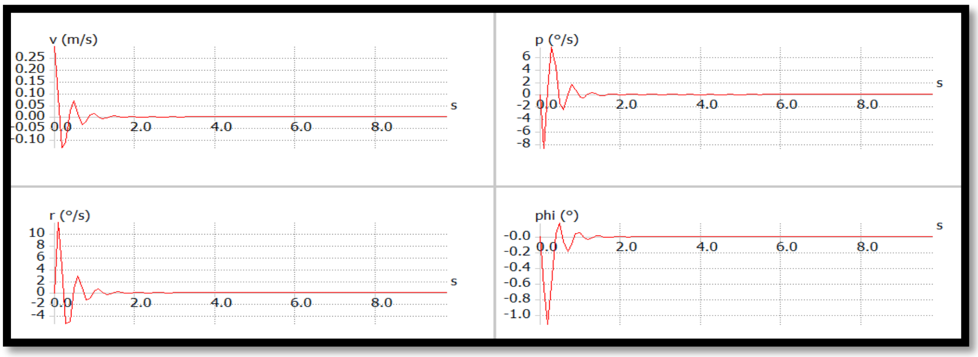


Fig 5: Dynamic Simulation of Crazy-M

Component Selection:

In this section, Power plant and autopilot are selected according to power requirement and controllability in flight respectively. The selected components for the MAV are shown in the Table below:

Component	Configuration

Motor: Turning 2730-3000	Power: 58 Nm/s , Current: 8 to 11 A
ESC: Plush 12A-E Brushless Speed Controller	Current: 12A
Battery: 500mAh Turning	2 cell, 7.4 v, 20C constant discharge
Servos: Turning tg9e Servo	Torque: 1.5kg/cm
Autopilot: Ardupilot (Arduino Mega platform)	3 axis gyros, 3 axis accelerometer, 5 to 10 Hz GPS

Table 2: Components of Crazy-M

Autopilot:

The main feature of our MAV is autopilot system based on pro-quality IMU autopilot board. Depending on which software you choose, it can fly fixed-wing aircraft, multicopters, and helicopters. It handles both autonomous stabilization and GPS navigation and allows fully scripted waypoint missions and camera control. Ardupilot(Fig 6) includes the following hardware:

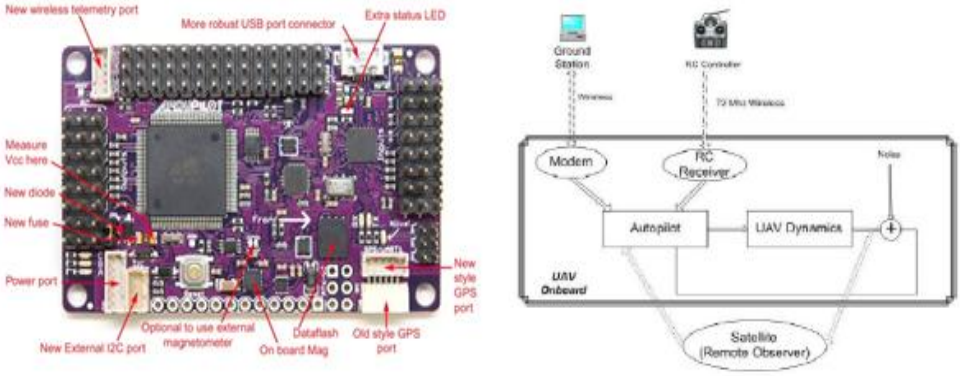


Fig 6: Ardupilot Board and telemetry system during flight

Gyroscope: measures pitch rate (q), yaw rate (r), roll rate (p), 2) Accelerometer: measures load factor or acceleration in x,y, and z direction (Nx, Ny, and Nz), 3) GPS module: measures position in latitude and longitude.

Flight test:

In flight test, different phase of flight such as take-off, climb, cruise, and Loiter have been performed. The data acquired from the MAV is collected on the ground station using ardupilot GUI is shown in figure

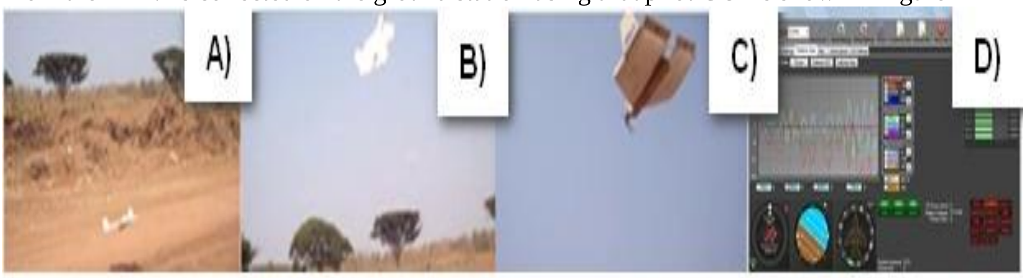


Fig 7: Flight test A) Take-off B) Climb C) Cruise with ALTHOLD D) GUI showing real time data from Sensors

III. CONCLUSION

The required configuration for our CRAZY-M MAV was achieved successfully. It has shown the behaviour which is highly stable and sustainable in air during flight, instead of its light weight. We have performed the autopilot locks such as ALTHOLD and position hold during the flight phase. This MAV can be better used for surveillance purpose with the of high-definition camera attached to control system.

IV. ACKNOWLEDGEMENTS

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