IUT MAV2013, Part II: Flight test results

*Mohammadreza Radmanesh (Rezaradmanesh90@hotmail.com), *Iman Samani* (*imansamani2020@yahoo.com*), Mostafa Hassanalian (Mostafa.Alian@gmail.com), Omid Nematollahi (O.Nematollahi@gmail.com), *Ahmad Sedaghat* (*sedaghat@cc.iut.ac.ir*), and Mahdi Niliahmadabadi (m.nili@cc.iut.ac.ir)

Department of Mechanical Engineering, Isfahan University of Technology,
Isfahan 84156-83111, I.R. of Iran

ABSTRACT

As the final stage, the IUT MAV2013 was tested in flight. The main goal of was to assess the manoeuvrability of the MAV through some flight tests programmes. For tracking this goal and showing efficiency of the procedure a control system was installed on MAV and data of flight was collected. The main purpose of using a control system during the flight is to stabilize the aircraft after being disturbed from its wing-level equilibrium flight attitude. In this study by using a Gyro sensor and the control circuit, the longitudinal angle of MAV has been measured.
The main reason of measuring the longitudinal angle is to find out the efficiency of the proposed cycle. The Gyro sensor has been normally placed on the wing with the Angle of 4 degrees and this angle has been considered as the Level Angle. Sensors data has been saved every 0.5 second and plotted for each Flight test. Flight tests include hand lunch, increasing altitude, cruse flying and landing.

Keywords: Micro Aerial Vehicle (MAV); Aerofoil flows, Flight tests, Tailless wing and body.

1. INTRODUCTION

The first flight was performed by Wright brothers in 1903 [1]. Corming [2] explained conceptual design of ultrasound and infrasound passenger air vehicles. The order he used in his air vehicle design was considered as one of the first design documents. Having introduced the amphibious air vehicles, Wood clarified their basics which were the preliminary discussion in this field [3]. Stinton [4] described the basics of airscrews and their condition. Nikolai [5] introduced mass estimation in conceptual design of air combats and ultrasound air vehicles. He is one of the introducers of the economic effects on the air vehicle design. Roskam [6] suggested a new design procedure in which various variables including aerodynamic, foil, flight dynamic and run force were considered separately. Whittford [7] analyzed the different design procedures of air combats. He evaluated effective variables in air combat performance from the First World War. Torenbeek [8] investigated the experimental relations of design and suggested a method to calculate the air vehicle mass. Raymer [9] proposed a method to increase the air vehicle maneuverability and decrease the drag force in ultrasound flight using the computational fluid dynamic and finite elements. Anderson [10] evaluated the relations between the air vehicles design and their performance Anderson [10] evaluated the relations between the air vehicles design and their performance.

2. CONSTRAINT ANALYSIS FOR MAV

Forces on a flying MAV including lift, drag, thrust and weight. In this MAV drag and thrust forces are in same lines, with the opposite direction and in the same direction with speed. In Figure 1 the forces on a MAV are shown.

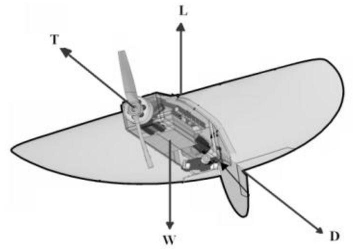

Fig. 1. Forces on MAV

With writing the energy balance equation for MAV the constraint equation of MAV would be gained.

$$\frac{T_{SL}}{W_{TO}}=\frac{\beta}{\alpha}\left\{\frac{qs}{\beta W_{TO}}\left[K_1\left(\frac{n\beta}{q}\frac{W_{TO}}{S}\right)^2+K_2\left(\frac{n\beta}{q}\frac{W_{TO}}{S}\right)+C_{D0}\right]+\frac{1}{V}\frac{d}{dt}\left(h+\frac{V^2}{2g}\right)\right\} \tag{1}$$

The above equation mentioned correlation between aircraft's wing loading and Thrust loading. In continue defined for 6 flight modes in mission. For a MAV with electric motor, simulation is in form of Thrust loading equation (T_{SL} /W_{TO}) on the wing loading (W_{TO} /S). In the following correlation R_C=Radius around, dh/dt = Ascent velocity, dv/dt= Acceleration, C_{Lmax}= Maximum lift coefficient.

State 1: Constant altitude/speed cruise, P_S=0

$$\frac{T_{SL}}{W}=\frac{1}{\alpha}\left[\left(\frac{1}{\pi eAR}\right)\frac{2}{\rho V^2}\left(\frac{W}{S}\right)+\frac{C_{DO}}{\frac{2}{\rho V^2}\left(\frac{W}{S}\right)}\right] \tag{2}$$

State 2: Constant speed climb, P_S= dh/dt

$$\frac{T_{SL}}{W}=\frac{1}{\alpha}\left[\left(\frac{1}{\pi eAR}\right)\frac{1}{q}\left(\frac{W}{S}\right)+\frac{C_{DO}}{\frac{1}{q}\left(\frac{W}{S}\right)}+\frac{1}{V}\frac{dh}{dt}\right] \tag{3}$$

State 3: Constant altitude/speed turn, P_S = 0

$$\frac{T_{SL}}{W}=\frac{1}{\alpha}\left[\frac{1}{\pi eAR}\left(1+\left(\frac{V^2}{gR_C}\right)\right)\frac{2}{\rho V^2}\left(\frac{W}{S}\right)+\frac{C_{DO}}{\frac{2}{\rho V^2}\left(\frac{W}{S}\right)}\right] \tag{4}$$

State 4: Horizontal acceleration, P_S = V/g dV/dt

$$\frac{T_{SL}}{W}=\frac{\beta}{\alpha}\left[\frac{1}{\pi eAR}\frac{1}{q}\left(\frac{W}{S}\right)+\frac{C_{DO}}{\frac{1}{q}\left(\frac{W}{S}\right)}+\frac{1}{g}\frac{dV}{dt}\right] \tag{5}$$

State 5: Accelerated climb, P_S = dh/dt + V dV/gdt

$$\frac{T_{SL}}{W}=\frac{1}{\alpha}\left\{\frac{qs}{W}\left[\frac{1}{\pi eAR}\left(\frac{1}{q}\frac{W}{S}\right)^2+C_{D0}\right]+\frac{1}{V}\frac{d}{dt}\left(h+\frac{V^2}{2g}\right)\right\} \quad (6)$$

State 6: Hand launching

$$\frac{T_{SL}}{W}=\frac{1}{\alpha}\left[\frac{1}{\pi eAR}C_{L\max}+\frac{C_{Do}}{C_{L\max}}\right] \quad (7)$$

With constraint analysis performance and plotting relevant graphs, ultimately solution space to MAV design point is determined. In Figure 2 the graph presented is a performed constraint analysis on MAV is shown [11].

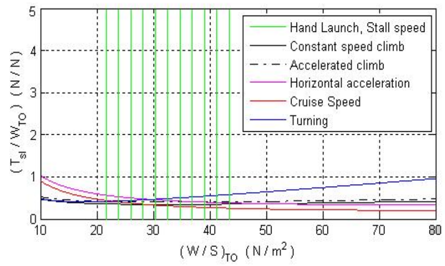

Fig .2. Constraint analyses for the IUT MAV2013

Performing the analysis and estimating the trust force, the wing area can be calculated according the following relations.

$$\frac{T_{SL}}{W_{TO}}=0.65\ \ (m^2) \quad (8)$$

$$\text{Pay Load}=\frac{W_{TO}}{S}=35\ \ (N/m^2) \quad (9)$$

To evaluate different plan-forms, some standard plan-forms such as Rectangular, Zimmerman, Inverse Zimmerman, Elliptical, Delta and Morphing are investigated to be considered as our plan-form. After considering the volume coefficient of the vertical tail 0.6, defining the tail place, the exact location of the elevators and aria of them, the final stage of designing had been done. Therefore, we can determine the best airfoil according to performance using flight test. The above stages are classified in Fig. 13 briefly. It is worthwhile nothing that in the most cases flight test is recommended and wind tunnel test is avoided because there are more differences between wing tunnel test used for low Reynolds numbers and flight test used in turbulent and instable flows according to Watkins researches [12]. The result of this designing and ready for flight test is shown in Figure 3.

Fig.3. Ready to fly tests MAV

3. EXPERIMENTAL FLYING TESTS

Flight tests include hand lunch, increasing altitude, cruse flying and landing. Flight Tests has been done in the condition of, Wind Velocity= 2m/s, Humidity= 5%, and Height from the sea=1400m. Flight Test No. 1: In this Test the designed MAV has done a nose up flight, which means the MAV has not been stabilized longitudinally. The Longitudinal behaviour of MAV has shown in Figure 4. Flight Test No.2: In this test The MAV has shown the behavior as flight test No.1 and it has been plotted in Figure 5.

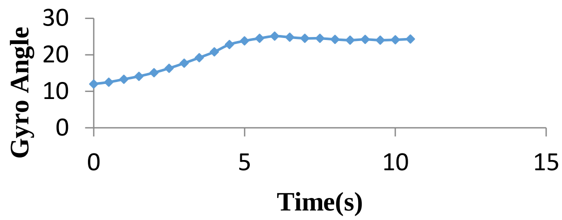

Fig. 4. Flight Test No. 1

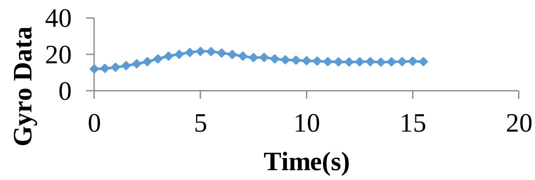

Fig. 5. Flight Test No. 2

4. CONCLUSION

The methodology proposed in this research for flight tests of IUT MAV2013. The main reason that the longitudinal behavior of MAV is Nose Up is that the static margin that has been was entered as an input to the cycle was inappropriate. In these Flight tests the MAV data has been gained just for the cruise mode. In these flight tests the MAV has performed the level flight perfectly.

ACKNOWLEDGEMENT

This Investigation is sponsored by Isfahan University of Technology and KhodranVafa Co. which is greatly acknowledged.

REFERENCES

[1] **Liebeck, R.H.** Design of the blended wing body subsonic transport. *Journal of Aircraft*, 2004, **41**(1), 10-25.

[2] **Corning, G.** Supersonic and subsonic airplane design. (Edwards Bros., Ann Arbor, Mich., 1953).

[3] **Wood, K.D.** *Aerospace Vehicle Design, Volume I, Aircraft Design*. (Johnson Publishing, Boulder, Colorado, 1968).

[4] **Stinton, D.** *The anatomy of the airplane*. (American Institute of Aeronautics and Astronautics, 1998).

[5] **Nicolai, L.M.** *Fundamentals of aircraft design*. (Nicolai : distributed by School of Engineering, University of Dayton, 1975).

[6] **Roskam, J.** *Airplane Design: Preliminary configuration design and integration of the propulsion system*. (Design Analysis & Research, 1985).

[7] **Whitford, R.** *Design for air combat*. (Jane's, 1987).

[8] **Torenbeek, E.** *Synthesis of Subsonic Airplane Design: An Introduction to the Preliminary Design of Subsonic General Aviation and Transport Aircraft, with Emphasis on Layout, Aerodynamic Design, Propulsion and Performance*. (Delft University press, 1982).

[9] **Raymer, D.P.** *Aircraft Design: A Conceptual Approach*. (Amer Inst of Aeronautics &, 2012).

[10] **Oroumieh, M.A.A., Malaek, S.M.B. and Ashrafizaadeh, M.** Proposing a Special Strategy for Platform RDTE Design Cycle of MAV and Small UAV Aircrafts. *IMAV 2010*Netherlands, 2010).

[11] **Hassanalian, M., Ashrafizaadeh, M., Ziaei- Rad, S. and Radmanesh, M.R.** A new Method for Design of Fixed Wing Micro Air Vehicle. *IMAV 2012*Germany, 2012).

[12] **Watkins, S., Abdulrahim, M., Marino, M. and Ravi, S.** Flight Testing of a Fixed Wing MAV in Turbulence with Open and Closed Loop Control. *IMAV 2010*Germany, 2010).