UAV[1] MINI-AIRPLANE DEVELOPMENT USING IT FACILITIES

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1. SUMMARY

Unmanned aerial vehicles are widely used in the XXIst century warfare. Low payload and short range reconnaissance missions are feasible with low cost mini planes. In the present paper authors propose an easy calculation method in aiming to determine the basic flight parameters of a mini plane. Mass data of the airframe are drawn from a 3D model.

2. SCOPE

The XXth century was the century of industrialized wars. Even in WW1 new technologies (airplane, submarine, machine-gun, radio technology…) were widely used but the technology development itself obtained a level never seen before during the war years (1914-18). The speed of the fighter planes was around 300 km/h in 1918. WW2 was even more characterized by new technology achievements. The development of warfare technology was enormous during the war years (1939-45). Mono-wing airplanes, jet engines, welded submarines, aircraft carriers, radar technology, nuclear technology were available at the end of the war. The speed of fighter planes obtained 800 km/h in 1945. The flight speed is only one of the characteristics but it shows quite good the enormous technology development. At the end of WW2 a completely new technology, the information technology came on.

Political strengths inducing strategic decisions in a war are more and more influenced by public opinion. The public opinion is subject to information and propaganda policy of a state, consequently technology facilities used in information of the society have an outstanding role. The efficiency of the information transfer increased according to the efficiency of means used in propagation of information. Printed papers, radio, TV, IT and internet technology were the major steps of this development. In recent days we see how IT becomes the tool of revolutionary movements in North Africa, and governmental authorities are unable to stop the propagation of information by internet and mobile phones. The easy propagation of information has an important effect on the population far from the battlefield. In spite of any prohibition all information reached the targeted population during WW2. Local authorities tried to falsify information in all sense, but the majority of the content reached the targeted persons. During the cold war (highly seasoned with local wars) the technology development was also important as before. In case of some peak points (Palestine, Korea, Vietnam, Cuba) the probability of the third world war was very high. According to requirements of permanent preparations for war the technology development was continuous also.

Bad news from the battlefield may cause hard consequences among the hinterland population, mainly in case of democratic countries where protest demonstrations are not prohibited. That's why any human losses may cause several difficulties for the policy and strategy makers. The conclusion was unambiguous: try to replace all human components to be risked at the battlefield. The massive use of V1 robot planes and V2 rockets by the Germans caused important damages in London in WW2. In the late forties when Israel started its airstrikes against Palestine the early reconnaissance robot planes were used successfully. In the nineties during the Gulf war and the Balkan wars both spy and attack planes were widely used.

In Hungary Zrínyi Miklós National Defense University (ZMNE) has started an UAV development project in aiming to satisfy the needs of Hungarian Army. About ten projects were carried out, each dealing with remote and GPS control of aerial vehicles. Dennis Gabor College developed short range airframes for UAV purposes [6]. In this later project two small airplanes were designed and constructed. Both of them meet the prescribed requirements. Finally Hungarian Army opted for Israeli made Skylark-1 UAV, which is used in the Afghanistan mission of HA.

[1] Unmanned Aerial Vehicle

Figure 1.
Skylark-1 used in Hungarian Army [2]

3. BASIC FLIGHT PARAMETERS

In this chapter we try to show a simplified method in aiming to estimate basic flight parameters of a simple micro-plane.

3.1 Horizontal flight

In case of constant speed horizontal flight both horizontal and vertical forces are in equilibrium. The lift force and the weight force should be equals as well as propulsion force and drag force. Let analyze in details the equilibrium of vertical forces [1]:

$$F_y = \frac{\rho}{2} v^2 A\, c_{lift} = mg \tag{1}$$

Where ρ is the air density (kg/m^3), v is the speed or the relative air velocity (m/s), A_y is the wing area (m^2), c_{lift} is the lift coefficient (-), m is the mass of the plane (kg), and g is the gravity acceleration (m/s^2).

Note that the lift coefficient with a given airfoil is the function of the incidence angle and the Reynolds number.

$$\mathrm{Re} = \frac{vl}{\nu} \tag{2}$$

Where v is the velocity (m/s), l is the length of the airfoil (m), and ν is the cinematic viscosity of the air (s^2/m).

From equation (1) the expected speed of the plane in horizontal equilibrium is:

$$v = \sqrt{\frac{2mg}{\rho\, A\, c_{lift}}} \tag{3}$$

As equation (3) contains the lift coefficient which is the function of the velocity, we choose a numerical iteration to solve this problem.

The drag force (N) equals with the propulsion force

$$F_x = \frac{\rho}{2} v^2 A\, c_x \tag{4}$$

Where ρ is the air density (kg/m^3), v is the speed or the relative air velocity (m/s), A is the wing area (m^2), c_x is the drag coefficient (-).

The useful power (W) is the composition of the horizontal speed and the propulsion force:

$$P_{useful} = F_x v \tag{5}$$

3.2 Climbing

Suppose that the velocity does not change considerably during climbing, the total energy required to climb into a given height H(m) is the sum of potential and kinetic energy E (W).

$$E = \frac{mv^2}{2} + mgH \tag{6}$$

Sure that the climbing velocity will be somewhat lower than that of in horizontal flight, but the kinetic part of the total energy content is much more lower, than the potential part, consequently we do not commit important error, when neglecting the change in velocity while calculating the required power.

3.3 Required electrical power

The required useful energy for climbing is given by equation (6). To estimate the required useful power P_{useful} (W) you should divide the total required energy with the time of climbing T (s).

$$P_{useful} = \frac{E}{T} \quad (7)$$

There are losses on each component of the power chain; consequently the required power will be much higher than the useful one. The components of the power chain are as follows: propeller, motor, electronic devices. Suppose that various types of efficiencies η do not vary considerably in the vicinity of operational point. The required electrical power P_e(W) will be:

$$P_e = \frac{P_{useful}}{\eta_{motor}\eta_{prop}\eta_{elect}} \quad (8)$$

Sure that there will be variation between zero and maximum value of the propulsion efficiency of the propeller, but it can be admitted, that a well selected and properly conditioned propeller runs with an efficiency of 70 %. The efficiency of other components can be estimated quite precisely.

The required electric power and the time of motor operation T give the capacity (Ws) of the battery.

$$Q = P_e T \quad (9)$$

4. PREDICTION OF REQUIRED FLIGHT PARAMETERS

4.1 Identification of operational requirements

The range is one of the most important parameters. In case of ground base radio control it may not overcome the natural visual capacity of the controlling personnel, say maximum 1,5 km. Whenever a GPS autopilot system is installed on board, the range depends mainly on the fuel (battery) capacity of the plane. In case of small UAVs (target drones) usually it is 25-30 km. However high capacity attack drones such as Global Hawk may operate in a distance of 25000 km.

The payload may vary in wide range also from some 0,5-1.0 kg in case of mini UAVs such as ZALA421-12 Russian reconnaissance drone [4] up to 6000 kg of the Global Hawk [3]. Usual equipment of mini UAVs is video camera, infrared camera and photo camera, the 0,5-1,0 kg useful payload may satisfy the minimum requirements.

The altitude is restricted in case of RC control with visual contact up to maximum 1000 m. When GPS control is used, the altitude depends only of the general flight capacities of the plane.

The main flight parameters in the case of our mini UAV are as follows:

Range	1,5 km
Payload	0,5 kg
Altitude	1000 m
Speed	10-30 m/s

4.2 Iteration method in aiming to estimate the horizontal speed

Suppose a specific wing load of 30 g/dm^2, (average value for small motor-gliders) and a wingspan/profile length ratio 10:1 (average value for wooden structure wings). If the mass of the airframe is given from the 3D model, one can determine the preliminary wingspan and the wing area.

Suppose a flight speed in the expected range of relative air velocity. Determine Reynolds number from the physical parameters of the airfoil and the air. Select an airfoil (in our case CLARK Y) from a catalogue. Suppose an incidence angle of 3^o. Read the value of lift coefficient from the chart of the selected airfoil.

Take the overall mass of the plane from the 3D model. Calculate the new speed from equation (3). Verify the difference between the new speed and the preliminary one. If the absolute value of the difference is higher than a predefined and acceptable absolute error, modify the preliminary speed and repeat the calculation until the obtained difference could be accepted. According to our experience, the convergence of this iteration is very fast. See the flow chart of iteration below. If the resulting speed doesn't meet the requirements, modify the 3D model, accordingly the overall mass will be modified. Reiterate the speed as before with this new mass.

The horizontal speed can be verified or in case of need modified from the drag force (4) and the useful power (7).

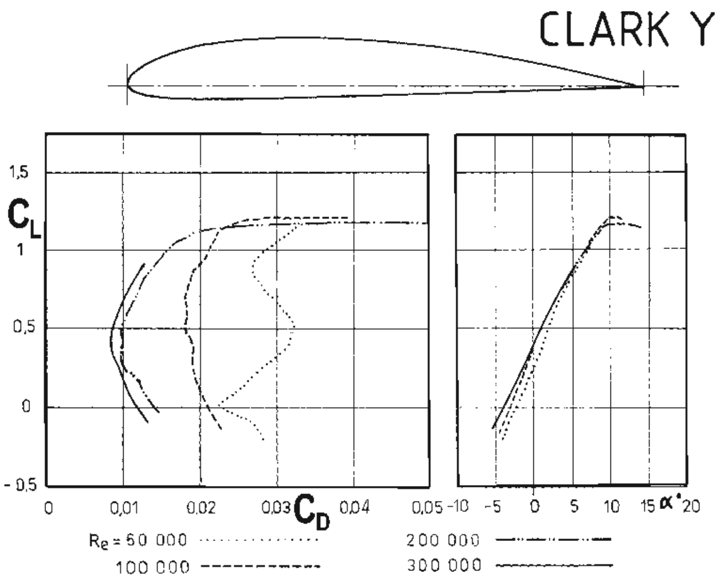

Figure 2.
Lift and drag coefficient of CLARK Y airfoil [5]

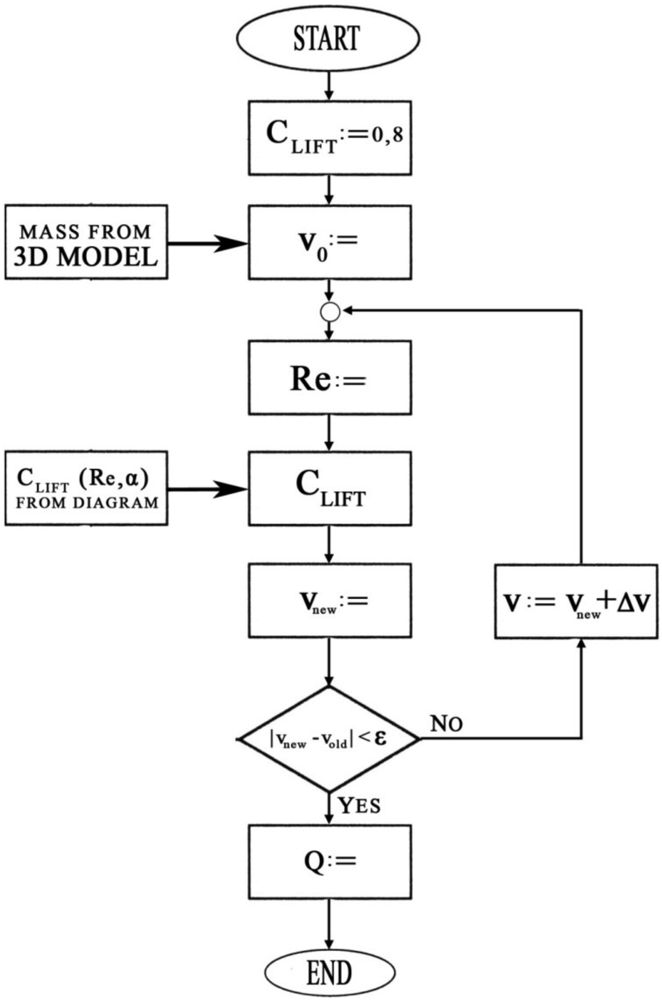

Figure 3.
Iteration flow chart

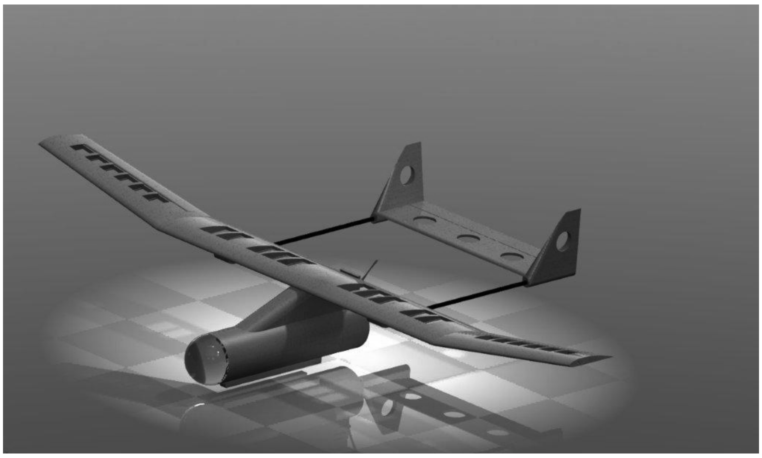

Figure 4.
Photorealistic view of GDF-UAV-V2

When the iteration is over one can determine the required motor power, as well as the battery capacity from equation (9).

5. SOLIDWORKS MODELING AND FABRICATION

In our project we used SolidWorks Student Design Kit 2010-2011 for 3D modeling.

5.1 Calculation of mass from the 3D model

The basic data for flight equilibrium is the mass of the airframe. A quite well estimation of the mass can be made from the 3D model of the airframe. In this case all the components of the structure are modeled, and the mass is calculated with the specific weight of the wood. The resulting mass shall be majored with 10% due to the weight of the bond. The mass of the covering material can be calculated from the area values with specific mass/area data from catalogue. Mass data of motor, battery, servos, receiver and other electronic components are available in catalogs on the internet.

5.2 Exploitation of 3D data

Whenever the 3D model is ready, all the geometry parameters of the plane are known, that is to say various exploitations of the above data is possible. For the visualization of the project a so called photorealistic representing of 3D data is the best. See the photorealistic view of the structure of our plane without surface covering.

However 3D data can be used indirectly for any NC technology of fabrication, but 2D drawings may be generated from the model as well. When using traditional fabrication technology, the use of 2D drawings is the most current method.

6. CONCLUSIONS

- Basic flight parameters of UAV mini air planes can be estimated by means of an easy iteration method.
- Mass of the airframe as primary data for the iteration can be drawn from the 3D model of the plane.

7. LIST OF REFERENCES

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