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Design of Coaxial Rotor Micro Air Vehicle

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***Abstract**: The main objective of this paper is the systematic description of the current research and development of small or miniature unmanned aerial vehicles and micro aerial vehicles, with a focus on rotary wing vehicles. In recent times, unmanned/Micro aerial vehicles have been operated across the world; they have also been the subject of considerable research. In particular, UAVs/MAVs with rotary wings have been expected to perform various tasks such as monitoring at fixed points and surveillance from the sky since they can perform not only perform static flights by hovering but also achieve vertical takeoffs and landing. Helicopters have been used for personnel transport, carrying goods, spreading information, and performing monitoring duties for long periods. A manned helicopter has to be used for all these duties. On the other hand, unmanned helicopters that can be operated by radio control have been developed as a hobby. Since unmanned helicopters are often superior to manned helicopters in terms of cost and safety, in recent years, accomplishing tasks using unmanned helicopters has become popular. Considerable expertise is required to operate unmanned helicopters by radio control, and hence, vast labor resources are employed to train operators. Moreover, it is impossible to operate unmanned helicopters outside visual areas because of lack of radio control, and the working area is hence limited remarkably. For solving the above problems, it is necessary to realize autonomous control of unmanned helicopters. However, no general method for designing the small unmanned helicopters has been developed yet – today, various design techniques by different study groups using different helicopters exist. In this paper the conceptual design process is explained.*

***Keywords:** Micro air vehicle, coaxial rotor, vertical takeoff & landing (VTOL)*

I. Introduction

Autonomous unmanned aircraft equipped with autonomous control devices called unmanned aerial vehicles & micro aerial vehicles. This is generally called as autonomous flying robots. Micro- and nano air vehicles are defined as “extremely small and ultra-lightweight air vehicle systems” with a maximum wingspan length of 15 cm and a weight less than 20 grams. In 1997, DARPA started a program called “MAV-project” where they presented some minimal requirements. In particular, they set the maximum dimension to be around 15 cm long, and the weight, including payload, to be less than 100 g. Furthermore, flight duration should be 20 to 60 minutes.

Many research institutions are actively studying and developing new air vehicles, reducing size and weight while improving performance, and adding more functionality.

Examples here are Harvard Micro-robotics Laboratory in the USA, Department of Aeromechanics and Flying Engineering from Moscow Institute of Physics and Technology in Russia, Aircraft Aerodynamics and Design Group at Stanford University (USA), the Autonomous Systems Laboratory at ETH Zurich (Switzerland), and Department of Precision Instrument and Mechanology at Tsinghua University in China. Several companies and agencies also play an important role in the manufacturing and development of AVS. Examples here are DARPA from USA, Prox Dynamics from Norway, and Syma from USA. AVS applications span a wide range, and the majority of them are military. AVS are capable to perform both indoor missions and outdoor missions in very challenging environments. The main applications are intelligence, surveillance, and reconnaissance (ISR) missions.

These systems can provide a rapid overview in the area around the personnel, without exposing them to danger. Infrared (IR) cameras can give detailed images even in the darkness. Furthermore, NAVs, thanks to their reduced dimensions, are perfect for reconnaissance inside buildings, providing a very useful tactical advantage. As reported in, such small vehicles are currently the only way to remotely “look” inside buildings in the battlefield.

II. History of Unmanned Aerial Vehicles

The first UAV was manufactured by the Americans Lawrence and Sperry in 1916. It is shown in Fig.1. They developed a gyroscope to stabilize the body, in order to manufacture an auto pilot. This is known as the beginning of "attitude control," which came to be used for the automatic steering of an aircraft. They called their device the "aviation torpedo" and Lawrence and Sperry actually flew it a distance that exceeded 30 miles. However, because of their practical technical immaturity, it seems that UAVs were not used in World War I or World War II. The development of UAVs began in earnest at the end of the 1950s, taking advantage of the Vietnam War or the cold war, with full-scale research and development continuing into the 1970s. Figure 2 shows a UAV called Fire bee. After the Vietnam War, the U.S. and Israel began to develop smaller and cheaper UAVs. These were small aircraft that adopted small engines such as those used in motorcycles or snow mobiles. They carried video cameras and transmitted images to the operator's location. It seems that the prototype of the present UAV can be found in this period.

The U.S. put UAVs into practical use in the Gulf War in 1991, and UAVs for military applications developed quickly after this. The most famous UAV for military use is the Predator, which is shown in Fig.3. On the other hand, NASA was at the center of the research for civil use during this period. The most typical example from this time was the ERAST (Environmental Research Aircraft and Sensor Technology) project. It started in the 1990s, and was a synthetic research endeavor for a UAV that included the development of the technology needed to fly at high altitudes of up to 30,000 m, along with a prolonged flight technology, engine, sensor, etc. The aircraft that were developed in this project included Helios, Proteus, Altus, Pathfinder, etc., which are shown in Figs. 4–6. These were designed to carry out environmental measurements. To take-off and land, or catapult launching.

Table1: Types of Unmanned Arial Vehicles

Sr No.	Figure	Name	Sr No.	Figure	Name
1		First UAV in the world, 1916	4		Civil use UAV by NASA (Helios)
2		UAVs in the 1960s and 1970s (Fire bee)	5		Civil use UAV by NASA (Helios)
3		Predator in military use	6		Civil use UAV by NASA (Altus)

III. Configurations of UAV

Fixed-wing UAVs, as shown in fig (7) which refer to unmanned airplanes (with wings) that require a runway. Rotary-wing UAVs, as shown in fig (8) also called rotorcraft UAVs or vertical take-off and landing (VTOL) UAVs, which have the advantages of hovering capability and high maneuverability. These capabilities are useful for many robotic missions, especially in civilian applications. A rotorcraft UAV may have different configurations, with main and tail rotors (conventional helicopter), coaxial rotors, tandem rotors; multi-rotors, etc.

Micro aerial vehicles (MAV): In the last few years, micro aerial vehicles, with dimensions smaller than 15 cm, have gained a lot of attention. These include the Black Widow manufactured by AeroVironment, the Micro Star from BAE, and many new designs and concepts presented by several universities, such as the Entomopter (Georgia Institute of Technology), Micro Bat (California Institute of Technology), and MFI (Berkeley University), along with other designs from European research centers fig 10.

Fig 7.Some configurations of fixed-wing UAVs

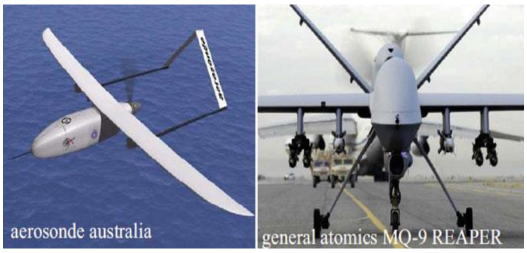


Fig 8.Examples of rotary-wing UAVs

Fig 10 Unmanned aerial vehicles, from big platforms to micro flying robots.

IV. Design Procedure for Micro Air Vehicle

The designer must go through a preliminary design procedure where the overall size and shape of the vehicle will be determined. This conceptual process is the focus of this paper and it is outlined Figure 11.

4.1. Components and Take-Off Weight

One advantage of MAV design over conventional full-scale aircraft design is that the calculation of take-off weight can be performed with relatively little use of empirical data. This is due to the fact that most of the components to be carried, as well as their size and weight, are known. Consider here take of weight as 40 gram. (W_o)

4.2. Estimation of Cruise Velocity

With the take-off mass defined, the next step in the design procedure is to determine the Cruise speed of the MAV. This step is particularly difficult because, there will be no experimental data of the thrust of the engine selected versus airspeed.

Relation for calculating Cruise velocity is taken as

$V_c^{Coaxial\ UAV} = 99.5.W_o^{0.268}$ where V_c is cruise velocity & W_o is the gross weight

$V_c^{Coaxial\ UAV} = 99.5.(0.04)^{0.268} = 0.699$ m/sec

4.3. Required Lift Coefficient

With the take-off weight and estimated airspeed known, it is possible to calculate the lift coefficient required to sustain level flight. That is,

$C_{L,req} = W_0/0.5\rho V^2 S$

$C_{L,req} = 40/0.5x1.29x(0.699)^2x3.14x(0.125)^2$

$= 2.58$

Where W is the weight of the aircraft, V is the estimated cruise speed, and S is the wing area.

4.4. Selection of Wing Plan form Shape:

In order to determine which wing shape is best suited for a micro aerial vehicle, wind tunnel experimental data is to be used to develop an empirically-based design and analysis procedure.

The results obtained from the University of Notre Dame's MAV entry to the 2000 Micro Aerial Vehicle Student Competition was used as the best wing plan form shape for a MAV. These results were summarized in a report written by Gabriel Torres and Thomas J. Mueller, entitled, "Micro Aerial Vehicle development: Design, Components, Fabrication, and Flight-testing".Torres and Mueller used wind tunnel experiments, which were used to develop an empirically-based design and analysis procedure, to determine the optimal wing shape for a MAV. In these experiments four different wing shapes were tested, shown in Fig. 11. All had zero camber, a thickness-to-chord ratio of 1.96% and aspect ratios of 1 and 2 (Mueller 2000). [4]

4.5. Selection of Aspect Ratio and Wing Area:

Having determined the optimum shape the next task will be to size it: that is, to select the aspect ratio and wing area. As is discussed earlier, this step is difficult to do accurately due to the uncertainty of the estimated airspeed, the assumptions used in the generation of the interpolation model, and the fact that a thin wing with zero camber will have different lift and drag characteristics than a ready-to-fly MAV with a fuselage and wings with camber and thickness.

Relation to calculate aspect ratio $AR = \frac{b^2}{S}$

As can be seen from Eq. 5 using a small aspect ratio, the MAV can maximize its wing area (Francis and McMichael 1997). It was found that a wing with AR=1.5 was close to the most efficient use of maximum dimension for a wing platform, similar in shape to the inverse Zimmerman wing

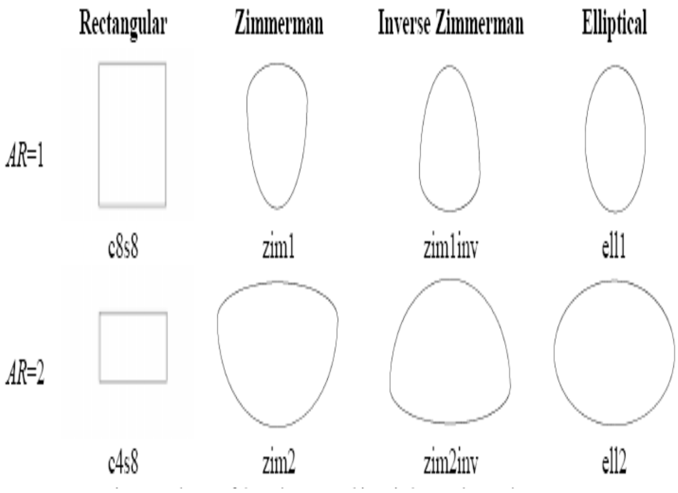
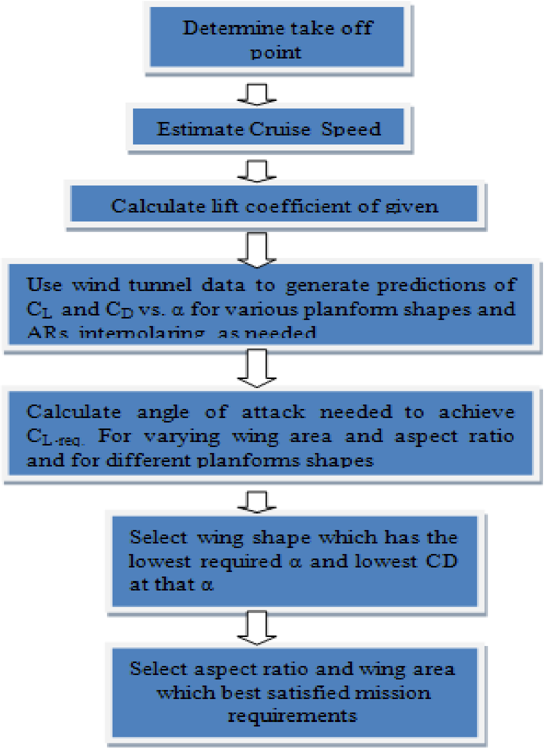


Figure 10.Shapes of the wings which were tested in the wind tunnel tests.

Figure 11: Design Procedure for Micro Aerial Vehicle



V. Applications

Potential civil applications of UAVs are

1. Inspection of terrain, pipelines, utilities, buildings, etc.
2. Surveillance of coastal borders, road traffic, etc.
3. Disaster and crisis management search and rescue.
4. Environmental monitoring.
5. Agriculture and forestry.
6. Fire fighting.
7. Communications relay and remote sensing.
8. Aerial mapping and meteorology research by university laboratories

VI. Conclusion

From above design method it is concluded that we can design a micro air vehicle ranging from 20 gram to 100 gram. Selecting density of air & gross weight of vehicle to be lift coefficient of lift will be obtained, force required to lift a vehicle i.e equal to gross weight of vehicle will be calculated.

REFERENCES

Books:

[1] Autonomous Flying Robots (Unmanned Aerial Vehicles and Micro Aerial Vehicles) by Kenzo Nonami Farid Kendoul • Satoshi Suzuki Wei Wang • Daisuke Nakazawa.

Journal Papers:

[2] Micro- and Nano-Air Vehicles: State of the Art Luca Petricca , and Christopher Grinde.

[3] Micro aerial vehicle development: design, Components, fabrication, and flight-testing by Gabriel Torres and Thomas J. Mueller.

Journal Papers:

[4] Samantha Hearne 'Minimum Structural Weight of a Micro Aerial Vehicle' University of New South Wales at the Australian Defence Force Academy, October 2008.