

Recent Advanced Bionic-inspired Aircrafts

JingJing Zhang*

U.C. International School, Shanghai, China

*Corresponding author: admin@ucisedu.cn

Abstract. Aircrafts is a noun which means the vehicle can travelling in air. The invention of bionic-inspired aircrafts makes human thousand years dream come true. Even though it still have problems that need be solved, human already walk a big step in this field. Recently, further researches brings better future and imagination to human. The concept of Micro Air Vehicle tells human that this technology has an opportunity to be used in military. This paper is about recent research and invention of bionic-inspired aircrafts, including introduction of existed types of bionic-inspired aircrafts. Briefly introduce the history of this technique. Stating the status quo of bionic-inspired aircrafts. Expounding the mechanics of bionic-inspired aircrafts. Looking forward of the future of this technique. Helping readers use less amount of time to have a basic understanding of bionic-inspired aircrafts.

Keywords: Bionic-inspired aircrafts, aerodynamics, micro air vehicle, flapping wing.

1. Introduction

The desire of humans of flying was always in our nature. Drawback to history, numbers of ancient stories include flight, such as those of the Greek legends Icarus, Daedalus and Vimana in the ancient Indian epic. 400 BC or thereabouts, A Greek man who called Archytas is credited with designing and composing the earliest artificial, autonomous flight device. Which is a bird-formed sculpt tossed by a jet, or apparently steam, reputedly have flown about 200 meters [1]. In the 9th century, The first recorded paragliding attempts were made by the Andalusian and Arabic language poet Abbas Ibn Firnas and by the English and Eilmer of Malmesbury in the 11th century. Unfortunately, both of experiments hurt the pilots [2][3]. In 1485, Leonardo Da Vinci built a dream of flying. The reason of it was called dream is because He ignores the sliding flight of birds and directly draws the sketches of wings by using less bionic approaching but more likely to be an aircraft. Where after, the glider replaced the position of this bionic aircraft in the aviation field. In fact, the real study of flapping flight mechanisms from the perspective of aerodynamics is only a hundred years of history. In the past, methods used by researchers are complicated to get accurate results, which retard the development of bionic aircraft [4][5]. Since the 1980s, With the progress of experimental observation methods and computational fluid dynamics (CFD) development, researchers began to analyze from a precarious perspective of flickering wing aerodynamics. It wasn't until the twentieth century that the first aircraft was man-made. Insects and birds and all of flying animals use their muscles to control and flap wings which provide the impetus for them to flutter in the air [6][7]. They are able to adjust the complicated aerodynamic force. Attaining this goal is by modulating power output through sensorimotor pathways. Such bionic-inspired flight systems are convoluted, that is results in the simulation of the aerodynamics of wings and their muscles of the whole body. Including mechanics and mechanical systems of flapping flights' wing kinematics, aerodynamics, and flight dynamics [8].

Furthermore, the research of bionic airplanes is accomplished during the process of developing Micro Air Vehicle [9]. With the coming idea of MAV by the Defense Advanced Research Project Agency (DARPA) in the 1990s and the unique utilization in both military[10] and civilian[11] fields, people first time realized that the rosy prospects of the bionic aeroplane [12]. For adapting to different requirements of missions, MAV also derives different types. There are 3 major branches: Fixed-wing Micro Air Vehicle (FMAV), Rotary-wing Micro Air Vehicle (RMAV), and flapping-wing micro air vehicle (also known as biomimetic, BMAV) [4]. Which separates by their flight principle and aerodynamic layout [13]. Overall, MAV is a micro and bio-inspired aeroplane which are fluttering wings. Nowadays, It is an operating and well-developed research covering different aspects of

mechanical and aeronautical engineering, computing, and biology. After all, the goal of this paper is to introduce and help researchers quickly understand the status quo of bionic-inspired aircrafts. The rest parts of this paper will demonstrate different branches of bionic-inspired aircraft and the problem of researchers currently facing.

2. Diverse categories of flying vehicles.

2.1. Research on flapping wing aircraft

When we mention flying creatures, there will be three species that come to our mind, bird, insect, and bat. They are also 3 main categories of flying vehicles [12]. During the clipping flying process of birds and bats, they normally use the method of gliding. However, when the speed of flying is low, the flapping airfoil can obtain enough lift to support its own weight. One of the normal ways of bats and birds increase the force of pull and lift is completed through active deformation. There are two main ways. One of type is variable span wing, which increases the under lifting force by spanning their wing when flying animals rush downwards. When flying animals rush upwards, they contract their wing to reduce their resistance. Normally, birds are able to achieve that rely on bending and folding wings. Bat can be achieved by folding joints and stretching their patagium.(As shown in figure 1) [5]

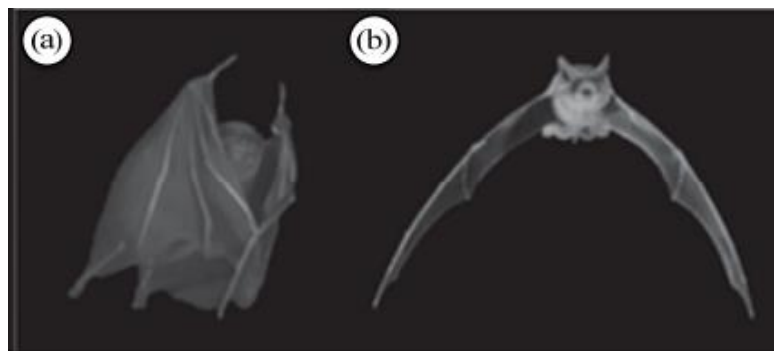


Figure 1 Changing wingspan process of the Brazilian free-tailed bat [5].

According to the research, The total amount of all species of birds in nature is 9000 [14]. Their admirable flying technique animated the human imagination of fly. Additionally, humans tend to create analogous bio-inspired flight systems. During the long-term imitation of flying animals, various innovator struggle with this and make the effort to innovate, design, and improve the theoretical basis of bio-inspired aircraft. To have a better connection with birds, plenty of scientists are equally committed to research on flapping-wing theory. As a result of bird-like aircraft being the most mature system, the following paragraphs will be starting from it.

2.1.1 Birds liked aircraft

Birds demonstrate their remarkable flight abilities and inspire people to develop a similar bionic flight system. Humans' first explorations of flight began with the imitation of birds. Every period during the antiquity of human advancement, many efforts have been committed to inventing and designing aircraft that has a similar outlook as a bird or improving the flapping wing theory. First to the previous period of bionic aircraft exploration, because the clue of technology related to finding bird-like aircraft is relatively mature, looking for bionic flight systems start with a craft that is similar to a bird. "As proof, Smartbird is a whirling aircraft that simulates seagulls and is a significant breakthrough in the advancement of bird-like aircraft. It was ideated by FESTO in Germany in 2011 20,21. 1.96m is the length of the wingspan of the smart bird, and 450g for its weight. It has a small turning radius. Using the aerodynamic flapping of a seagull's wings, a parallel linkage can control the twisting motion of the wingtips to drive the flaps. Furnished with a supremely automatic flight console, the Smartbird is able to travel in the sky by itself. There are two parts of its body that can

curve which are tail and head, even has resilience similar to the real bird, which can be faked in flight.” [12]

2.1.2 Bat liked aircrafts

The only type of mammal that has the ability to fly as a bird is a bat. Bat has an extremely complex wing structure. The wing and buoyancy skin evolved them to become the master of flying. In the bat-type aircraft's exploration, it is imminent to confer the mechanism of synergy between fluid and flexible structures. Among them, considering technical and theoretical limits, relatively little research has been done on bat-like planes. In the article, there is two significant flight structure that is comparable to bat are demonstrates the improved goals of the vehicle which has the layout of the bat in the work of bionic aviation structure.

Figure 2 demonstrates Microbat, which is an antecedent classical bat-like aircraft. Microbat has a weight which only 10 g, it was innovated by the California Institute of Technology under DARPA funding [12]. The outlook of Microbat is covered by a transparent material, which observes its inside structure directly. Even though it was the first bat-like aircraft, the similarity between Microbat and bat is the wing only. The design of Microbat is still more close to an airplane. The innovator trying to make the size of Microbat as small as they can. The length of the wing is 23 cm only. The mechanics of Microbat is activated by simple crank and pushrods which provide power, controlling flying posture with a stabilizer that includes horizontal and vertical directions. The specific structure of the thick and flexible wing directedly connects to the head parts and edge. The result of its outlook similar to a bird is a perpendicular tail. Retrospection about the process of testing Microbat, it only kept flying for 9 s when its first test. But after several improvements, Microbat fly for 25 min in August 2022, which also create a new world record for flapping-wing aircraft [12].



Figure 2. Microbat [12].

2.1.3 Insect comparable aircraft

The structure of flapping wing aircraft is the simulation of flying animals in nature. Additionally, on the basis of the bionic principle, the flapping wing aircraft is an innovation. With the comparison of fixed wing and revolving wing, this innovation has stronger maneuverability, efficiency, and lower noise. Getting through the bionic system, the flapping wing aircraft can reach the goals of rising, holding, and pushing. Besides the goals that were just mentioned, another advantage is it can realize the long-distance travel with low energy requirements. In the early research, scientists often used a single degree of freedom of rigid wing to be the model of flapping wing aircraft, however, the single degree of freedom flapping wing is unable to adapt to various inconstant airflow. Therefore, the results are inaccurate and have differences from the real values. Besides, during the flapping, the flexible wing will rotate. Which leads to a change in form of the surface. Even though the flexible wing has a larger pushing force, there still require improvements in the manufacture and restraint for finding solutions to problems that already exist [15].

3. Mechanics applying in bionic aircrafts

3.1. Aerodynamics applying

3.1.1 Reynolds number

A number that is represented by the proportion of inside forces to viscous forces. It represents a dimensionless quantity that is accustomed to describe fluid systems where viscosity has a meaningful effect on moderating a fluid's velocities or flow pattern. When it is included in math, the definition of Reynolds number as shown below.

$$N_{Re} = \frac{\rho v d}{\mu}$$

Which μ =viscosity, ρ =density, v =velocity, and d =diameter [16].

3.1.2 Drag/Resistance

During the history of aerodynamics, its drag has always been classified to pressure drag. About aerodynamics, It includes lift-related drag and inviscid drag, drag due to interference and roughness, shock drag, skin friction drag, and lift drag. It changes as the aircraft's speed and the drag's intensity do. Friction drag and drag from lift are the main drag factors in subsonic aircraft. Similar to lift and friction drag, The magnitude of wave drag can equal at supersonic speeds. (Bushnell & Tuttle, 1979) [17]. Theoretically, drag is a type of force that includes 2 of important parts. The initial is the 'induced drag'. Representing wings spanwise. Which separates between the design of the wing and the shape of the platform or Reynolds number but with a closely linked ratio. Second, although a component force that has a lower strength and combined with the drag due to lift has a strong attachment to the Reynolds number, the platform's shape mostly has no connection with the aspect ratio.

There are two independent studies were conducted by different researchers to decrease the induced drag. In the initial strategy, numerous unfamiliar wingtip ideas influenced by bird wingtips were suggested to evaluate the results on the wingtip and aircraft aerodynamics. In the second strategy, the feathers of the birds were extensively studied to ascertain the influence of particular feathers on the tip layout to investigate feasibility and acceptance for direct use in real aircraft. The following categories apply to the second way when considering how feathers are used: first, experimenting with feather substitutes. Second, experiment with primitive bird feathers. This branching is intended to facilitate our investigation according to the categories just mentioned, in addition to understanding and comprehending the region's scientific history [17].

4. Summary

After stating several types of MAV and discussion about problems of this technology currently facing, some of scientist already figure out their solution. In fact, except for some specific bionic aircraft, the mechanisms and aerodynamic principles of other types of bionic aircraft have been basically overcome. Based on the portability and concealment of bionic aircraft, this technology will be widely used in different fields in the future. Battery life and counterfeiting may be key factors in that number. Not only miniature aircraft, but the corresponding research may also help researchers in other fields, such as using the experience found on MAVs to help aircraft better maintain stability in turbulent airflow.

Not only for bird, there is also various types of insect which is not made to similar shaped aircraft. Some types of insect's aerodynamics theory is still a mystery for researchers and wait for further research. In the past, human already innovated aircrafts of housefly-liked, bee-liked, moth-liked, dragonfly-liked and locust-liked and several types of insects and did sufficient research on them. For instance, mechanics of high lifting. However, there is still types of insects such as butterfly and ladybug, in result of their complicated movement and shape, there is no much of research and realistic applying on them. For butterfly, they have different size of wing and center of mass which depend on

different branches and categories. Butterfly also has lower frequency of flapping wings, this make the innovation of butterfly-liked aircraft become much harder. For ladybug, during the flight of the ladybug, the flexible wings flap repeatedly, the hard shell unfolds over the flexible wings, which is markedly different from most insects that only using flapping wings to generate its aerodynamic force. Both of them includes further discussions and requiring more research. Therefore, it is necessary to carry out corresponding kinematic observation, flow field measurement and high-precision digital simulation technology according to its characteristics. In-depth exploration of insect flight aerodynamics will help to increase people's understanding of the flight mechanism of high-lift insects, and then apply it to the design of micro planes [18].

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