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BIONICS IN AVIATION

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Abstract

In the paper bionics as a field of knowledge and inspiration in the aviation technologies is presented. Bionics is a branch of science on the borderline of art and biology that studies the way living organisms work, as well as their structure, in order to use the results to build technical devices. In the introduction part definition of bionics is described. In the next part of this document the aviation technologies inspired by nature is depicted. Then, technologies inspired by the butterfly wing are presented. The paper ends with conclusions.

Keywords: bionics, aviation, butterfly wing.

1. INTRODUCTION

For ages people have been observing nature's phenomenon and watching the world around them, trying to imitate some of the solutions existing in it. As a result, the creation of many tools such as the pounder, wheels or boats was possible. It is in human nature to develop and increase the diversity of technical thought and to have a desire to explore the world around them, which leads to the imitation of nature and bionics. Mankind have been using the Earth's resources to fulfil our needs since the beginning of time. However, the behavior of different organisms along with different solutions used by them in order to survive is only recently being studied from the technical - engineering point of view.

Bionics is a branch of science on the borderline of art and biology that studies the way living organisms work, as well as their structure, in order to use the results to build technical devices. Bionics originated from Biocybernetics which is an example of the trend to integrate various fields of science. It concerns the use of laws governing the function of living organisms in various fields of technology, mainly automation, electronics and mechanics. Technical devices used for processing information and control do not measure up to even the simplest biological configurations, not only in the complexity of the tasks to be solved, and time of their execution, but also in dimensions, demand for energy and reliability. Therefore, the goal is to study the algorithms used in the process of controlling and processing

information by living organisms [1]. Bionics can be described as imitation of nature and inspiration with its solutions.

It is perceived as a source of ideas and a human approach to the world based on making use of nature, and the use of natural models and solutions in many aspects of human life [2].

In recent years a growing interest in bionics and fields related to it can be clearly observed. This is due to the continues need for development and finding new technological solutions. This supported by growing number of scientific publications in the field of bionics shown in Fig. 1.

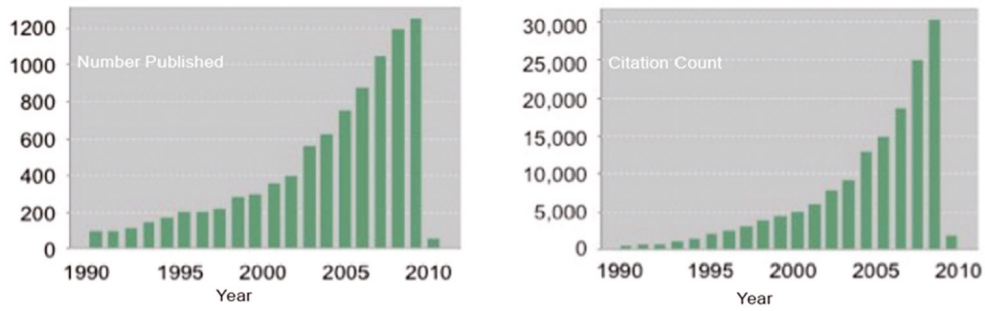


Fig. 1. A growing trend in the number of publications (left) and quoted text (right) in the field of bionics and similar fields [3]

Nowadays there are at least three distinguishable directions of aviation developments based on bionic research:

- construction of new, efficient and safe gliders and paragliders, modeled on the gliding flight of birds,
- flying constructions with stationary wings, ornithopters,
- construction of various types of unmanned, flying apparatus and micro-apparatus, which are remote controlled and modeled on flying insects.

The main directions of aircraft development are limited to:

- increasing speed,
- reducing weight,
- the development of electronic control systems,
- reliability of engines with increased power.

In the development of helicopters the key issues include:

- development of lightweight and strong rotor blade structures with good aerodynamic efficiency,
- quiet operation of the helicopter,
- minimizing the vibrations of the helicopter.

Manufacturers are trying to build faster, more reliable and cost efficient airplanes. They are searching for new solutions which will reduce air resistance during flight, new materials, which without the loss of endurance and increasing costs will make the plane lighter. Solutions to these problems can be inspired by bionics, which more than once was the originator of modern technologies.

2. AVIATION TECHNOLOGY INSPIRED BY NATURE

Among the most recent modifications of aircraft structures there is a big interest in bionic projects. Tests are conducted on active constructions of aircraft wings, solutions from the domain of flying micro-robots and testing new surfaces for strategic carrier elements of flying mechanisms.

Among new active structures, there is the "smart nose" (Fig. 2) at the end of an aircraft wing, built of fiberglass and coal, changing shape during flight [4].

Fig. 2. The structural model of the wing in a standard position (left) and during deflection due to air pressure generated during flight (to the right) [4]

There is also an increasing popularity of smart materials used in cutting-edge technologies. An example might be the prototype of a new wing of an unmanned aircraft, made of shape memory materials (Fig. 3). Adjusting the shape of the wing is made possible by a specially designed circuit configuration of the shape memory materials which after suitable heating and cooling cyclically ensures optimal efficiency of the wings, adapting to the flight conditions [5].

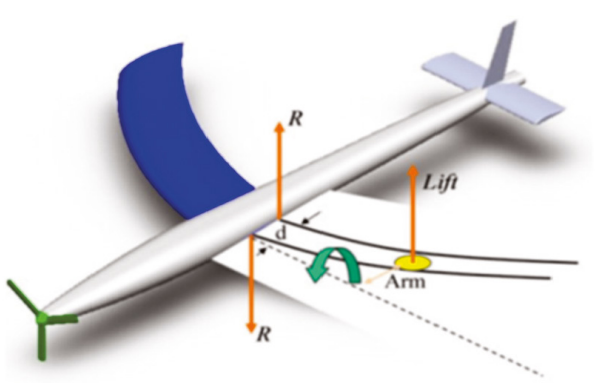


Fig. 3. Model of aircraft with an intelligent wing [5]

Tests include several types (Fig. 4) of deformed wings in order to investigate changes in air resistance at high speeds and the forces and torques acting on the wing in flight when its changing shape [5].

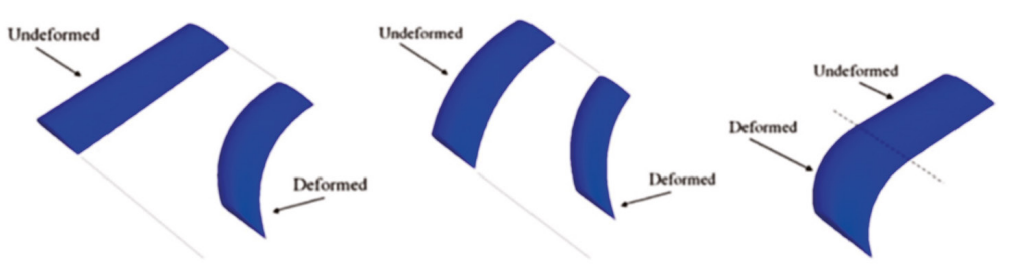


Fig. 4. Models smart wings shape change [5]

After several computer projections it was calculated that the new wing after deformation during flight can reduce the need for power at the maximum speed by approx. 9-12 %. This allows for lower fuel consumption and hence a longer flight by this type of construction.

Other research has focused on making the rear trailing edge of the wing, made of an flexible skin, more elastic, increasing the aerodynamics of the profile (Fig. 5).

Fig. 5. Model of the elastic rear trailing edge of the wing [6]

The next step was to reduce the weight of the wings by removing part of the ribs supporting it. In order not to impair the strength parameters of the design, the other bars were oriented at an certain angle while maintaining the rigidity of the element (Fig. 6).

Fig. 6. Construction of new wing ribs with a lower weight [6]

After the implementation of these new concepts, conducted tests have shown an increase of 5 degrees in the angle of attack, with wing stiffness meeting the minimal requirements.

Aircraft with elastic wing structures encountered a problem with the inelastic structural skin of the wing. The layer of tinware covering the wings cracked, curled up or became detached from the structure. To overcome the problem, a concept of transverse elements supporting the tinware was introduced (Fig. 7). They stiffen the surface and are capable of changing shape according to the desired specifications. Shape memory materials, polymeric materials, and hydraulic systems were also used.

Fig. 7. Model of elastic structural skin on an airplane [4]

Such a structure is composed of a layer of structural skin and an active truss, and is activated by actuators placed within the structure. This design allows the active surface to change shape, solving the problem of the structural skin adjusting to the deformation of wings.

Among the studies on the surface of aircraft wings new solutions resulting from bionics have appeared. Research has begun on thin coatings imposed on the surfaces of machines, having the task of reducing air resistance. An example of such a coating is paint designed based on shark skin, applied to the surface of cargo aircraft. A study was conducted in which the surface of the shark's skin was projected. Fig. 8 presents a picture from a scanning electron microscope of a model shark skin and paint replicating surface.

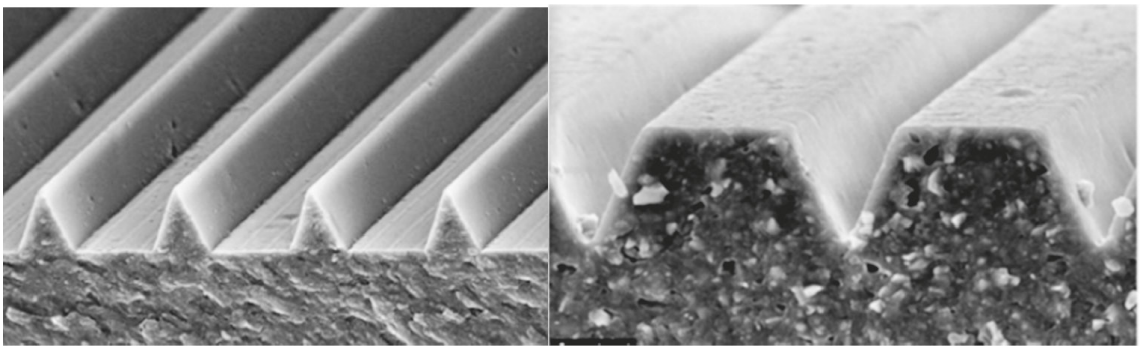


Fig. 8. A picture from a scanning electron microscope of a model of shark skin (left) and paint replicating surface (right) [7]

The created shell's role is to ensure a laminar flow of the environment around the element on which it is applied to. The structure derived from the applied coating will organize the movement of the environment's molecules, which eliminates vortexes and smooths flow. A study was conducted in a special wind tunnel on a sample imitating an aircraft wing profile and a 5% drag reduction was proven with the use of the mentioned paint.

Another widely studied issue are mini-robots modeled on the shapes of insects (Fig. 10). Many publications concern the analysis of the mechanisms of active twisting and fluttering of wings as well as evaluating the turn angle and the effectiveness of flying mechanisms. In some cases, the movement of wings was modeled on the hummingbird wings flutter (Fig. 9).

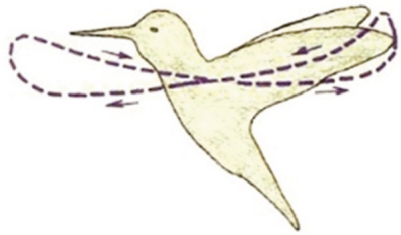
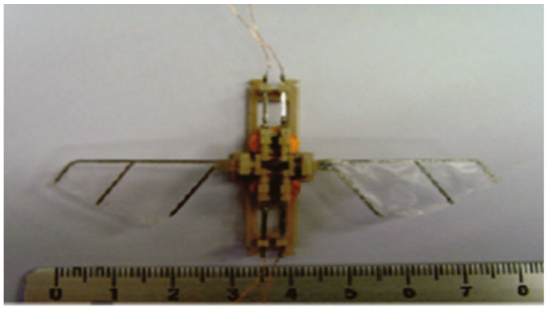


Fig. 9. Lines mapping the movement of the wings of a hummingbird [8]



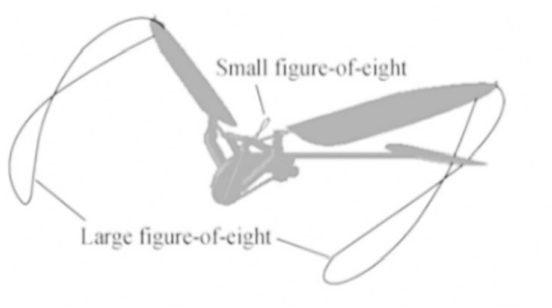


Fig. 10. A mini robot [9] (left) and a scheme of the flying robots movement (right) [10]

3. TECHNOLOGIES INSPIRED BY BUTTERFLY WING

Recent studies were conducted both on the anatomy of butterflies as well as the biomechanics and aerodynamics of their flight. The study consisted of measuring many of the elements making up the body of a butterfly, as well as recording the flight of butterflies placed in a special terrarium [11].

During measurements, attention was mainly paid to things such as [11]:

- body mass,
- weight of the torso,
- the length of the wings,
- the length of the body,
- the total area of the wings,
- wingspan,
- the ratio of the butterfly's mass to the surface of its wings,
- weight of the wings,
- thickness of the wings,
- diameter of the body.

The relationship of some parameters with the speed of flight was noticed among other things. Studies of this type can be useful in the search for new solutions for aviation, through the use of analogies in the construction of structures. More in [11].

In technology as well as in other fields of science, more and more devices inspired by nature are being created, some which design and functionality is based on the wings of butterflies. There are many elements, to which attention is paid to, while designing new technical solutions of this type. The

detailed structure of the butterflies can be distinguished, the coating of their bodies, their size and weight, as well as the kinematics and dynamics of their flight. Closer analysis of the wing structure reveals that thanks to their specific composure, they have the ability to self-clean and are hydrophobic. The wings also have an impact on the specified movements of butterflies. The use of solutions based on the bionic construction of butterfly wings can be found for example: in art, electronics, medicine, and also in military technology or in internal security. These properties are also used in the production of materials with special properties, in construction, and aviation.

In connection with the development of technology, multiple devices have been introduced, which are known as mechanization of wings, allowing the reduction of speed, easier control and maneuverability, the decrease of resistance acting on the aircraft, as well as the increase in its lift. Flaps, among others, can be classified as such devices [12].

Unmanned aircraft have become increasingly popular in military applications, as well as devices that monitor and make the discovery of new planets possible. Recent projects of such micro-ships are modeled on the structure of birds and insects, including butterflies, such as the red admiral, shown in Fig. 11. They are black butterflies with reddish bars on the dorsal surface of all four wings, moving with a specific technique. Their wings in fact, can move in multiple planes [13].

Fig.11. Red admiral [14]

Researchers took numerical photographs of the individual phases of butterfly flight in a specially constructed wind tunnel with smoke-filled air. Analyzing the vortices formed after each stroke of wings, they noticed that these butterflies use a whole range of aerodynamic mechanisms to take off, maneuver in the air and land. They can strike both wings symmetrically, at different times, and even each in a different plane to make better use of air currents [15].

Solutions modeled on the mechanism of butterfly flight are much more efficient than previously used conventional ones. In addition, the designed micro aircraft are characterized by a highly developed level of mobility, namely they can fly horizontally, ascent, soar, hover motionlessly in air, and crawl on both earth and water surfaces. All these possibilities result from the flexibility of the wings. This phenomenon is called aeroelasticity [13].

In this case, the main inspiration was not the structure, but the butterfly's flight mechanics. This project analysed two types of mechanisms, active and passive kinds of wings. In the case of active wings, an rotation was applied which aimed to increase the angle of attack with every change of position. On the other hand passive wings used the phenomenon of aerodynamic resistance and aeroelasticity to cause rotation of the wing [13].

One of the first devices of this type were Microbat (Fig. 12), Delfly (Fig. 13) and the prototype origination from the University of Delaware. Work is also underway on a the CF3 prototype (Fig. 14) [13].

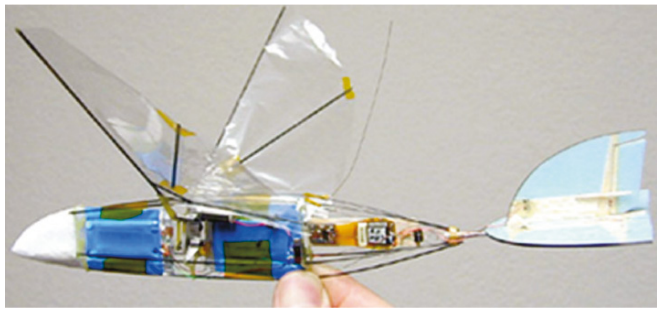


Fig. 12. MAV „Microbat" [16]

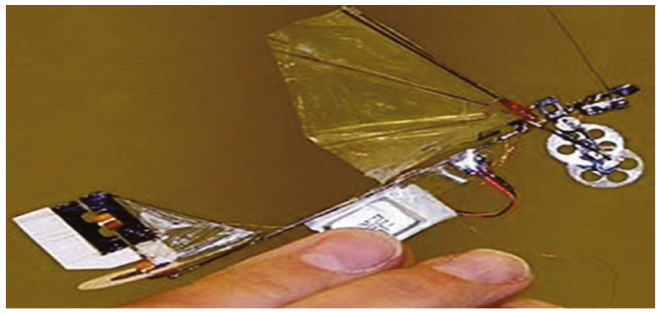


Fig 13. MAV „Delfly" [17]

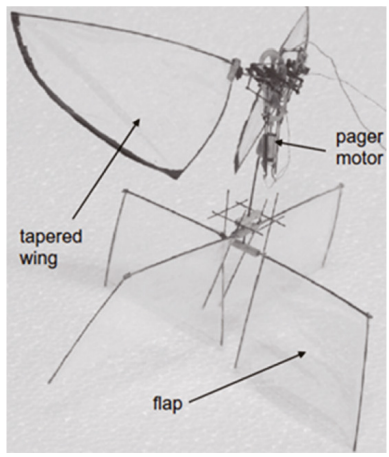


Fig. 14. MAV „CF3" [13]

At the Lublin University of Technology, a project inspired by nature, more specifically by the butterfly's wings mechanisms of movement, was developed. A rotor was designed with adjustable positioning of the working rotor blades [18].

It could be used in household windmills with small wind turbines with a vertical axis of rotation. It would have the purpose of producing electricity. Turbines, however, are expensive and less profitable, because the rotor blades must be made of strong, heavy and expensive materials, as they can be destroyed by strong winds.

In the project inspired by nature [18] developed at the Lublin University of Technology the materials used were lightweight and cheap and had an automated system that protects the elements of the rotor.

In case of strong winds, the blades fold like the wings of a butterfly, so they avoid destruction. The concept of the described wind turbine with a variable angle of flare between the two working surfaces is shown in Fig. 15 [18].

Fig. 15. Wind turbine [18]

4. CONCLUSIONS

Wildlife and living organisms surrounding us are a huge repository of knowledge and inspiration for researchers and engineers. Bionics is developing very quickly. This is supported by the vast amount of research done on it, as well as the large number of devices inspired by nature. Projects which were created based on the basics of bionics offer many possibilities. The resulting innovative solutions are characterized by improved properties and greater efficiency compared to older, classical elements. Moreover, these are mostly ecological solutions. It seems that in a short while we will see the influence of this growing field on everyday objects.

Summing up the definition of bionics as well as the principle of bionic research it can be said that bionics is the study of biological systems in order to apply their rules in the design of technical systems. The whole process is derived from knowledge about nature, where through the transfer of information including the analysis of natural methods and understanding of principles, technical knowledge is acquired which allows for implementation.

In recent years, there is a clear growing interest in bionics and its related fields. This is due to the continued need for development and the need for finding new technological solutions. It is used increasingly in the aerospace industry. Over the past several years the interest in smart materials has also increased. These materials have become the subject of tests because of the possibility of their of pro-innovative practical use in many fields of science and technology. A more recently used solution is the innovative combination of bionics and the use of smart materials. This is the future for the development of many fields of science and industry.

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BIONIKA W LOTNICTWIE

Streszczenie

W niniejszej publikacji bionika jest przedstawiona jako obszar wiedzy i inspiracji w technologiach lotniczych. Bionika jest dziedziną nauki na pograniczu sztuki i biologii, która bada funkcjonowanie żywych organizmów, a także ich budowę, w celu wykorzystania uzyskanych wyników do budowy urządzeń technicznych. We wprowadzeniu została opisana definicja bioniki. W kolejnej części pracy omówiono technologie lotnicze inspirowane naturą. Następnie, są zaprezentowane technologie inspirowane skrzydłem motyla. Praca kończy się podsumowaniem.

Słowa kluczowe: bionika, lotnictwo, skrzydło motyla.