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A Review on Applications and Effects of Morphing Wing Technology on UAVs

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Abstract

Unmanned aerial vehicles (UAVs) have excelled with their ability to perform the intended task on or without personnel. In recent years, UAVs have been designed for civilian purposes as well as military applications. Morphing wings are changeable wing applications developed as a result of the need for a different lift and drag forces in various phases of the flight of aircraft. It is an application that enables altering the wing aspect ratio, wing airfoil, wing airfoil camber ratio, wing reference area and even different angles of attack are obtained in different parts of the wing. Although morphing wing application has just begun on today's UAVs, modern airliners already have morphing wingtip devices such as Boeing 777-X's. The benefits of the use of morphing wings for UAVs make this technology important. UAVs with morphing wing technology; may increase its payload ratio, may achieve a shorter take-off distance, may land and stop in shorter distance, may take-off where runway clearance is limited, has more efficient altitude change at lower engine RPMs, can obtain higher cruise speeds, may decrease its stall speed, may lower its drag if necessary, thus; saving energy and time. This study concludes a review of literature over morphing wing technology.

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1. Introduction

The purpose of the morphing wing is to increase aircraft performance in different flight phases. Performance parameters that can be developed with the morphing wing concept; are important parameters such as maximum speed, fuel consumption, maneuverability, carrying capacity, range, durability, stability. Improving some or all of these parameterrs will increase flight efficiency and expand the possible mission profiles that the aircraft can perform. Improvement of performance parameters can be achieved especially by changing the wing section and air net shapes.

Changing the wing planform; while it means changing the wingspan, chord length, arrow angle, dihedral angle and some geometric parameters such as wing camber, the airfoil change can be achieved with morphing parameters such as maximum thickness and camber line curvature. Many studies have been conducted on small-scale models that allow changes in one or more of these geometric parameters and the wing morphing concepts.

Abdulrahim and Cocquyt [1], have conducted studies on flexible wings on micro aircraft that allow complex wing shapes at the University of Florida. With these wing surfaces, active flight control was attempted to be made possible without the control surface during the flight (Fig. 1).

After the complex wing study at the University of Florida, seagull wing studies were carried out to increase flight stability [2]. With a mechanical system, the wing dihedral angles were changed and their effects on flight stability were examined (Fig. 2).

Abduldrahim [3] designed, produced and tested partitioned wings in order to increase the aerodynamic efficiency by performing the lift-drag ratio optimization

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in the unmanned aerial vehicle. The movement of the partitioned wings is provided with the help of servomotors (Fig. 3).

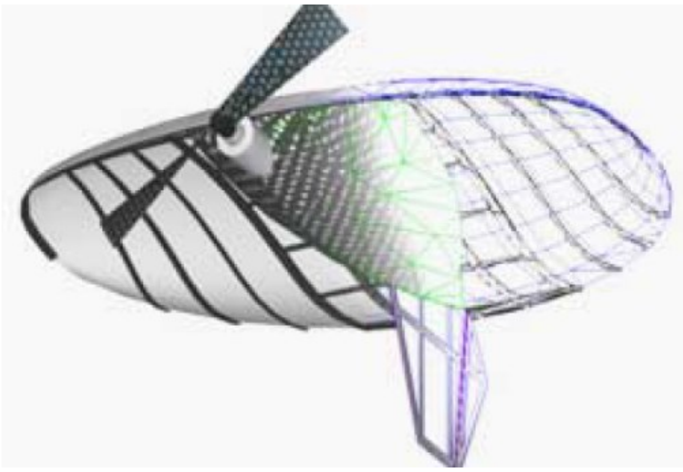


Fig. 1. Complex wing [1]

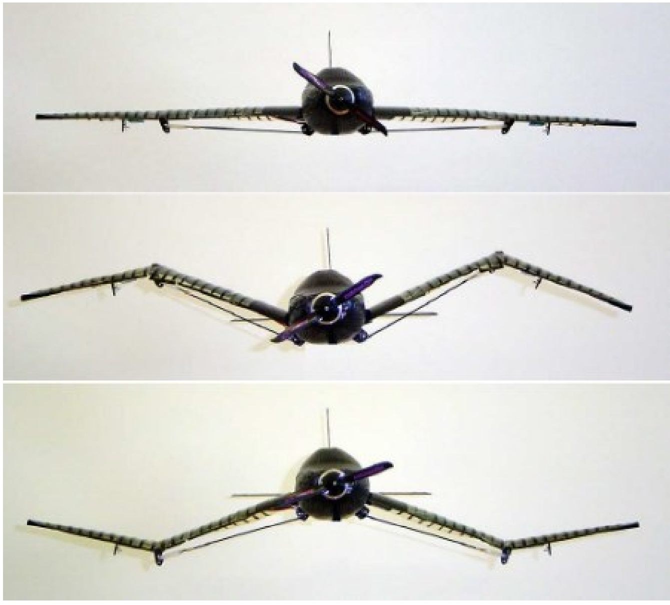


Fig. 2. Gull-Wing that changes shape [2]

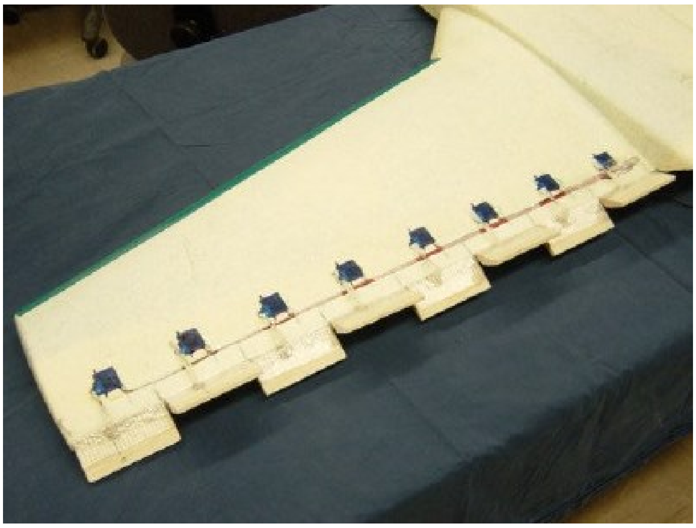


Fig. 3. Partitioned wing [3]

Another wing oriented project, aimed to reduce the weight of the wing by producing inflatable wings activated by piezoelectric actuators and to change the lift and drag coefficients of the wing by changing the camber line during flight [4] (Fig. 4).

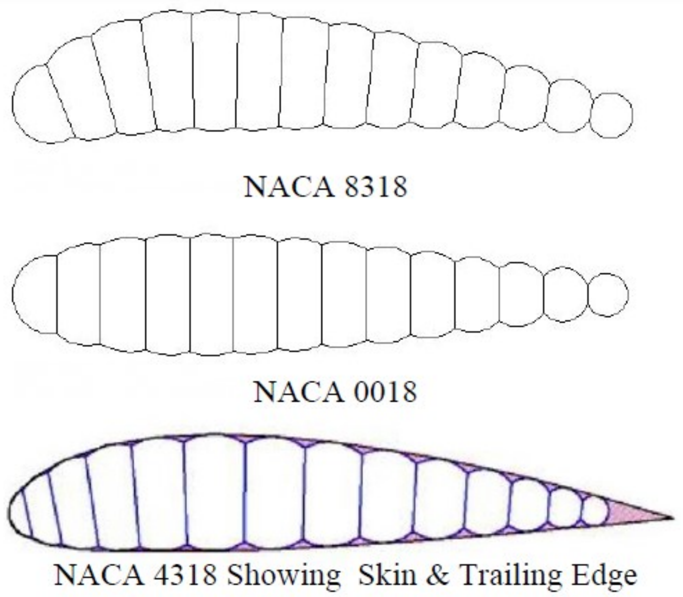


Fig. 4. Inflatable wing application [4]

In the study, it has been suggested that the inflatable wings can be nested with a telescopic system over the spars, thereby increasing and decreasing the wing area at different stages of the flight. It was also mentioned that this kind of wing design will contribute to the placement of the plane in a way that it can take up less space (Fig. 5).

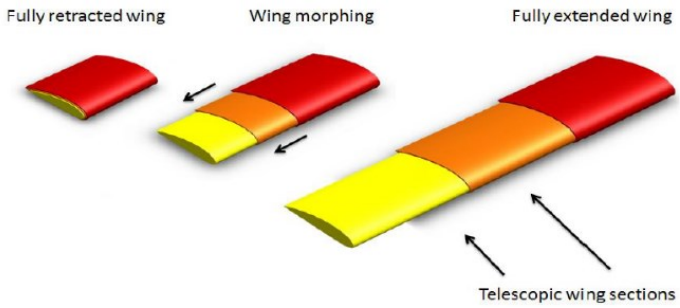


Fig. 5. Telescopic wing application with the use of inflatable spar [4]

With the inflatable wing application, Bat type wing modeling of Next Generation Aeronautics manufacturer in Fig. 6 and 7, respectively, and Z type wing modeling of Lockheed Martin manufacturer company are mentioned in the study. It is not possible to produce such wings with conventional wing design and production methods. However, these morphing surfaces can be obtained with the inflatable wing.

In a morphing winglet study researchers aimed to reduce the induced drag in various phases of the flight and to control the wing tip losses more clearly with the morphing angle winglet application they designed by designing in their study [5]. (Fig. 8).

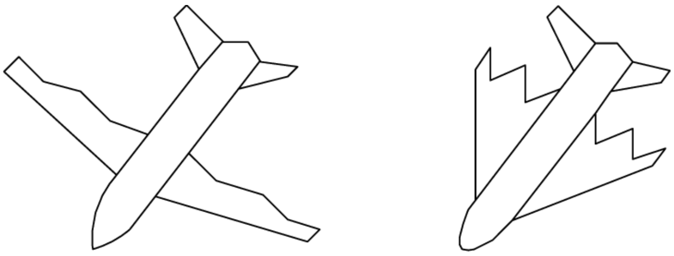


Fig. 6. Bat-type wing modeling of Next Generation Aeronautics [4]

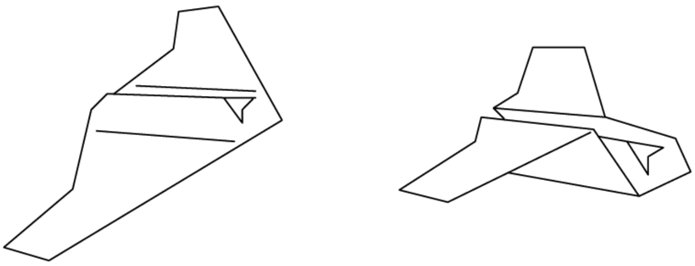


Fig. 7. Z-type wing model of Lockheed Martin company [4]

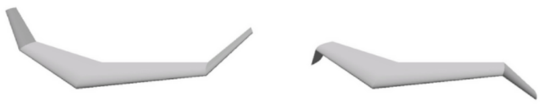


Fig. 8. Morphing angle winglet application [5]

Fig. 9. Flexible winged albatross water bird [6]

The morphing surface concept is used with the materials that can change shape and return to their original state after this change. The main benefit of the morphing wing concept is its high energy efficiency. The first starting point of the concept is inspired by large-winged animals, such as albatross, which can glide for miles over long distances, using only the flexibility of its wing, with a minimum drag of miles (Fig. 9).

The application of the morphing wing to the aircraft can result in the removal of many handicaps by achieving long gliding distances and durations, low drag force and high lifting force, just as the Albatross bird does.

Morphing wing that changes the aerodynamics of the plane according to the different phases of the flight; In the T / O, G / A, APR and LND phases of the flight, it can provide more efficient and safer flight phase time by increasing the airfoil performance. More efficient engine designs, lower engine noise levels, lower fuel consumption and greatly reduced runway area required, as well as the increase in the achieved thrust efficiency, both make the morphing wing concept more attractive and play a role in guiding the sustainable aviation of the future.

2. Wing Morphing Methods

The morphing wing does not only mean wing-shape change but also covers the characteristics of wing characteristics and performance changes, so we can say that it is a whole of scientific studies and research that sheds light on the progress of both military and civil aviation sectors. Unfortunately, the morphing wing structural application, which has not yet taken its place in mass production benches and aircraft factories, is only subject to research for now, and if it is considered as a production stage, it is produced only as a prototype. The reason for not being able to take its place in serial production benches is that it is necessary to work with high precision and meticulousness during the production phases, as well as the materials to be used in the production of more morphing wings can not be of the desired properties and the desired structural strength and wing stiffness can not be provided when necessary.

Research on morphing wing concept and application shows us that this wing design and production, which is very advantageous, is generally not preferred due to its production difficulties. According to the information obtained from the researches, if a morphing wing of mass production is desired, a great number of people from various disciplines should come together and conduct sensitive research and reveal a design and engineering wonder that the entrepreneurs can undertake with peace of mind.

If we classify the researches on the subject of morphing wing, we have focused on two different subjects. Although a small part of the researches on this subject is encountered in the study of the materials and materials that will be used in morphing wing production, we often encounter various design studies on the morphing wing.

2.1. Morphing Wing Studies Using Material Technology

Kuder et. al. [7] conducted research on shape memory alloys, shape memory polymers, elastic memory composites, shape memory composites, fluid filled flexible composites in flexible material research at the

Zurich Structural Technologies Center, which conducts morphing wing production material research. In this study, the results of the use of sandwich composites in morphing wing production have been investigated. Although pneumatic force-operated air balloons are used to make the honeycomb structure to be used in the sandwich composite structure, a test image quoted in Fig. 10, has been used, a material that will cover the honeycomb structure and will not lose its strength despite reaching great flexibility has not been found.

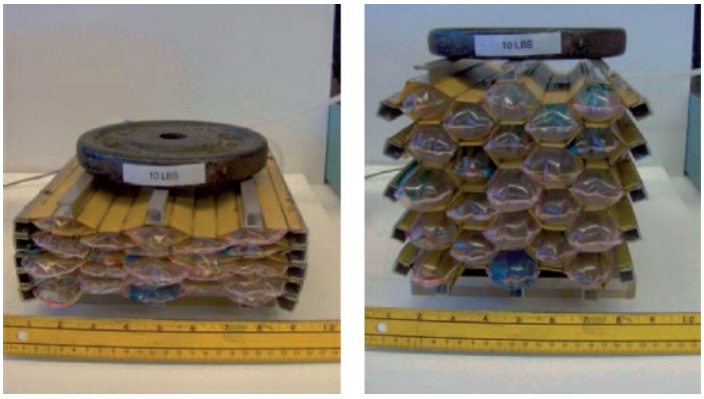


Fig. 10. Honeycomb that changes shape by balloons inflated with the help of pneumatic force [7]

Lee et. al. [8], at the Nanyang University of Technology in Singapore, a UAV was made using a flexible membrane with a tendon structure similar to the skeleton-muscle system in anatomy (Fig. 11). In this prototype, which has no contribution to increase flight performance, it is aimed to produce only a modularity and a portable platform, and researches on material technology have been made on it.

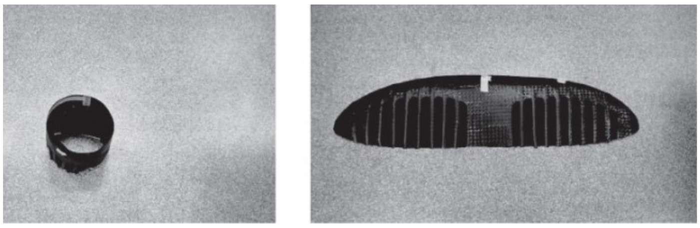


Fig. 11. Foldable wing designed as a tendon structure [8]

Dayyani et. al. [9], in their study, they produced a wing structure which was obtained by using honeycomb and only the wing trailing edge has a shape-changing structure. The trailing edge of the deformed wing applied in this wing has acted as the basic flight control surfaces, increasing its mobility to a certain extent.

Diaconu et. al.[10], performed research that investigates the potential of using bi-stable laminated composite structures for morphing an airfoil section. In the project, the researchers identified geometry and lay-ups for a candidate configuration. Thermal curing has been applied to achieve bi-stability. It has been discussed that the bistable flap-like structure at the trailing edge of the airfoil found the most adequate from a manufacturing point of view.

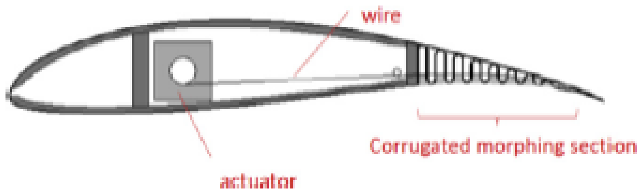


Fig. 12. A semi-deforming wing obtained using a corrugated structure [9]

Tong et. al., [11], studied a topology optimization for adaptive leading edge using composite materials. The researchers used glass fiber reinforced epoxy composite plates based on the symmetric laminated plate theory. An optimization has been performed to achieve the desired curve and aerodynamical shape on the airfoil. A prototype was manufactured during the research for testing purposes which verified the morphing capability of topology structure and illustrated the feasibility of the technique.

A poly-morphing winglet development based on material technology was carried out by Ursache et. al., [12]. The morphing winglet demonstrator that was designed in the project established the feasibility of scalable technology integration for product development, material compliance, mechanism kinematics, and experimentation. Potential composite materials for flexible skins were assessed which were Hexweb, Kevlar49, and Hexply. An aluminum mold for the corrugated skin was manufactured during the project. A Kevlar corrugated skin was manufactured and its performance was investigated both numerical FEM methods and function tests. The paper presented a demonstration of the final prototype that can achieve 30 degrees of dihedral angle and 5 degrees of twist angle.

Digital Morphing Wing concept was presented by Jenett et. al., [13] which uses composite lattice based cellular structures for active wing shaping. The researchers described an approach for the discrete and reversible assebly of tunavle and actively changeable structures by employing modular block parts. The approach presented by researchers offers a number of potential benefits over conventional methods. The discrete assembly provided a reduce in the manufacturing complexity. The case study in the paper presents a modular and reversibly assembled wing that can perform continious span-wise twist deformation. The presented design was reported as lightweight and easy to repair. The design for the airfoil was based on the NACA 0012. Waterjet cut carbon fiber lattices were used as wing ribs with a flexible wing skin. Tip twist of the wing was actuated via a flexure arm. The resulting design had ability to +10 and -10 degrees of twist along the span. Wind tunnel tests performed during the research have been suggested that the digital morphing wing has the ability to increase the roll efficiency compared to a conventional rigid aileron system.

2.2. Morphing Wing Studies Using Mechanism Design

The "Zigzag" wing box design for a span morphing wing has been introduced as a mechanism design by Ajaj et. al.[14]. The Zigzag wing box concept enables wingspan to be changed by 44%. The design allows wingspan to extract and retract 22%. The right part has been kept as a fuel tank housing and used to transfer the morphing loads t the fuselage. The morphing partitions have been designed with two spars each have two beams hinged together. The morphing partitions have been covered using flexible skin and bounded by two wing ribs. The Zigzag wing box design was incorporated in the rectangular wing of a MALE UAV to enhance its operational performance and increase the roll control. The research presented feasible results on using Zigzag wing box design to increase UAV performance capabilities.

One of the design ideas found in the literature was the usage of the "belt-rib" concept to varying the camber of the airfoil which was based in a paper published by Campanile and Sachau, [15]. The belt rib idea used structural flexibility instead of mechatronic solutions which includes hinges or linear bearings. The resulting system was both structurally reliable and lighter. Although, the system was easier to maintain due to the absence of a joint wearing problem. The belt rib project was accompanied by experimental tests on different prototypes. Then a prototype was selected to further developments which were manufacturing, weight optimization, and strength aspects. The researchers used a hybrid glass fiber-carbon fiber-reinforced composite structure and the model was actuated by cables. The paper provided valuable data for further researches by presenting the major advantages of a structronic approach.

A project with a novel design was presented by Di Luca et. al., [16], which includes the design, testing, and flight validation of a UAV that has a featherlike partitional morphing wing like the birds have. The design in the study is composed of artificial feathers that can rapidly modify its geometry to fulfill different aerodynamic requirements. The paper presented that a fully deployed configuration increases maneuverability while a folded configuration offers lower drag force at high speeds. Also, the asymmetrical folding of the wings has been shown as a method that can be used for roll control. The aerodynamic performance of the wing was assessed in simulations and wind tunnel measurements. A comparison between CFD and wind tunnel results were performed. The flight-testing data was also provided which includes inertial measurement unit provided data on maneuverability of the mini UAV.

Gamboa et. al. [17], in their study, designed a morphing wing design that changed the shape and therefore the characteristic of both the wingspan and the wing when viewed from above.

In this design, each wing consists of three parts. These; The rotary shaft charge edge is the rotary shaft charge edge and the rib expansion mechanism that provides the connection of these shafts (Fig. 13).

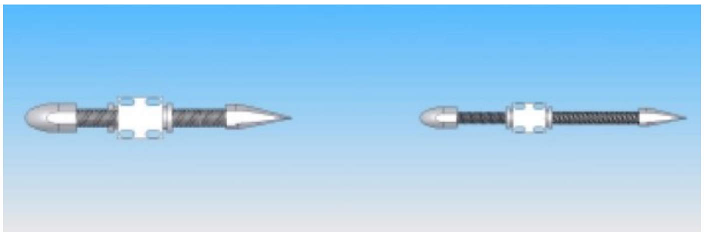


Fig. 13. Morphing wing application that can be changed wing area [17]

During the production of the parts, it was produced from both acrylic material with the help of 3D printer and aluminum material on CNC machine. Although the weight of the pieces obtained is almost the same, the material chosen in the prototype production is aluminum because aluminum can withstand a pulling force of 160 MPa. Thanks to these parts, a trapezoidal, rectangular or elliptical wing can be obtained by changing the wing shape, while at the same time, the wing area can be changed by increasing the distance between the edge of attack and trailing with the help of rotary shafts.

Wang et. al., [18], performed a modeling study on multisegmented folding wings. The study included a general aeroelastic model that predicts flutter speed and flutter frequency of a folding wing with simple geometry. The structural model derived from Component modal analysis that used to derive the structural equations of the folding wing system. Experiments have also been applied after the theoretical study, three configurations were manufactured to study the behavior of two segments, three-segment, and four-segment folding wings. The experimental setup consisted of an accelerometer, an amplifier, an acquisition device, and Labview software for analysis. One of the several trends in the test cases was the flutter frequency. The flutter frequency typically decreased as the fold angle becomes more positive. From the tests, it was observed that from the zero outboard fold angle to either positive or negative 75 deg outboard angle the four-segment wing flutter speed increases 30%. This result suggests that a folded wing can increase the aeroelastic stability and extend the flutter boundary.

The wing section, which is of great importance with this morphing wing study, cannot be changed. As a disadvantage of this, it can be shown that the wing section, which has to be permanently fixed, in addition to the wing area and the changeable wing shape, cannot change to more cambered airfoils.

Jankee and Ajaj, (2018), In the study they carried out at Southampton University, researchers made an application that can only change the wingspan in a wing morphing study. In this application, a material application requiring surface flexibility is not required.

In practice, it is based on the logic of pushing an additional small wing hidden in the main wing to the end of the wing and locking it in the desired position with the help of servo motor power.

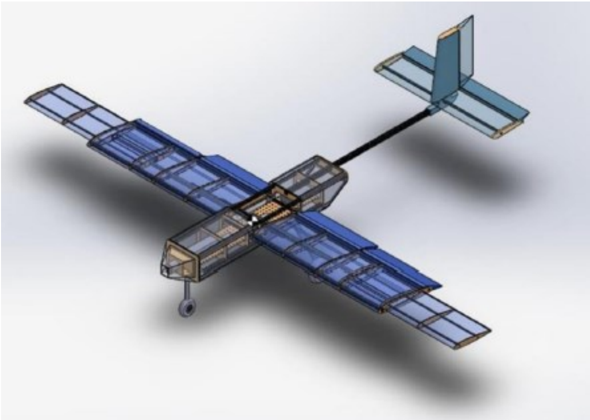


Fig. 14. Morphing wingspan with adjustable wingspan [19]

While it can be shown as the wingspan and wing area as the advantage of the application, the disadvantage is again that the camber cannot be changed and the aircraft has to complete the flight with the same wing section in all phases of its flight. The technical drawing of the design is given in Fig. 15.

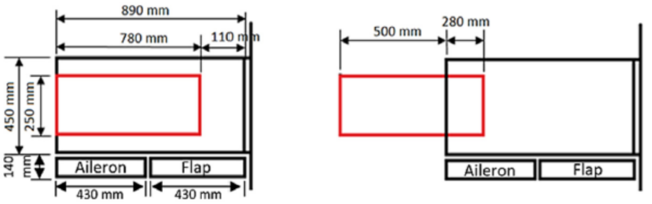


Fig. 15. Technical drawings of the wingspan changeable wing [19]

Hui, Zhang and Chen [20], in their study, examined the aerodynamic performance of the deformable winged drone aircraft used in nature emulation. They designed a deformation mechanism similar to the large deformations achieved by the bones and cartilage on the wings of birds. In the study, a pigeon wing was chosen for simulation. A structure similar to the pigeon wing was obtained by using rigid and flexible structures together (Fig. 16).

The wing created in the study was placed on the outer wing of an unmanned aerial vehicle. Two different states of the tip of the wing are defined as fully open and fully backward angle. With the computational fluid dynamics analysis and wind tunnel tests performed on these two conditions, the change in the coefficient of lift and drag in two states was tried to be revealed. In Fig. 17, the graph of the coefficient of lift with the angle of attack and the graph of the drag coefficient with the angle of attack are given. In the graphics given in the Fig., the difference between the discrete form of the wing and its continuous form is shown with curves.

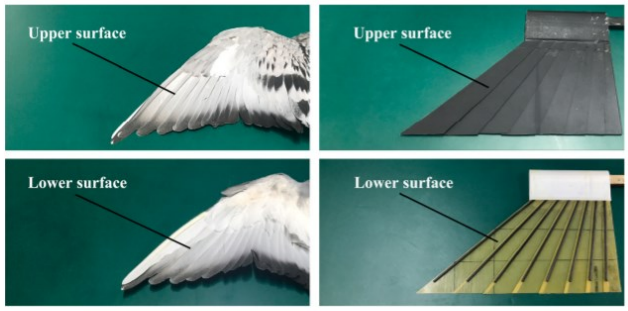


Fig. 16. Pigeon wing and nature simulated wing structure [20]

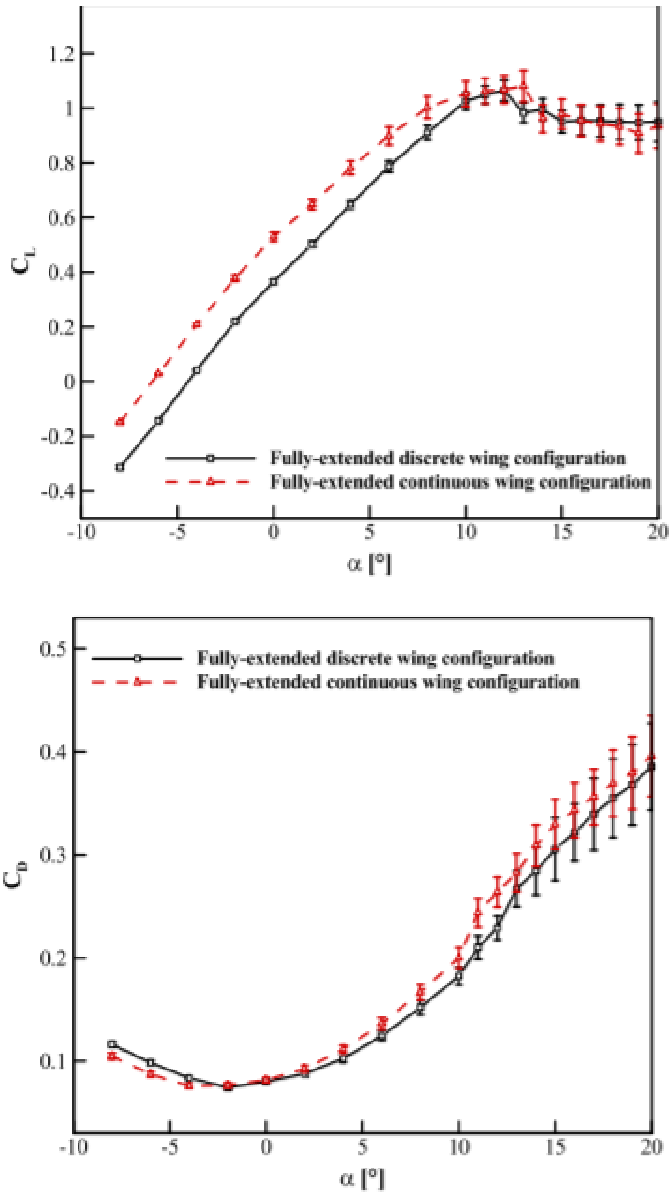


Fig. 17. Variation of Lift Coefficient and Drag Coefficient with Angle of Attack [20]

In the graphics given in Fig. 17, it is seen that the wing form with continuous structure provides an increase in the lift coefficient and does not cause an increase in drag in a low angle of attack. In other words, the aerodynamic efficiency of the aircraft has increased in flight phases performed at low attack angles such as cruise flight.

Kan et. al. [21], in their study, made it possible to delay the stall state and change the critical stall angle by rotating the trailing edge in a wing section. In the study, a NACA 0012 symmetrical wing section was modeled with a flexible trailing edge. On this flexible trailing-edge wing section, the portion of the chord up to 60% from the edge of the is fixed and the rest is modeled as in Fig. 18.

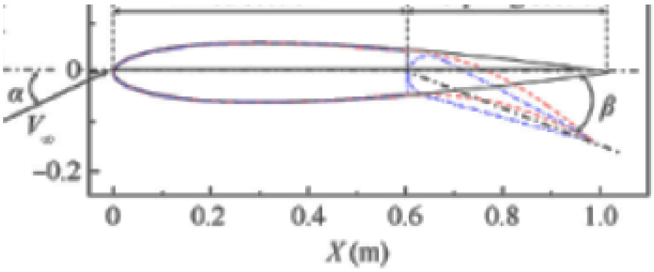
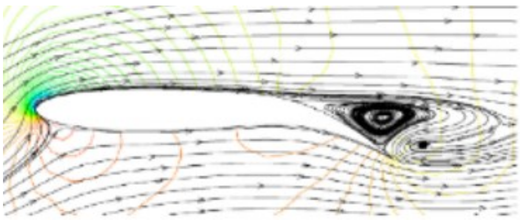
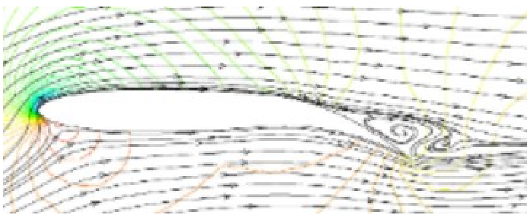


Fig. 18. NACA 0012 wing section model [21]

On the model created in the continuation of the study, the flexible part will remain static and 1.33 Hz. Two models were subjected to computational fluid dynamics analysis, moving at a frequency between the normal state and the flexed state. As a result of the CFD analysis, the eddy formations given in Fig. 19 were seen.



(a) Static



(b) Dynamic

Fig. 19. CFD Analysis results [21]

As a result of the study, it was observed that the stall state of the wing section can be delayed by performing periodic shape changes on the trailing edge. In addition to this result, the information that the coefficient of lift increased with periodic shape change is given in the results section.

Wu et. al. [22], in their study, investigated the effect of changing the surface of a solar powered unmanned aerial vehicle with Z-shaped wings on energy optimization. Solar powered unmanned aerial vehicles produce electrical energy during the flight with solar panels on their wings. The positioning of these panels in such a way that the sun's rays are perpendicular is important in terms of energy efficiency.

In the concept design that they carried out, the researchers revealed that, with a wing that can take the form Z in Fig. 20 according to the angle of arrival of the sun, more electrical energy can be obtained than the planar wings.

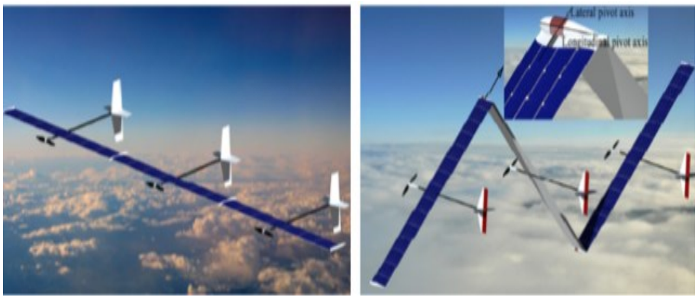


Figure 20: Planar and Z wing designs [22]

With the model they created, the researchers calculated different amounts of electrical energy generated by the beam angles coming to the solar panels. The results obtained are given in Fig. 21.

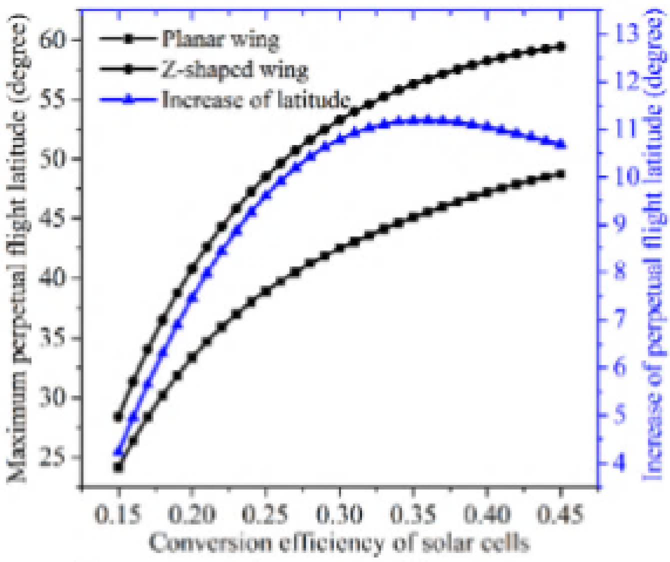


Fig. 21. Planar wing and Z wing solar panel efficiencies [22]

From the graphic in the Fig., it is seen that Z wing provides higher efficiency than solar panels in continuous flight compared to planar wings. In addition, the angle variations experienced during the flight between latitudes around the world make it difficult to travel with solar energy in certain latitudes due to the elliptical orbit around the sun. In the latitudes and in winter days close to the polar regions, the results of the study are given that the flight with the Z wing will provide a more efficient energy conversion performance than the planar flight.

Ajaj et. al. [23], presented a paper that develops a novel span morphing wing concept, the gear-driven autonomous twin-spar (GNATSpar) mini UAV. GnatSpar has proven the ability to increase span extensions up to 100%. For demonstration purposes, it kept in 20% in the study and provided a reduction in induced drag and increased the flight endurance. The GNATSpar wings were designed as overlapping structures and bearings which is in a telescopic form. A physical prototype was also developed and the test results on 7'x5' wind tunnel of the University of Southampton were also presented in the study. The graphs provided in the results of the paper were indicated that at all three different speed regimes that tests were applied, L/D ratio increases with the span increment.

Woods and Friswell [24], have introduced a new surface change concept that will increase the span ratio of the aircraft wing. The concept they designed includes a telescopic wing beam structure and wing ribs that open in the form of an accordion. A driver motor aid is pushed out of the outer part of the spar inside the wing. Thus, the wing takes its form seen in Fig. 22. With this deformation process, the wingspan and span ratio are increased.

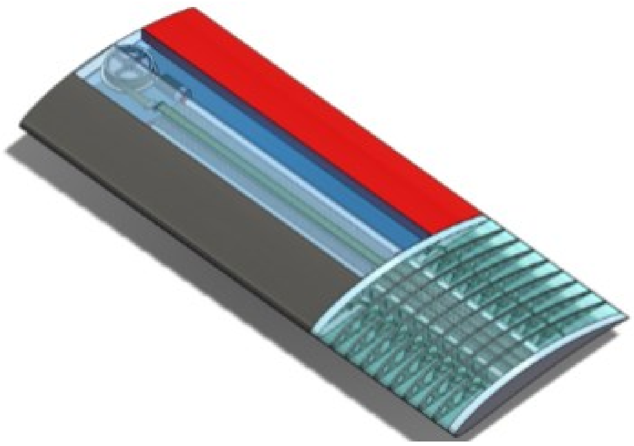


Fig. 22. Wingspan increment mechanism design [20]

Apart from the fixed-wing aircraft surface designs that utilize morphing technology, the rotary-wing aircraft also provide a field to improve the performance within the usage of morphing surfaces. Vocke III et. al. [25], have performed a study that presents the design and validation results for a quasi-static morphing helicopter rotor blade with an adaptive tip. The adaptive tip had the ability to increase its local span by 100% with the constant chord. The design of the morphing airfoil structure consisted of polyurethane sheets and unidirectional carbon fiber layers. The EMC skin was analyzed using linear and nonlinear Finite Element Method analysis to ensure the in-plane stiffness. A genetic algorithm was applied to search the entire design space for minimum mass designs. As a result of the project, a light final design was presented that matches the stiffness design goals.

3. Parameters That Coulds Change Using Morphing Wing

There are original designs as discussed in the literature with the concept of morphing wing. Each design was developed with a focus on a different performance parameter or parameters. While some morphing wing designs focused on changing only one parameter, some morphing wing designs tried to develop more effective designs by focusing on multiple parameter changes. In this section, which purpose these changing parameters serve and which parameters are made for changing designs are examined.

3.1. Changing the Wingspan and Aspect Ratio

The concept, called the wingspan, is the distance between the two ends of the wing. The wingspan ratio is the ratio of the span of an airplane wing to the average chord length. If the chord length is not constant across the span, it is the ratio of the square of the wing span to the wing top-view area.

Changing the wingspan, which is one of the wing characteristics, is considered as an important characteristic feature for a UAV in flight phases where high lift force is required. Due to the increasing air traffic in today's aviation, aircraft with high wingspan are not preferred by companies and squares, and smaller planes are thought to have more returns.

Although the low wingspan is seen as an advantage by companies and squares in terms of occupying space in the hangar, aircraft with low wingspan lose their advantages in the phases of the flight, where the lifting force per m2 is desired. This can be achieved only if the wingspan values varying in the air and on the ground can only be achieved with the application of morphing wings.

3.2. Changing the Wing Area

It is only possible to provide the high lifting force needed during the take-off and landing phases of the flights, but it is only possible to achieve as high lift force as possible by using it in certain parts of the wing. Increasing the wing area means increasing the surface from which direct lift force is obtained.

Increasing the wing area will allow for the increase of carrying force and naturally to pass the landing and take-off phases more easily. Nowadays, only the flap strength and flow characteristic allow the wing area to increase, while this handicap can be eliminated with the use of morphing wings. The increase of the wing area obtained by using the morphing wing can be supported by the increase in the camber, and the lift coefficients in the wing can also be increased. If the deformed surfaces can be achieved by using conventional high conveying devices, a more efficient flight can be realized. In addition, both cost and time can be saved in the maintenance of these control surfaces, hinges and other sub-parts.

3.3. Changing the Airfoil and Wing Camber

The ability to change the wing section allows different performance values to be obtained in different phases of the flight. A wing's profile can directly change flight performance, efficiency, savings and comfort. With the profile change, desired flight speed, desired drag amount and desired cambered can be achieved. With the morphing wing, the desired profile shape can be obtained in the desired phase of the flight. This is one of the features that make the use of the morphing wing perhaps the most attractive. Fig. 23 shows two profiles obtained from the same wing by the blow molding method.

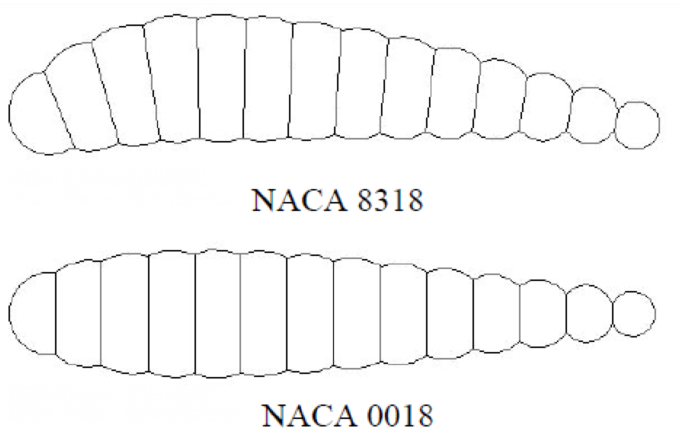


Fig. 23. Profile change with inflatable corrugated structure [4]

Communier et. al., [26], studied a design and validation for a new morphing camber system. The project included both design phase and the testing process of the final aerodynamic shape on wind tunnel. The morphing camber system that designed in the project consisted of a combination of two subsystem which were the morphing trailing edge, and the morphing leading edge. Results in the study provided the effect of each subsystems combined without interference with each other. The results of the study indicated a drag reduction on UAVs. In the case study which was carried out during the research, the morphing camber system was found to allow a reduction of the drag when the lift coefficient was higher than 0.48.

For example, a UAV can switch to a more cambered profile, the NACA 8318 profile, to carry out its take-off easily and with shorter distances with the help of high lifting forces. When it comes to flat flight altitude, it can switch to NACA 0018 profile, which is a symmetrical profile that can reach higher speeds, produces lower pitching moment and less drag force. When the UAV, which completes the cruise flight, switches to the landing phase, it can again switch to a more cambered profile, the NACA 8318 profile, and regain high lifting force. Within this scenario, the aerodynamic efficiency increase that can be achieved by changing the wing section and cambered can be understood.

4. Conclusions

The use of a morphing wing allows the aircraft to have more than one characteristic, regardless of a single characteristic. It is a very important application for achieving future developments and popularity both in the UAV sector, civil aviation sector and military aviation sector, by performing the desired characteristic changes in the desired phase of the flight, by switching to the desired characteristic features. Researches show us that even though morphing wing production is not easy, as it starts to take its place in mass production benches, the needs of human beings in terms of aviation will be met at a higher level and if so to speak, sustainable aviation will continue to put bricks on its wall.

Considering the harmfulness of the raw material and fossil fuel market, which decreases day by day, to the economy and the environment, the use of morphing wing designs in both passenger and military fighter jets and UAVs helps to reduce the consumption of raw materials and fossil fuels to a lesser extent, Thanks to the increased flight comfort, it will both increase the interest in the aviation industry and lead to a decrease in the casualties caused by traffic accidents as the rate of travel by plane, which is the safest form of lift in the world, will increase.

The use of morphing wings will undoubtedly bring great advantages with its use in the future. With the advancement of production techniques with technology and the most accurate design in the use of morphing wings, morphing wing application will take its place in mass production machines in the short-term future. The shape-changing construction that has just been tested on the wing will perhaps be tried for all aircraft components in the future and will lead to a useful technology for everyone with a more advanced production.

We can try the steps of contacting the entrepreneurs and the manufacturer companies to make a morphing wing design that changes more performance parameters using the materials and production techniques used in the researches conducted so far, and if the prototype of this design is tested, if positive results are obtained, to proceed with mass production.

The production of skeleton parts can be tried with the help of parts obtained from 3D printer in terms of ease of production and variety in the material production stage. Since flexible composite production is difficult in the wing outer surface coating, a different surface coating model may be considered. In addition, all the advantageous aspects of different shape changes that have been tried in different studies so far can be collected and applied in a single wing and the effects can be investigated. The most suitable of all methods that can be used in multiple surface changes.

The production of the parts that provide mobility with less cost and less weight can be applied in future studies.

Abbreviations

UAV	:	Unmanned Aerial Vehicle
RPM	:	Number of Spins per Minute
RC	:	Radio Control
CG	:	Center of Gravity
CT	:	Central Tank
TT	:	Trim Tank
T / O	:	Takeoff
G / A	:	Go Around
APR	:	Approach
LND	:	Landing
3D	:	Three Dimensional

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