

## **Pertinent Smart Materials to Improve Aerodynamic Efficiency**

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### **Abstract**

The morphing technology, inspired by bat and bird flight can enable an aircraft to adapt its shape to enhance mission performance and optimize flight altitude controlling efficiency. Present day aircraft structure is greatly influenced by morphing at different points of time. Morphing indicates gradual change in the shape of any object by varying the cross section. It is achieved with the help of electrical actuators in the earlier scenario and gets upgraded with smart materials like Piezo-electric and shape memory alloys. Among the identified smart materials, Shape memory alloys have attracted a great interest by many researchers as a promising morphing wing material because of its shape recovery upon application of voltage. Shape memory concept refers the property of a material or an alloy which regains its original shape when external load or electrical energy is applied. The design possibilities in the field of aerospace engineering are advanced by the unique thermal and mechanical properties of shape memory alloys now a day to improve the aerodynamic efficiency. This paper presents the feasibility analyses of employing the shape memory alloy to modify the traditional flap in an aircraft wing. The published literatures were reviewed under this ground. This paper unveils the applicability of the smart materials in the field of aeronautical engineering for the performance improvement.

**Keywords:** Morphing technology, Aircraft, Structure, Electrical actuators, Piezo-electric, Shape memory alloys, Aerospace engineering, Flap.

## 1. Introduction

The morphing concept is widely focusing on the adaptability of the aircraft to enable the optimized performance. This would make the aircraft to perform viable in fast and as well as in slow condition to work efficiently. This paper will reveal some of the historical example where morphing concepts are used, which can fly efficiently at various flight conditions for various missions. The morphing wing has attracted many research attention and effort in the aircraft technology development because of its advantage in lift to drag ratio and flight performance. Morphing wing technology combines the lift and control surfaces by modifying its shape. Since from the Wright brother concept, the morphing technology has adapted in large areas to increase the performance of the aircraft which work efficiently during each performance. Over a hundred years later, unconventional aircraft adaptability, often called "aircraft morphing" has become a topic of considerable renewed interest. In past two decades this interest has been largely fuelled by advancements in multifunctional or smart materials and structures. As said, "Necessity is the mother of invention", with each necessary flight condition the morphing concept has been applied from time to time. The conventional aircraft airplanes are generally optimized with bias towards a single design point; morphing vehicles are optimized for multiple design points. Since the beginning of the flight, the desired for more has pulled aircraft in the direction of multi-point optimized performance. Many decades ago, designers quickly exhausted the performance available with aircraft designs that were basically fixed. But after the introduction of the morphing concept these basic designs adopted itself to the upgraded trends.

## 2. Morphing

The term "morphing" refer to the airplanes with wings capable of significantly changing their planforms during flight as a result of a given input. Such ability has the potential of increasing the fuel, economy, mission adaptability, performance and flexibility. A more formal definition of a morphing air vehicle provided by DARPA (DEFENCE ADVANCED RESEARCH PROJECT AGENCY) that it uses a design that integrates innovative combination of advanced materials, actuator, flow controller, and mechanism to achieve the state change. This is done mainly due to the increase the adaptability, aerodynamic efficiency; eliminate the complex and heavy high lift device such as flaps etc., and its mechanisms. In the research field of aeronautics, a formal definition is not given to "aircraft morphing" that is universally agreed upon the technical community. One of reason for this disagreement is because of the discussion of how the morphing is done and, such as how large and in what way the transformation is accomplished. In morphing technology the use of smart material and structures while the others exclude the virtual shape change and flow control approach. But the vehicle mission will determines the best method to use not the definition of the terminology. Morphing is more appropriately focused on the mission requirement for transformation than the method or degree of transformation. The types of morphing

wings can be classified with regard to two purposes. The first one is to change the wing shape. Much research on the development of Morphing Aircraft Structures (MASs) has been carried out for the improvement of aerodynamic efficiency, and also for the development of an aircraft for the operating conditions or to improve mobility. These morphing aircrafts can perform multiple flight missions that are difficult to achieve using a fixed wing shape. Since the morphing concept is attracted from the bird's flight by analyzing the birds wing planform for different condition of its flight. The birds wing structure is analyzed at different flight condition at times of take- off, landing, loiter, fluttering.

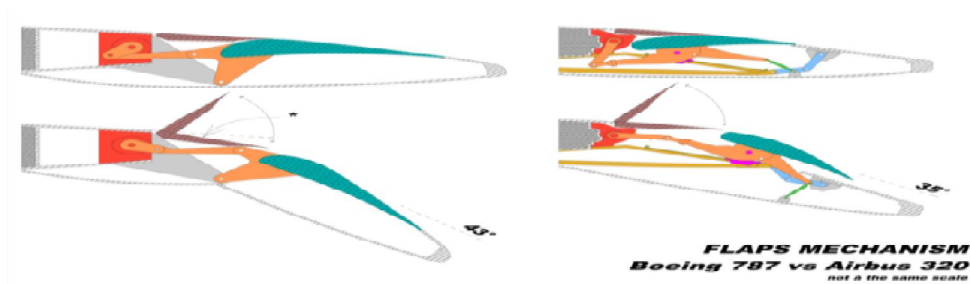
### **3. Smart Material**

In recent decades, materials science has drastically gained importance in view of the development of newer material with exotic properties, new process technique smart material performance etc. the development of multi-functional material is due to the demand for materials with additional engineering functionality such as sensing, actuation, electro-magnetic shielding, etc., it was discovered by Buchler and his co-worker from "NAVAL ORDNANCE LABORATORY (NOL)". Hence the discovery of nickel titanium shape memory alloy has got the name has "NITINOL". The shape memory alloy has a peculiar characteristic that when a load Or electric current is applied to the SMA it will regain its original position this effect is called "SHAPE MEMORY EFFECT" and the material which follow this effect is called "SHAPE MEMORY ALLOY". The formation and dissociation of phases of alloys at fixed composition is mainly because of the change in temperature. The shape memory alloys (SMA) are two phases namely martensite and austenite within the operating temperature region. At, high temperature, the material is in austenite (A) phase while at low temperature it is transformed in to martensite (M) phase. The smart materials played a major role in morphing technology which would make the configuration reliable, light weight, simpler structural configuration. Smart actuators are compact and light-weight solid-state actuators made of materials such as shape memory alloys (SMA), piezoelectric materials, or Magnetostrictive materials. The crystal structures of these materials change shape when subjected to external energy fields (heat source, electric field, or magnetic field). The crystal structure shape change results in bulk deformation of the material, which can be used for displacement or force actuation. Since the bulk displacement is the sum of the small deformation in crystal structure, the resulting output stroke is proportional to the overall dimension of the actuator. The output stroke in these "compact" actuators is, therefore, often limited in range.

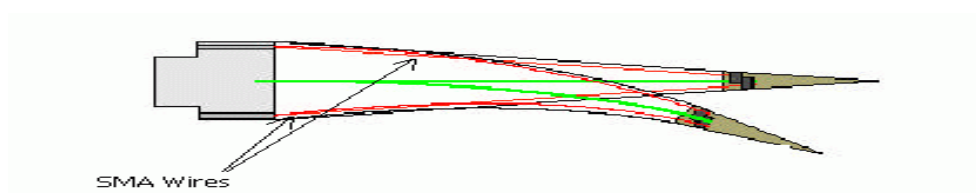
### **4. Development of Morphing Technology:**

Much research has been carried out for the development of aerodynamic efficiency, and also for the development of an aircraft which can fly efficiently at various flight conditions for various mission. The types of morphing wings can be classified with

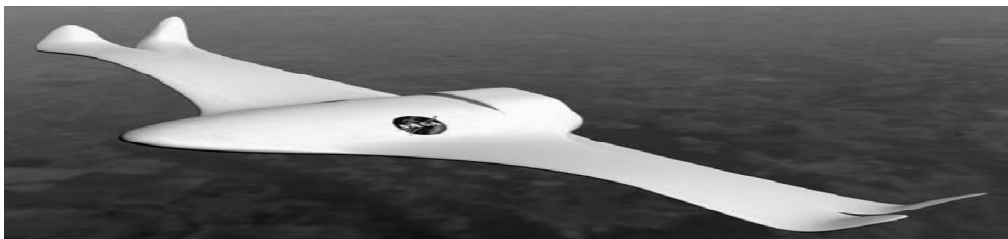
regards to two purposes. The first one is to change the wing shape for the operating conditions or to improve the mobility. These morphing aircraft can perform multiple flight missions that are difficult to achieve using the fixed wing shape. The other one is to maximize the aerodynamic efficiency by substituting the section that causes aerodynamic losses. Earlier in the deflection of the control surfaces such as flaps are done by push pull rods, electrical actuators, Piezo electric actuator etc.,. But now the deflection is done through “shape memory actuator” which is lighter and simpler in structure and reduces the structural complexity and it brings a continuous geometric surface which would increase the aerodynamic efficiency of the airplane.



**Fig. 1:** Deflection of flaps using electrical actuator or the conventional flap deflection.



**Fig. 2:** Deflection of flap using SMA actuator with a continuous geometry.



**Fig. 3:** NASA recent research about the morphing technology.

The above consecutive figure1 shows the deflection of flaps using electrical actuator, the next fig2: shows the deflection of flaps with a continuous geometry surface using “SMA ACTUATOR”. The fig3: shows the recent approach by “NASA’ using the “SHAPE MEMORY ALLOY” and without a control surfaces how we

achieve the maximum efficiency. Many Research activities on morphing of airplanes have been going on in USA since 2003 under the “Morphing Aircraft Structure” program supported by DARPA. The MAS program consists of three phases where there will be a development in each and every phase. In the figure 4- phase 1, it consists of research groups were the design and manufacture wings capable of changing their spans by 150% and associated subsystems to be tested in a wind tunnel. In the figure 5 - second phase, scaled wind models of full-scale airplanes were considered. As a result of the conducted research, two designs with substantially different approaches have been developed. The second concept is developed in the next generation concept is the “variable sweep wing”, “variable chord concept”. The next concept is the reduction of drag using “wing let”. The next concept of morphing is the inflexible wing ribs at the trailing edge were replaced with a few plates-like elements that are joined together and could rotate relative to each other.

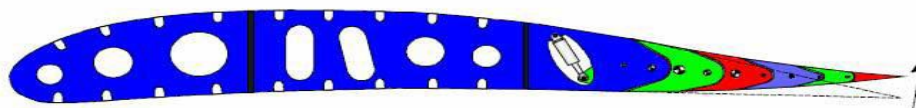


**Fig. 4:** phase 1 research groups of DARPA.



**Fig. 5:** “variable chord and variable sweep”

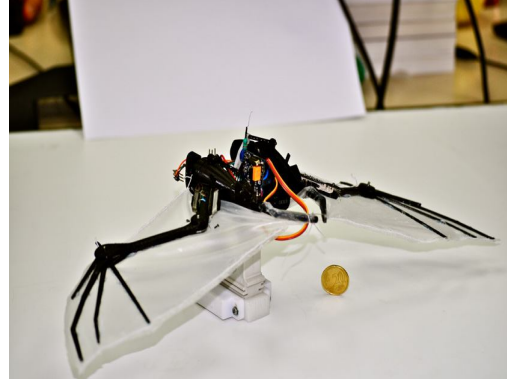
The next morphing concept is making the control surface which is shown in fig7 and fig2: with continuous geometry to increase the aerodynamic efficiency by the usage of shape memory alloy actuator. Since this being very compact and is very reliable hence the SMA is installed instead of complex electrical actuator which makes the structure very simple and hence making the aerodynamic efficiency to increase. Since this technology has more viably used in the used in the unmanned air vehicle mainly because of its feasibility design, reliability and flexibility. In the fig9: it shows many uav’s uses morphing concepts using shape memory alloy due to its advantages since it diverges a very simple and reliable expanders and fasteners. Similarly many concepts have been proposed using the smart materials. The shape memory alloys shown the figure8: are used in recent research concepts due to its flexibility, simple and reduces the complexity of the structure.



**Fig. 7:** morphing concepts of inflexible wing tips with finger like plates.



**Fig. 8:** shape memory alloy actuator



**Fig. 9:** Biomechanics of smart wings in a bat robot: using SMA actuator

## 5. Conclusion

Since the morphing technology is in its infant stage, the material and structures enabling a large scale shape changes are still in identification and development stage. Implementation of this technology will almost make the technology be in fixed wing and in unmanned air vehicle. The morphing air vehicles and associated technologies have the potential of introducing revolutionary developments to the aviation field. This will introduce the important improvement in the control mechanisms, performance, characteristics, fuel economics and weight of fixed wing airplanes. In considering the next century of flight, performance demands will likely continue to increase and even diversify. As with the dawn of powered of flight, it may be the dream and associated engineering curiosity that propels next leap. The morphing air vehicle will introduce revolutionary developments to aviation.

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