

Design and Realization of Single Axis Mechanism for Morphing Wing UAV

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ABSTRACT: A shape change in the wing at cruise has the potential to improve the Aerodynamic performance and Morphing on UAV is a challenging task. In recent years many researchers are working on the inventions in the field of morphing wing using hydraulics, electromechanical and smart material based actuation concepts and architecture. In this work the concept for actuating wing UAV design for single axis morphing has been addressed for the selected model for in-plane shape change. The sweep change mechanism has been adopted and analysed.

KEYWORDS: UAV, Wing, Morphing, Kinematics, mechanisms.

I. INTRODUCTION

Unmanned Aerial Vehicles (UAV) has ability to fly without human pilot onboard with or without carrying pay loads. It can be operated autonomously or by remote pilot within its range of operation. Its size may vary from small hobby plane to large ones comparable to global Hawk. This may categorized through HALE and MALE. In earlier days the application of UAV was restricted to military purpose only. They are becoming very popular in daily life for the purpose of reconnaissance and for the surveillance.

The UAVs are classified based on many factors like endurance, size and type of wing adopted. Reg Austin [1]. Depending upon the type of wing adopted the UAVs are classified as shown in Figure 1. Over the past years interest in the area of UAV has been increasing, especially on morphing wing UAV because its efficiency and way of lift and thrust generation in aerodynamic point of view. These morphing or flapping wing flights mimics the fly of natural flights like birds and insects which will have high endurance less drag force due changing of shape of wing during fly. Thus morphing wing technology has more advantages over the fixed one. Md Jalal Uddin Rumi et al [2]. The study of kinematics of bird wing is very complex. We could realize the major application of flapping concept in the field of micro-UAVs. In this work mechanism for morphing of wing has been addressed.

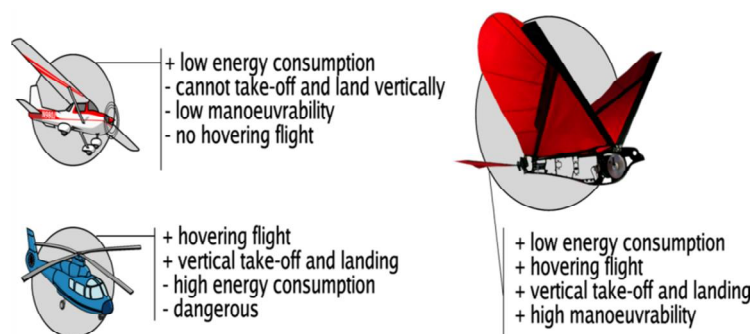


Figure 1: Types of UAVs.

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II. LITERATURE REVIEW

REVIEW OF MORPHING UAV

The research work on morphing UAV started in 18th century. The concept of morphing wing began on December 17, 1903 by the Wright Brothers. Most of the mechanism for morphing of wing is designed by considering four bar mechanism. By Following the Hong-Sen Yan's creative design theory for mechanical devices provided 31 different mechanisms for production of flapping. Tao Zhang et al [3]. By considering the bird and its mimic as reference researchers are developing the morphing concept. From kinematic point of view the bird has four degrees of freedom which helps in flying as explained by Francesca Negrello1 et al [4]. In the late 1700s, scientists realized that the lift function and the thrust function of bird wings were distinct. NanduJith P.J. and Harsh Gupta developed a UAV by considering the Festo Smart Bird and White Tailed Sea Eagle as their references. The wing was divided into 2 parts first part is for producing lift and outer part of wing is used for producing propulsion [5]. Attempted was made to develop the mimic flapping wing mechanism with near resonance type UAV. Sutthiphong Srigrarom et al [6]. The application of morphing is not only to improve aircraft performance but it also leads to the replacement of conventional control surfaces for flight control, to reduce the drag to improve range and for reduction of the vibrations or control flutter Michael I. Friswell et al [7]. The morphing mechanism may be achieved by using either compliant mechanism or by using rigid mechanism. Most of the application this variable wing configuration is MAV area. Using simple gear and pinion mechanism one can get the flapping of wings. Cheng-Kuei Hsu et al [8]. Now days the smart material technology has becoming very effective area for wing morphing.

CLASSIFICATION FOR MORPHING WING SHAPE

The classification of the different shape morphing techniques has been outlined in Figure 2. The three main changes that help in wing morphing are in-plane deformation, airfoil profile changes and out-of-plane deformation.

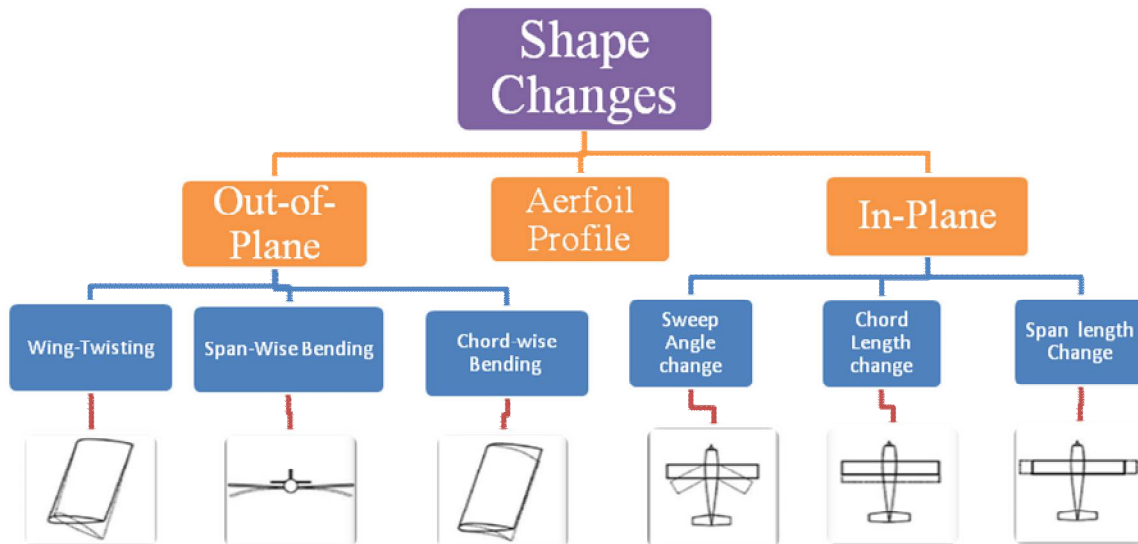


Figure 1: Classification of Morphing Wing Shape.

III. MORPHING WING MECHANISM DESIGN

Morphing concept is generally envisioned the shape and structure change of an aircraft. The control of aircraft in air is not as simple as in ground. The direction of aircraft can be controlled using primary and secondary control systems which are of conventional method of control. But in morphing wings the flight control can be done by using wing itself.

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The mechanism design for morphing wing is a very challenging task. The mechanism must be capability of producing the required wing motion.

MECHANISM DESIGN

In this work slider crank mechanism is considered to get the motion of wing. The length of sliding is called stroke length. The length each link is calculated using mathematical expressions. The relationship between the crank and stroke length is given by,

$$\text{Crank length} = \frac{\text{stroke}}{2} \quad (1)$$

The mathematical calculation is carried out to find the dimensions of other links mechanism as per the requirement of selected model. stroke length of 10mm is taken which enough to produce required angle. The DOF of mechanism is calculated to be one using Gruebler's equation. The mechanism is designed by making it a single degree freedom system and its kinematic simulation is studied in CATIA software. As per model selected the dimensions of linkages of mechanism are scaled down. The mechanism will be placed in the fuselage of the model and wing is attached to output link of the mechanism. The conceptual model of mechanism is illustrated as shown in Figure 3 and 4. The front spar of wing will be connected to the wing attachment through which linear motion is converted into oscillatory motion of wing. One complete rotation of crank will give one complete motion of wing. Depending upon the stroke length the oscillatory angle can be calculated. The main aim of this mechanism is to change the span and area of wing during fly. The material used is balsa wood.

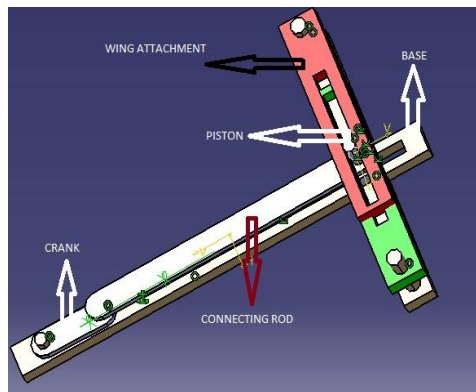


Figure 3: CAD Model of Mechanism, Initial Position.

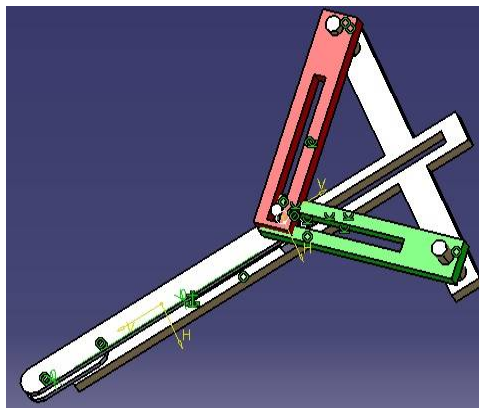


Figure 4: CAD Model of Mechanism, Position after One Stroke.

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WING DESIGN

A wing with a suitable surface produces aerodynamic forces for flight. Wing has streamlined aerofoil shape which produces lift. The wing structure is made up of spars, ribs and stringers which help to transfer the loads acting on wing. The ribs resemble the shape of airfoil. The wing has been designed as per the standards by selecting the suitable airfoil. The details of the wing and its airfoil are given in the Table 1 and Figure 4 represents the shape of airfoil used.

Table 1: Details of Wing Selected

Wing Airfoil	Selig 1210
Wing span	1.7m
Aspect ratio	7
Taper ratio	0.7
MAC	0.254m
Wing area	0.415 ²

The airfoil shape selected for the model is ‘Selig 1210’ which has maximum thickness at 12% of chord length. It has low Reynolds number and mostly used for high lift. The total length of wing (one side) is 800mm in which first 300mm is of uniform cross section and remaining 500mm is tapered cross section with 0.7 taper ratios. In this design the wing is divided into 8 sections of distance 100mm each. The shape of each section resembles the shape of airfoil. Ribs are constructed at the end of each section. The coordinates with respect to the airfoil selected are generated in a excel sheet. The 3D model of wing along with the ribs is shown in the Figure 5.

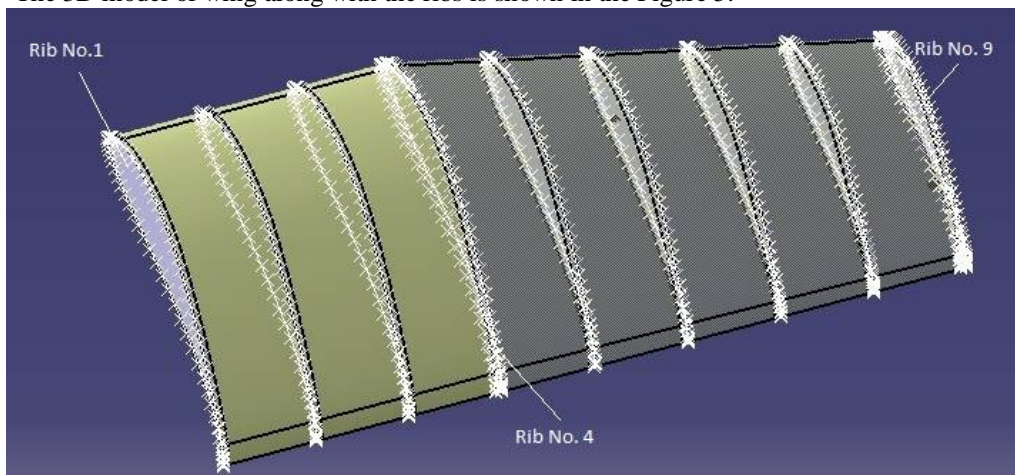


Figure 5: 3D Model of Wing (RHS).

IV. WING ACTUATION DESIGN

Morphing Plane Wings for Efficient Flights Flying efficiently at high speed requires small, perhaps, swept wings. Flying at slow speed for long periods requires long narrow wings. In this work attempt is made to change the span length area of wing which reduces the drag force during flying condition. The front spar of wing is pivoted to output link of mechanism for the actuation of wing. The rib (rib-1) near to the fuselage is fixed to it. Each rib is hinged to the spar which can rotate about the pivot axis. Stringers are used to connect between the ribs to avoid collision of ribs in morphed position. Tapered section is connected to base. When motion is given, the tapered section of wing move towards the trailing edge whereas uniform section of wing move away from trailing edge.

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The actuation of wing illustrated in the Figure 6 and 7. The skin has to be formulated over the ribs. Using suitable RC actuator crank rotation is controlled.

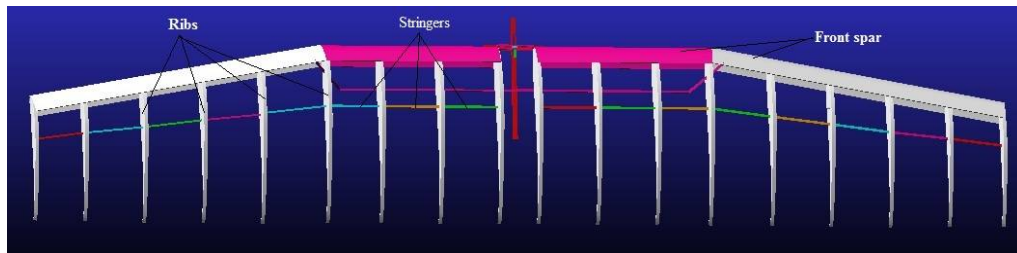


Figure 6: Position of Wing before Actuation.

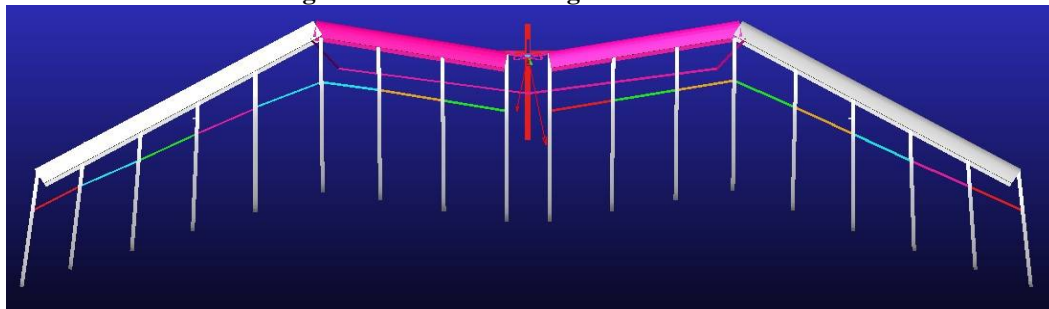


Figure 7: Position of Wing after Actuation.

V. RESULTS AND DISCUSSIONS

By numerical calculation using trigonometric expressions the change in angle of output link of mechanism is found to be 18.235° for half rotation of crank on both sides. During motion the uniform section of wing oscillate along the output link. The results obtained from ADAMS modelling are shown in Figure 8. The results obtained are nearer to the calculated angle.

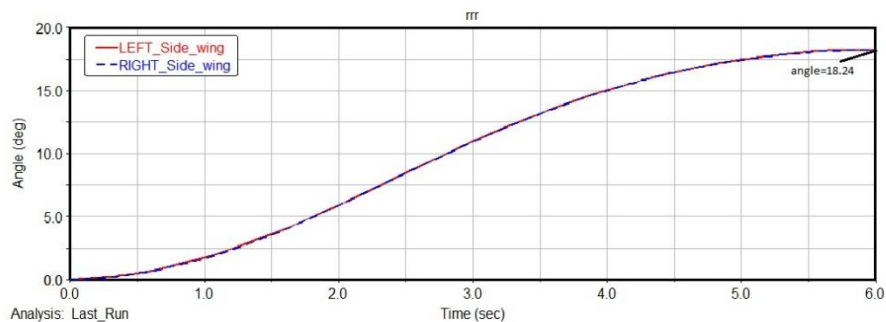


Figure 8: Angle Made By Uniform Section of Wing.

Rod is connected between the base and tapered section at hinge point. As uniform section move forward the tapered section move backward. The variation in the angle between the sections of wing obtained from ADAMS software is shown in figure 9. The angle change is found to be 16.72° .

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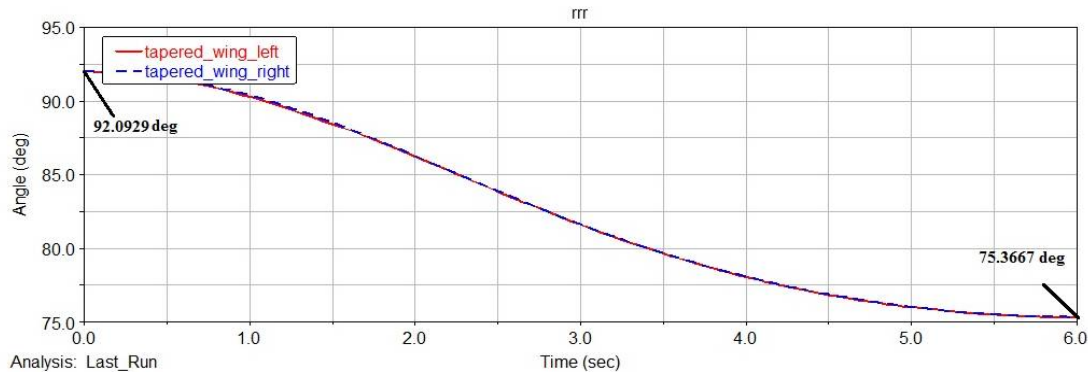


Figure 9: Angle Variation of Tapered Wing.

VI. CONCLUSION

The morphing concept is becoming wide research area in the field of aerospace due to its advantages. In this research work slider crank mechanism is found out to be the suitable mechanisms to achieve the sweep motion of wing. The kinematics of wing actuation is studied. The mechanism used changes the span and wing area for in plane wing shape change. Further study on aerodynamic analysis and mechatronics system integration for flying will be carried in the future research.

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