International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-3, January 2020

Mechanism and Performance Analysis of Morphing Wing

K Arunkumar, K Veeranjaneyulu, Om Prakash, Sreekanth Sura, M Srikanth

Abstract: Morphing wing concept is introduced to analyses wings aerodynamic performance the through warping mechanism. Thread rod mechanism is installed at the trailing edge of the wing to warp. Relative displacement between upper and lower skin of wing leads to have twisted wing. This new concept is applied at the demonstration wing which was built based on NACA 23012 airfoil section with a span of 0.580m and a chord length of 0.235m. Demonstrated model was tested using wind tunnel and analysis software. In general, it was demonstrated at lower AOA and the tests showed that warping could change the lift force in optimized manner. This study proved that a morphing wing can have optimum L/D ratio to minimize the fuel consumption of an aircraft and to ensure that the lift-to-drag ratio remains constant at various flight conditions.

Keywords: Warping mechanism, Aerodynamic performance, Twist wing, Test tunnel

I. INTRODUCTION

The concept of morphing is utilized to achieve higher performance of an airplane by changing shape of the wing. A morphing wing is defined as changes in shape of the wing during flying condition to get higher performance of an aircraft. In order to achieve morphing concept on wing, change in span, chord, aspect ratio and plan form shapes. Morphing wing can do multi-role by changing their external shape to change mission during flight. This creates high possible maneuvering at various flight conditions. Aim of morphing concept is to get high aerodynamic performance. Morphing aircraft are more competitive as doing multi task when compared to conventional aircraft as their requirements.

For certain project, morphing also having limitation for changing the shape of the wings, this limitations can overcome by studying biologically inspired techniques such as birds wing shape changes during flight. The way of morphing techniques can be studied through bird's wing and compared.

Revised Manuscript Received on January 30, 2020.
* Correspondence Author
Arunkumar*, Department of Aeronautical Engineering, MLR Institute of Technology, Hyderabad, India. Email: arunssksamy@gmail.com
Veeranjaneyulu, Department of Aeronautical Engineering, MLR Institute of Technology, Hyderabad, India. Email: veerak2k@gmail.com
Om prakash Department of Aerospace Engineering, UPES, Dehradun, India. Email: omprakash@gmail.com
Sreekanth Sura, Department of Aeronautical Engineering, MLR Institute of Technology, Hyderabad, India. Email: sreekanthsuramlrit@gmail.com
Munigala Srikanth, Department of Aeronautical Engineering, MLR Institute of Technology, Hyderabad, India. Email: sriaeromlr@gmail.com

Usually birds change their shape of wing depending upon the mission that they need to perform. Birds are having high maneuver ability during flight, suddenly it can do high risk maneuver such as diving, climbing etc., by changing its wing span, chord etc., even birds passes the airflow in between their wings to perform mission. Complete study about birds wing change gives clarity about morphing techniques.

In the past, different methods and mechanisms were employed to induce wing twisting. The most effective and less in cost is threaded rod mechanism. Thread rod mechanism working under the principle of warping. Warping is induced on wing is done through relative motion between upper and lower skin of the wing. In order to twist wing to achieve morphing techniques, the wing should be consider as closed tube but closed tube always have high torsional stiffness with low twist. To imply high twist thread rod is located at the trailing edge of the wing, by doing so wing achieve high torsional stiffness and high twist. Thus achieve high twist of the wing, we can perform morphing techniques and can achieve higher performance. The basic principle of warping mechanism is shown in below figure 1.

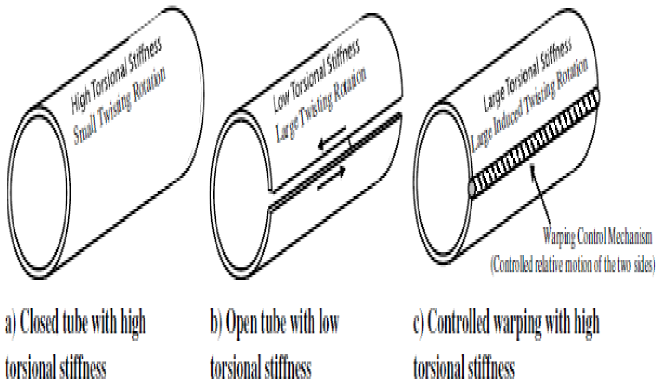


Fig.1 Basic principle of warping mechanism

II. EXPERIMENTAL WORK

A. *Design Criteria*

To demonstrate the performance of morphing wing with respect to wind tunnel size, a model was built and designed. Based on a NACA 23012, the wing model with a chord length of c=0.235m and a span of b=0.580m is designed. An Aluminium rod used as a fixed main spar carries the internal structure ribs which rotate about spar. This particular NACA 23012 airfoil was chosen imaginarily to prove the concept of morphing wing.

However, the similar mechanism can be applied to any type of airfoil shape with proper thickness to have the separate components of structure.

B. Requirements

- Skin must be flexible with less thickness.
- Less Weight.
- Good Strength.
- Ribs of the wing must be tightly rotate about the spar.
- A span wise threaded rod
- Bonding glues, rubber bushes, composites, carbon fiber thin layer.

C. Warping Mechanism-Thread Rod

At the first time screw mechanism did by using the MS rod and bars, but that mechanism was failure because of weight of the material. Its total weight is around more than 1 kg, so it was not suitable for that mechanism. Here the size of the sliding houses is 1inch*1inch, and the screw thread rod is 6mm.

D. Screw mechanism using aluminum:

After that decided a material which was much weight less and stronger, so we chose aluminum rod with diameter of 8mm rod in this rod we had to convert this one as thread rod by turning lathe. As per standard pitch for the 8mm rod is 1.25mm.The sliding houses were manufactured in the lathe with the required and suitable dimension for the airfoil trailing edge of the wing as tapered dimension bar with threaded inside of the houses.

The main and challenging part of this mechanism is both thread rod and sliding houses are not roaming well, because that sliding houses was threaded as per as the standard pitch (1.25mm).so we import another plane that sliding houses is bored and its thread was removed so it's moving freely on the thread rod and then we bonding the nuts at this aluminum sliding houses, so this time its gave success to my work.

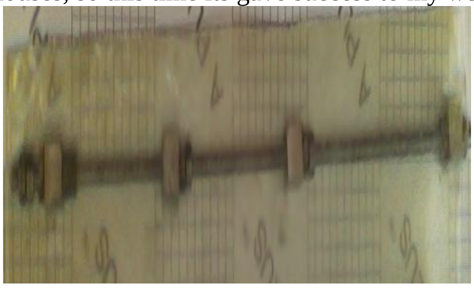


Fig.2. Threaded rod mechanisms

E. Wing Components

The main function of the ribs is to support the skin of the wing. As per as the NACA 23012 Airfoil section the aluminum sheet was cut by the laser cutting successfully and that aluminum sheet was very thin so it's not support to structure, so 60mm aluminum sheet were fixed at both top at bottom of the airfoil by using quick bonding resins and cut pieces of glass fiber gave additional strength to the structure. Here there are 3 ribs are used they are fixed at each distance from the ribs at 580mm total distance.

Spars are important part, its passes on the aerofoil mid centre of the hole the spar is 12mm aluminum solid rod that ribs must be rotate tightly about on spar, so by using the rubber bushes ribs rotated tightly rotated on spar. The Spars are important part, its passes on the aerofoil mid centre of the hole the spar is 12mm aluminum solid rod. The spars which is at the distance from leading edge of the ribs to 72 mm here is only the maximum chord thickness

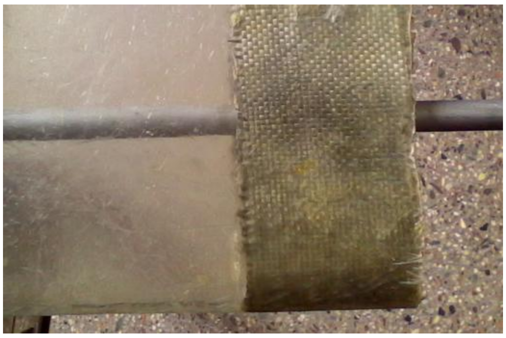


Fig.3. Ribs and Spars

F. Houses

Here we are using two types of houses, namely sliding and threaded houses, totally using 4 houses in these two houses are threaded houses and remaining two are sliding houses. The sliding house which was taken all the dimensions as per the airfoil, which was took 120mm from the leading edge that sliding and threaded houses were having the dimension 20mm breathe, and tapered in size its one side is 20mm and another side is 15mm thickness tapered. This houses are having dimensions as per the drawing, it's all are like tapered section.

G. Skin

We are using two types of material to ensure good structural design and strength, at the inside a thin (0.7mm) glass fiber composite used because it's having more stiffness and flexibility. Sliding and threaded houses are fixed in this fiber composite, the total skin section must be fixed correctly at the ribs evenly then only force will be distribute evenly at all sections by using the heavy bonds and resins. The skin was fixed correct position and size per requirements used quick bonding resins, those houses is also fixed as per the drawings and requirements.

H. Assembly:

The final assembly of this twisted morphing wing is having 3 ribs which are placed at the equal distance of spar at the total distance of 580mm. The ribs are rotated tightly about the spare according to degree as per requirements and then fixation of rod is done for supporting arrangement. The wing is covered with carbon fiber and internally composite glass fiber.

Fig.4. Demonstrated model

I. Testing of mechanism:

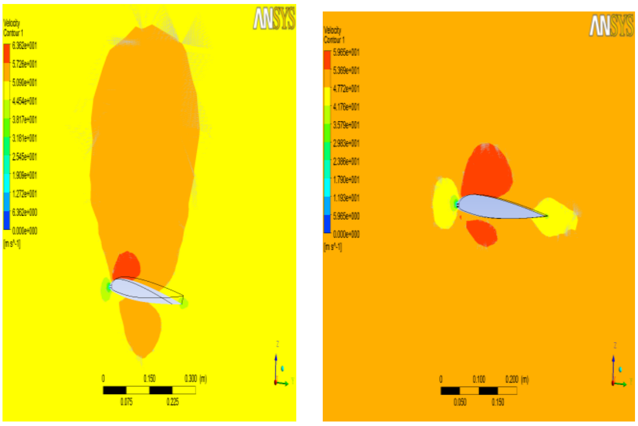
This time we were testing the mechanism by choosing different types of skins like 1mm polymer thin sheet,0.8mm thin polymer sheet. At trailing edge nuts and blocks are placed at equally spaced stations. The two at the bottom and one at the top of the wing. The outer two threads give rotation and guidance to the thread rod.

Thread rod is positioned at the trailing edge of the wing with respect to nuts which is attached to the upper and lower skin of the wing. Totally three nuts are attached to the wing, two at the bottom of the skin and one at the top of the skin. The nut which is fitted at the upper wing is placed exactly at the middle of the threaded rod. All three nuts also threaded inside. When thread rod rotates the middle nut produces relative motion between other two nuts and results in wing twist.

Fig.5. Warping mechanism Testing

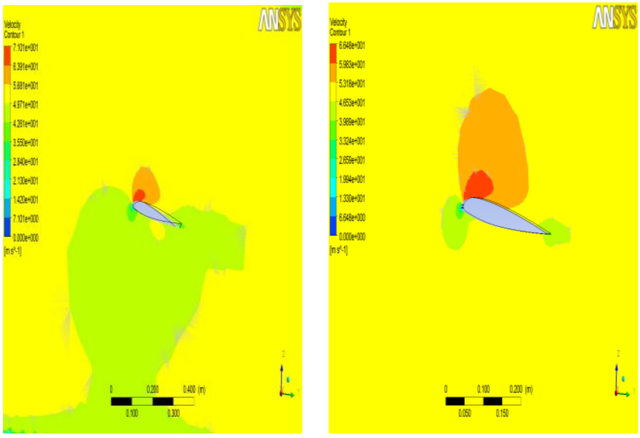
J. Velocity contour

It can be observed from the velocity contours of the morphing wing at 5^0 angle of attack that on the lower side of the airfoil due to stagnation of the air flow, the velocity is decreased when compared on the upper side of the airfoil (Figure 7a and b). On the contrary the flow on the conventional wing velocity at the lower side gets increases. As a result static pressure on the lower side decreases which in turn affect lift force at an angle of attack 5^0.



(a) (b)

Fig.6. Velocity contour for angle of attack 00 a) morphing wing b) conventional wing

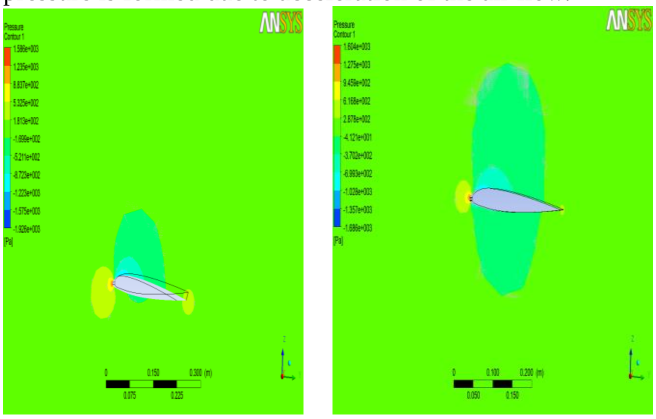


(a) (b)

Fig.7. Velocity contour for angle of attack 50 a)morphing wing b) conventional wing

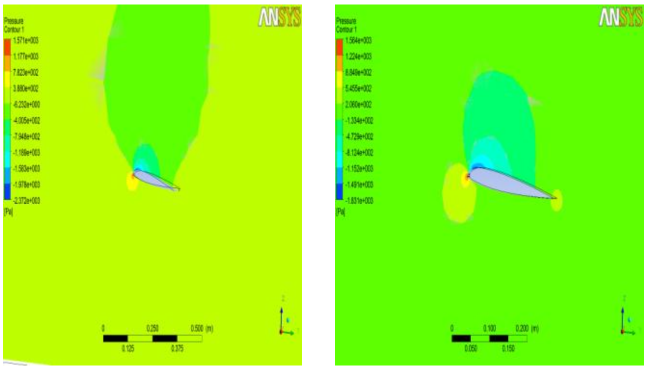
K. Pressure contour

The pressure contours of the morphing wing design indicate a high pressure zone on the lower side of the wing and low pressure zone on the upper side of the wing (Figure 8a and b). Behind the trailing edge, a wake region with very low pressure is formed due to acceleration of the air flow.



(a) (b)

Fig.8. Pressure contour for angle of attack 00 a) morphing wing b) conventional wing



(a) (b)

Fig.9. Pressure contour for angle of attack 50 a) morphing wing b) conventional wing

III. WIND TUNNEL TEST

To determine the lift and drag characteristics of the warping wing, a wind-tunnel experiment was carried out on low-speed wind tunnel. The objective of this wind tunnel test was to demonstrate that the morphing mechanism would alter the aerodynamic performance of the wing. The test section with 600mm in width, 450mm in height and 1200mm in length was taken to place the wing model. The wing was placed horizontally on the test section. Required Forces were calculated through a three component balance instrument for both conventional and morphing wing. Readings were taken at a maximum velocity of tunnel as 50 m/s for various angles of attack say 0 and 5 deg. From the obtained lift and drag values, ratio of L/D was calculated and the relation between the angle of attack and L/D ratio is plotted.

Force calculation

Morphing Wing

At Angle Of Attack =0^o

Drag, D=3.8612N
Lift, L=41.7489N
Lift To Drag Ratio, L/D=10.8122

At Angle Of Attack=5^o

Drag, D=9.2259N
Lift, L=98.7522N
Lift To Drag Ratio, L/D=10.7038

Fig.10. Wind tunnel test

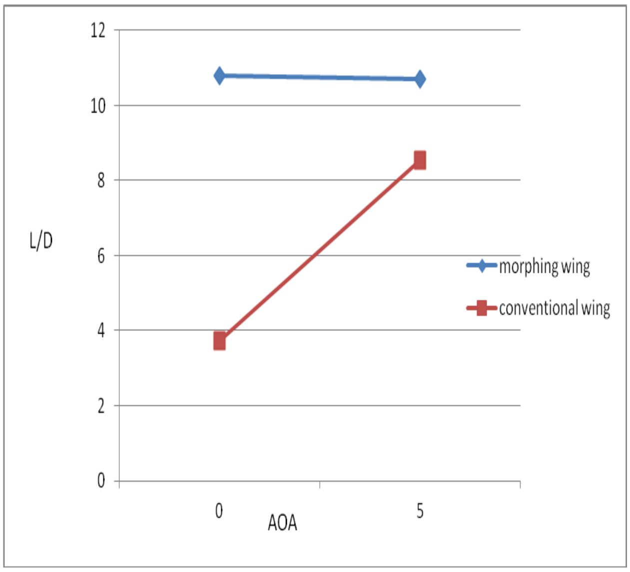
Conventional Wing

At Angle Of Attack=0^o

Drag, D=3.5854N
Lift, L=13.3495N
Lift To Drag Ratio, L/D=3.7233

At Angle Of Attack=5^o

Drag, D=7.7362N
Lift, L=65.9632N
Lift To Drag Ratio, L/D=8.5265



Graph-I Angle of Attack vs. L/D ratio

IV. RESULT AND DISCUSSION

From graph it is clearly shown that L/D ratio of morphing wing remains constant, but for conventional wing it varies in linear manner up to stalling angle. It is desirable in order to lower the fuel consumption, L/D ratio should constant at all maneuver.

In airline operation 50% budget is considered for fuel costs. Scientists who are familiar in aerodynamics field suggest that aircraft wings should change their shape in order to get higher performance. Thus morphing wing concept reduces the consumption of fuel which in turn reduces the budget for fuel cost by optimize performance. Conventional wing consist of rigid and hinged control surfaces which affects airfoil shape change when compared to morphing wing.

In general, commercial aircrafts are often in cruise condition. It decides the aerodynamic performance such as **Range and Endurance.** An important criterion which affects this performance is specific fuel consumption.

Breguet formula for Range and Endurance:

$R= 1/C_t*L^{1/2}/D*(W_O^{1/2}-W_1^{1/2})$

$E= 1/C_t*L/D*\ln(W_0/W_1)$

Where,

C_t =specific fuel consumption

$W_{0,}$ W1=airplane weight with fuel, airplane weight without fuel

L/D =lift to drag ratio

From the above equation,

We can clearly say that increase in lift to drag ratio (L/D), increases aerodynamic performance of the airplane (RANGE AND ENDURANCE).

From the results,

L/D ratio for morphing wing at α=0 is 10.8122, similarly

L/D ratio for normal wing at α=0 is 3.7233

Thus aerodynamic performance is greatly achieved in morphing wing when compared to conventional wing.

V. CONCLUSION

Based on warping mechanism on the trailing edge, morphing wing performance has been discussed at lower angle of attack. Warping displacement could be created in a straight wing by placing threaded rod mechanism at the trailing edge. This threaded rod mechanism creates relative motion between upper and lower skins, as a result wing twist was occurred. This new concept of wing twist leads to morphing wing technology. Twisted morphing wing was demonstrated on a wind tunnel with 580 mm span could change the aerodynamic performance at lower angle of attack. It was noticed that at lower angle of attack it showed higher L/D ratio but at higher angle of attack it showed remains same L/D ratio values as got at lower angle of attack. So this study proved that a morphing wing L/D ratio remains constant at various angles of attack whereas conventional wing shows drastic variation in L/D ratio. As we know that aerodynamic performance importantly fuel consumption always depends upon aerodynamic efficiency L/D ratio, this study proved morphing wing have low fuel consumption when compared with conventional wing..

REFERENCES

1. Bisplinghoff, R., Ashley, H., and Halfman, R. L., "Introduction to Aero elasticity," Aero elasticity, Dover, New York, 1955.
2. Veeranjaneeyulu Kalavagunta 'Optimization Of Wing Through Computational Fluid Dynamics'Publication date 2014/12 Journal International Journal of Engineering Research and Technology Volume3 Issue 8 Pages Pg. No.37 Publisher IJERT
3. A Sai Kumar A, B AvinashVamsi Krishna C; "Conceptual Design of Hybrid UAV" International Journal of Engineering Research & Technology 41226-322015 IJERT
4. Phillips,W. F., Fugal, S. R., and Spall, R. E., "Minimizing Induced Drag with Geometric and Aerodynamic Twist, CFDValidation," 43rd AIAA Aerospace Sciences Meeting and Exhibit, AIAA Paper 2005-1034, Reno, NV, Jan. 2005.
5. Sreekanth sura, Sai kumar A, Nirmith kumar mishra, Sohail Raheman "Design and Fabrication of Micro Air Vehicle (Mav) with Double-Bubble Fuselage"
6. Vos, R., Hodigere-Siddaramaiah,V., and Cooper, J., "Aero elastic Flight Control for Subscale UAVs," 48th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conf., AIAA Paper 2007-1706, Waikiki, HI, 23–27 April 2007.

AUTHORS PROFILE

Arunkumar K is an Assistant professor in the Department of Aeronautical Engineering, MLR Institute of Technology. He has completed M.E from IJCE, Tirunelveli. He has published 2 research papers in International conference.

K Veeranjaneyulu is a professor in the Department of Aeronautical Engineering, MLR Institute of Technology. He has completed M.E from MIT, Chennai. He has 24 years of Industrial, Teaching and Research experience. He has published around 20 research papers in reputed journals and holds two patents in his name. He guided many community projects and one of the projects is listed in the top ten at the international level. He got an award for the best poster design.

Dr. Om Prakash is a Professor in the Department of Aerospace Engineering at UPES. He has completed Ph.D from IIT Bombay. He has solid rich industrial. Teaching and research experience. He has published many papers in reputed international and national journals. He has presented papers in international al conferences. He was a convenor for national and international conferences.

Sreekanth Sura, Assistant Professor in Department of Aeronautical Engineering at MLR Institute of Technology, Hyderabad, India. And also Research Scholar at Osmania University.

Munigala Srikanth, Assistant Professor in Department of Aeronautical Engineering at MLR Institute of Technology, Hyderabad, India.