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Study on Aerodynamic Characteristics of Span-Morphing by Bending the Wing

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Abstract: Wing morphing is a technology which plays a very vital role in aircraft industry. In our analysis we will mainly focus on a particular type of wing morphing which is basically a span morphing. In this by using analysis tool software we design a wing configuration by folding a part of wing by some particular angles for 45°,0°, and -45°. Then we perform a study by making different simulations in order to get important parameters like stall angle, lift to drag ratio, downwash, static stability. By getting all this parameters, we will do comparative study on all these three different angles of span morphing.
Keywords: Morphing, Span-Morphing, Stall-Angle, Downwash, Aerofoil, Aspect ratio.

I. INTRODUCTION

Morphing is not a recent thing but has been present since the time of the first flying plane was invented by Wright flyer and the materials used at that time were not so strong [1]. Morphing in general means change or transformation of any sort and therefore for aircrafts it is the geometrical change in shape so as to improve a number of parameters and factors that actually affect the plane. Morphing helps to create an aircraft with high performance and change the performance which includes creation of aerodynamically efficient and having multiple regime too. The design of versatile components and structures, together with the advancement of materials that are smart and also permit the configurations based on bio-mimicry in airplane is exceedingly craved for much efficient and eco-friendly future. The conventional airplanes put so many limitations and not able to exploit the environment into its favour. The modern concepts and advances are a consistent thing to improve the in general flight execution of airplane, empowering modern approaches to the plan of flying machine and to make various missions at a time possible. The types of morphing and materials used have evolved with time. Different types involve chord, span, sweep etc. under planform alteration and span wise, dihedral & twist under out of the plane type transformation also thickness and camber type [2]. In this paper the main focus is span morphing which is the morphing done to change the span of the wing during the flight. When the wingspan is increased, the wing area and the aspect ratio also becomes more, and it in turn decreases the span wise lift distribution for original lift. Due to the change in the length of the wing the stall angle, aspect ratio, lift and other important factors can be altered for better performance [3]. The misshaping from the streamlined loads is much bigger than that of the customary wing. The drag can be lowered, optimal lift to drag ratio is achievable, better roll control in case of asymmetrical type span morphing are few of the many plus points by having variable span.

A. Symbols And Acronyms

Cl-coefficient of lift
Cd-coefficient of drag
ar-aspect ratio
Re-Reynolds number
α- alpha

II. METHODOLOGY

After performing aerofoil analysis for the selection of appropriate aerofoil for the wing, the wing has been designed. The wing taken for analysis have constant chord with tapered outer chord. For performing comparative analysis, the other parameters have kept constant like fuse and tail configurations and dimensions.

All the analyses have been done in static medium. The wing has been morphed in different ways by bending some part of the tapered section at different angles 45º, and -45º. By using an analysis tool software various aerodynamic characteristics will be compared like stall angle, downwash, coefficient of lift to coefficient of drag ratio between different morphed wing and also with wing without morphed.

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III. ANALYSES

A. Aerofoil Analysis

While performing aerofoil analysis Reynolds number is an important measure. Depending on the weather condition, the Re was calculated and was found less than 500,000. The performed prototype has a wing span of 100cm. The analysis was performed for some aerofoils from Selig catalogue. According to the Selig Catalogue and taking into consideration high lift, low drag, stall angle, polar moments and various aspects, the analysis was performed of following aerofoils S2091, S3025, S4180, and S1223.rtl, and selected the most suitable one which is S1223.rtl. The aerofoil S1223.rtl shows maximum lift to drag ratio which is one of the reasons to choose among all other aerofoils. The coefficient of moment or pitching moment is one factor looked into the selection of aerofoil also stall angle is high for S1223.rtl compared with other aerofoils. These were the suitable reasons to choose S1223.rtl among the aerofoils selected.

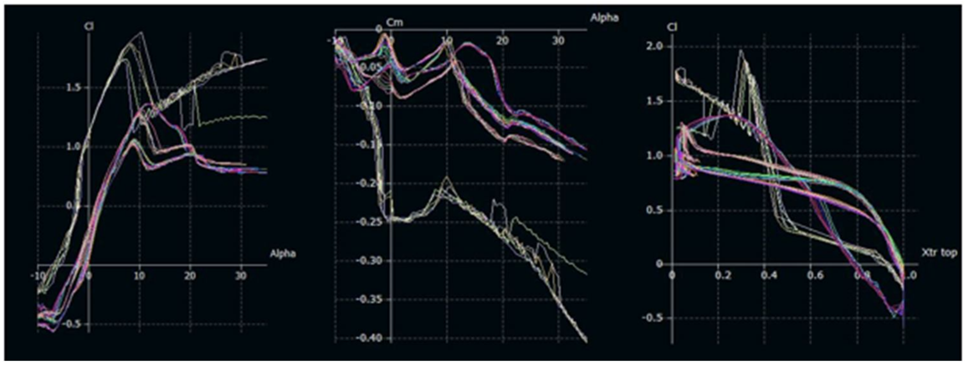

Fig. 1 Aerofoil Analyses

B. Wing Analysis

First, the wing has been morphed by bending in upward and downward direction at an angle of +45° and then at -45° as shown below and compare its downwash characteristics, stall angle, and Cl vs Cd characteristics with non-morph wing with same dimensions.

Fig. 2 Span morphing at +45°, 0° and -45°

The Cl for the above three wing configurations are as follows 0.859, 0.852 and 0.861 for +45°, 0° (without morphed) and -45° morphed wing respectively. Downwash is basically the downward deflection of the airflow on an aircraft wing. It is basically represented in terms of coefficient of lift(Cl) and aspect ratio(ar). In this aspect ratio is the ratio of span length to the chord length.

1) Downwash: Downwash is always directly proportional to lift coefficient and inversely proportional to aspect ratio.

Downwash(degrees)=(36.5*Cl)/(ar); ar=5.4

The downwash values are 5.806, 5.758, and 5.819 for +45°, 0° and -45° respectively. Clearly, we can observe that the downwash is more in case of +45° wing morphing. But if we compare the induce drag in all three configurations, we observed that cd values as 0.047, 0.042, 0.045 for +45°, 0° and -45° wing configurations. Below pictures shows the induce drag variation in all three configurations.

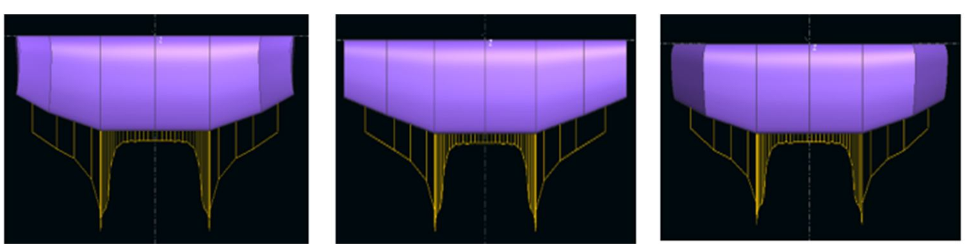

Fig. 3 Drag

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2) *Cl vs α plot:* In this plot α is on x-axis and Cl is on y-axis. This graph represents the variation of coefficient of lift with respect to angle of attack, α. As lift is directly proportional to alpha, the Cl moves linearly with respect to α and then after a certain point the lift becomes maximum then the line gets curved and Cl becomes constant [4]. The angle at which Cl becomes maximum is called stall angle. If we increase the angle of attack further beyond the stall angle, then there will be no lift generation and plane becomes unstable. This situation happens because beyond this angle the drag increases abruptly and also boundary layer separation occurs which further decreases the speed. Hence the lift decreases significantly and plane becomes unstable [5]. In order to increase the limit of maximum lift we have to increase the stall angle. To solve this problem morphing is done so that less drag will be produced and due to less drag boundary layer separation will be low and hence will generate more lift thereby increasing the stall angle [6].

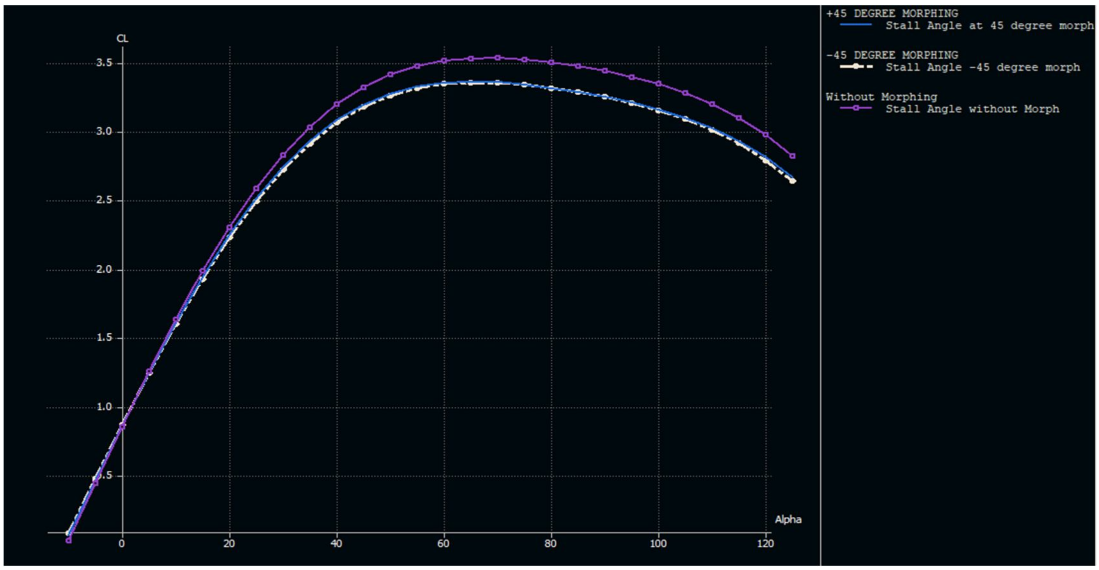

Fig. 4 Cl vs α

The stall angles are as follows 65º, 70º and 65º again for the wing morphed at +45º,0º (without morphed), and -45º.

3) *Cl vs Cd plot*: This graph represents the variation of coefficient of lift with respect to coefficient of drag. From graph we can clearly view that initially the Cd decreases slightly with increase in Cl and reaches a certain point when it becomes minimum. Then it increases with Cl and follows a parabolic curve. There will be a point in the curve where Cl/Cd ratio is maximum and at that point there will be a specific angle of attack and speed. At this point plane will be maximum fuel efficient since more lift is produced compared to drag. So by less drag, less amount of fuel will be consumed and will produce greater lift and thrust.

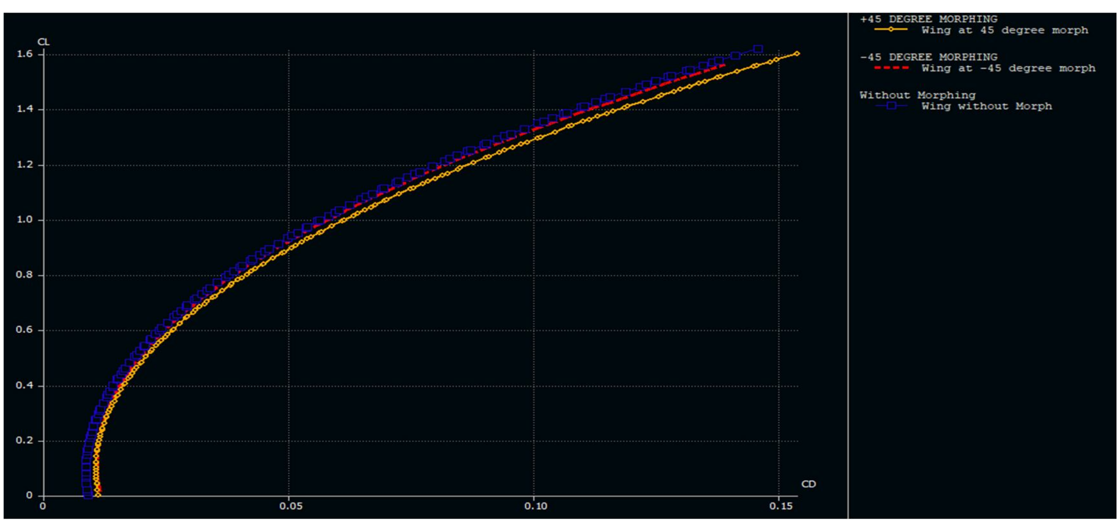

Fig. 5 Cl vs Cd

IV. RESULT AND DISCUSSION

The Cl is more for the wings morphed at +45º and -45º and this can be due to reduction in wingtip vortex as the folded parts can act like winglets and also the downwash generated is more as compared to wing without morphed wing. But the profile drag is more in +45º and-45º morphed wings because of the wing bend as compare to the non-morphed wing. Therefore, the Cl/Cd ratio is less in case of morphed wings. The Cl vs Cd graph shows the relation between Cl and Cd variation for different wing morphing. As the wing has been morphed by bending some part of the wing, the projected wing area which generates lift gets reduce but slight increase in velocity can compensate the lift decreased and thus lift remains constant. The stall angle is less for morphed wings as compared to the non-morphed wing because Cd is more for the morphed wing. Morphed wing can be also helpful in parking the aircrafts in hangar as the wings can be bend and more space can create for other aircrafts.

V. CONCLUSION

We started from scrap and without considering any prior assumptions, purely based on analytical methods, the iterations were carried out. We have observed some of the basic aerodynamic characteristics of morphing wing and also compared it with non-morphed wing.

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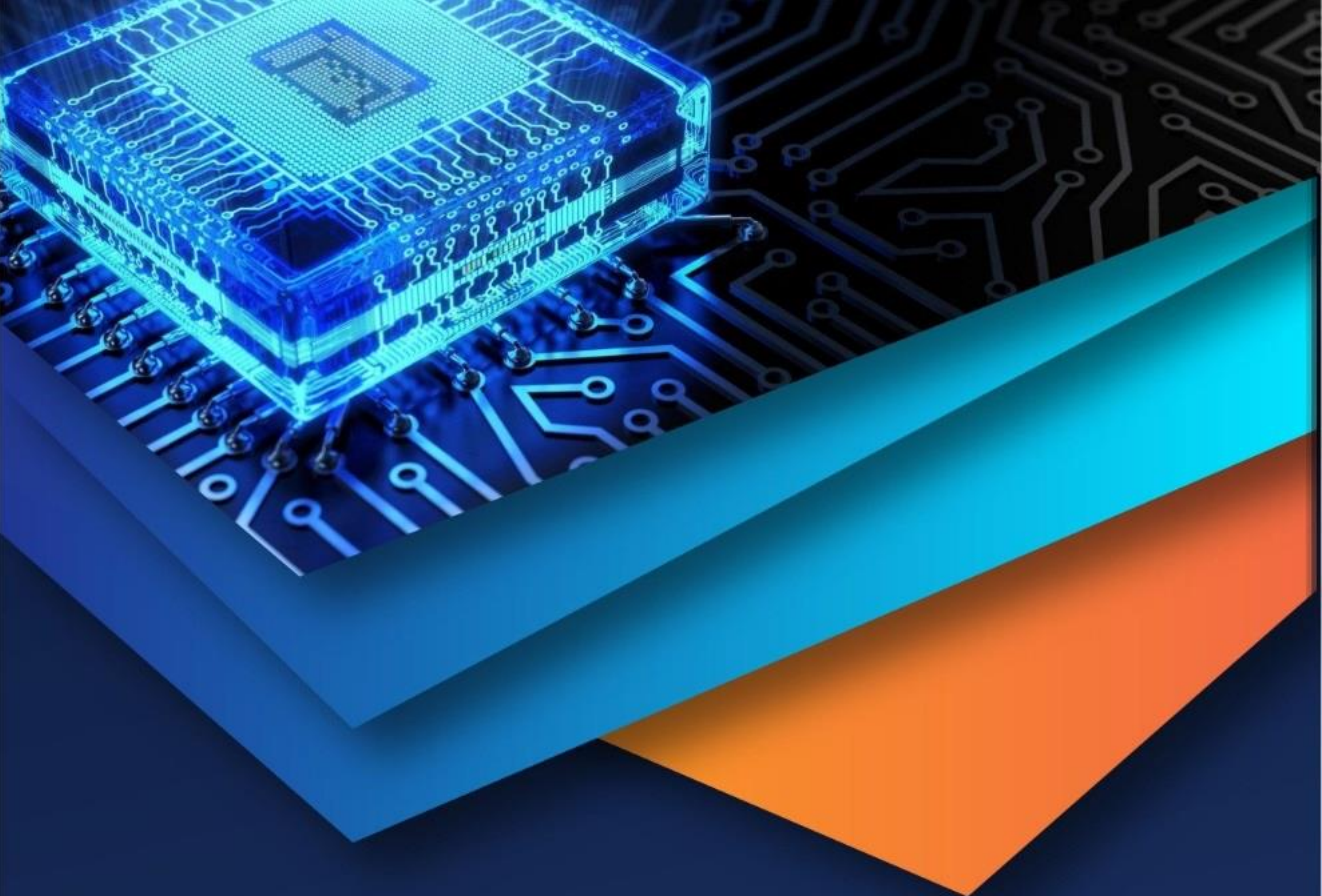

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