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LOCAL ANGLE OF ATTACK EXTRACTION METHOD FOR TWIST MORPHING MAV WING

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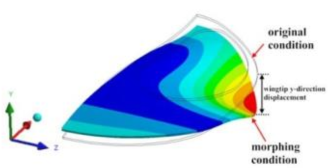
Graphical abstract



Abstract

The geometric twist characteristic on twist morphing MAV wing has significant influence on its aerodynamic performances. Higher geometric twist magnitude induces higher lifts and drags generation. However, in order to determine the geometric twist performance, a detail analysis has to be carried out to extract the local angle of attack (AOA) value on each wing cross section. Thus, current works introduces a new method in extracting the local AOA value on a twist morphing MAV wing. The method manipulates the automated coordinate generation produced by Ansys software and combined the generated coordinates with manual determination of local AOA magnitude. Based on the analysis executed on a twist morphing wing sample, 30 local AOA values were obtained from 30 wing cross sections. By using the local AOA value at the root chord and wing tip, the geometric twist magnitude or twist intensity for a twist morphing wing is determined. Based on a selected twist morphing MAV wing sample, the local AOA extraction method able to calculate the wing geometric twist at $\epsilon = 12.5°$.

Keywords: Micro air vehicle (MAV), local angle of attack, twist morphing wing.

1.0 INTRODUCTION

MAV is defined as a small scale aircraft with a wingspan dimension lesser than 15cm, flying at low Reynolds number regime (10^4–10^5). MAV is seen to replace unmanned aerial vehicles (UAVs) for futuristic intelligence and surveillance in confined space areas. The rigid wing MAV type is the earliest version of MAV and it can offers better payload and endurance capability[1]. However, this MAV type usually suffers from low lift generation. In order to improve the aerodynamic performance of MAV wing, the biomimetic design is introduced through the application twist morphing mobility on MAV wing[2], [3]. Previous study had shown that the geometric twist characteristics on twist morphing MAV wing had a significant influenced on its aerodynamic performance. Higher geometric twist magnitude exhibited by a twist morphing wing had induced higher lift and drag generation [2], [3]. However, in order to analyze the geometric twist performance, a detail analysis has to be carried out to extract the local angle of attack (AOA) value produced on each twisted wing cross section. Thus, present work is carried out to introduce a new method in extracting the local AOA value on a twist morphing MAV wing. The method manipulates the automated coordinate generation produced by Ansys software and combined the generated coordinates with manual determination of local AOA magnitude.

2.0 PRINCIPLE OF LOCAL AOA EXTRACTION METHOD

In order to improve the geometric twist reading on twist morphing MAV wing, a local AOA extraction method was developed. The main principle behind the new method is combining the automated coordinate generation (analyzed by Ansys software) with manual determination of local AOA in single iteration process. The process started in the post-processing unit in Ansys-Fluid Structure Interaction (FSI) module. Based on the TM wing deformation result (shown in Figure 1), a series of polyline is created across the wing span. By using the polylines, Ansys software automatically generate the wing coordinates and plotted into a single graph. Then, the local AOA is manually determined based on the plotted wing profile.

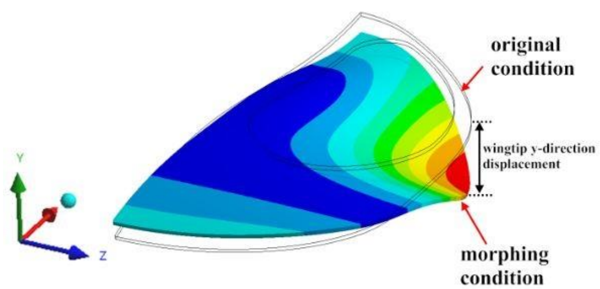


Figure 1 TM wing deformation result.

3.0 DESCRIPTION OF LOCAL AOA EXTRACTION METHOD

The local AOA extraction method for twist morphing MAV wing can be divided into the following steps:

1) After the Ansys-FSI solving process, the total deformation on the twist morphing wing is visualized in the Ansys post-processing module. For current case, the origin of the wing coordinate system is located at the center of the wing leading edge and following coordinate system is adopted: x is chordwise, z is spanwise, and y is normal to the wing.
2) By using the Ansys post-processing function, a number of planes (e.g. 30 planes for current case) are created along the wingspan and perpendicularly intersect the wing surface. The planes visibly create a number of sub-division on the wing planform.
3) A number polylines (e.g. 30 polylines for current case) is created on the wing surface by using Ansys post-processing view function. This step is guided by the location of wing surface-plane intersection.
4) Ansys post-processing module automatically generates X and Y coordinates for every polylines and plot the wing cross section coordinates (e.g. 30 cross section coordinates for current case) into a single Y vs X graph.
5) Select one wing cross section for local AOA extraction.
6) Construct the horizontal, vertical and inclined lines on the selected wing cross section by using the leading and trailing edge coordinates. The length of horizontal, vertical and inclined lines are determined manually also by using the leading and trailing edge coordinates.
7) The local of AOA value is determined by using the trigonometric angle created between the incline and horizontal lines. Repeat step 5 to 7 for other wing cross section (e.g. 30 cross section coordinates for current case).

Step 1 to 4 is executed based on the automatic function available in Ansys post-processing module whereas, step 5 to 7 is executed manually by user outside the Ansys post-processing module. The summary of aforementioned steps is illustrated in Figure 2. The local AOA value for each cross section is then plotted in a local AOA vs. wingspan (2z/b) graph for geometric twist evaluation.

4.0 RESULTS

The outcome of local AOA extraction method applied on a twist morphing wing [3] is plotted in a local AOA (°) vs. wingspan (2z/b) graph as shown in Figure 3. Each dot represents the local AOA value extracted from every wing cross section. Based on the current example, 30 dots were marked on the graph represents 30 local AOA value obtained for 30 wing cross sections. The result (Figure 3) clearly showed that the local AOA value varies along the wing span of twist morphing wing. The local AOA value almost maintained at 4.5° near the root chord cross section (2z/b=0.0 to 0.2). However, the local AOA magnitude started to increase from 4.5° to 18.0° at wing cross section area between 2z/b=0.22 to 0.9. The maximum local AOA magnitude (18.0°) found at 2z/b=0.9 before the value decrease to 17.0° at the wing tip cross section (2z/b=1.0). By definition, the wing geometric twist (ϵ) is the difference in the local AOA magnitude between the root chord and the wingtip [4]. Hence, the geometric twist for TM wing is calculated based on following equation[4]:

Geometric twist, ϵ = Local AOA at wingtip (2z/b=1.0) − Local AOA at wing root (2z/b=0.0) (1)

Based on the equation, the geometric twist for current twist morphing wing is calculated at ϵ = 12.5°. This magnitude represents the intensity of twist condition produced on current twist morphing wing. Thus, the results presents the evidence behind the capability of local AOA extraction method in providing the geometric twist magnitude or twist intensity for a twist morphing MAV wing. The increment in local AOA magnitude shall induced a *washed-in* condition on the MAV wing which consequently encourage higher vortex interaction and improved the pressure distribution on the MAV wing [3], [2].

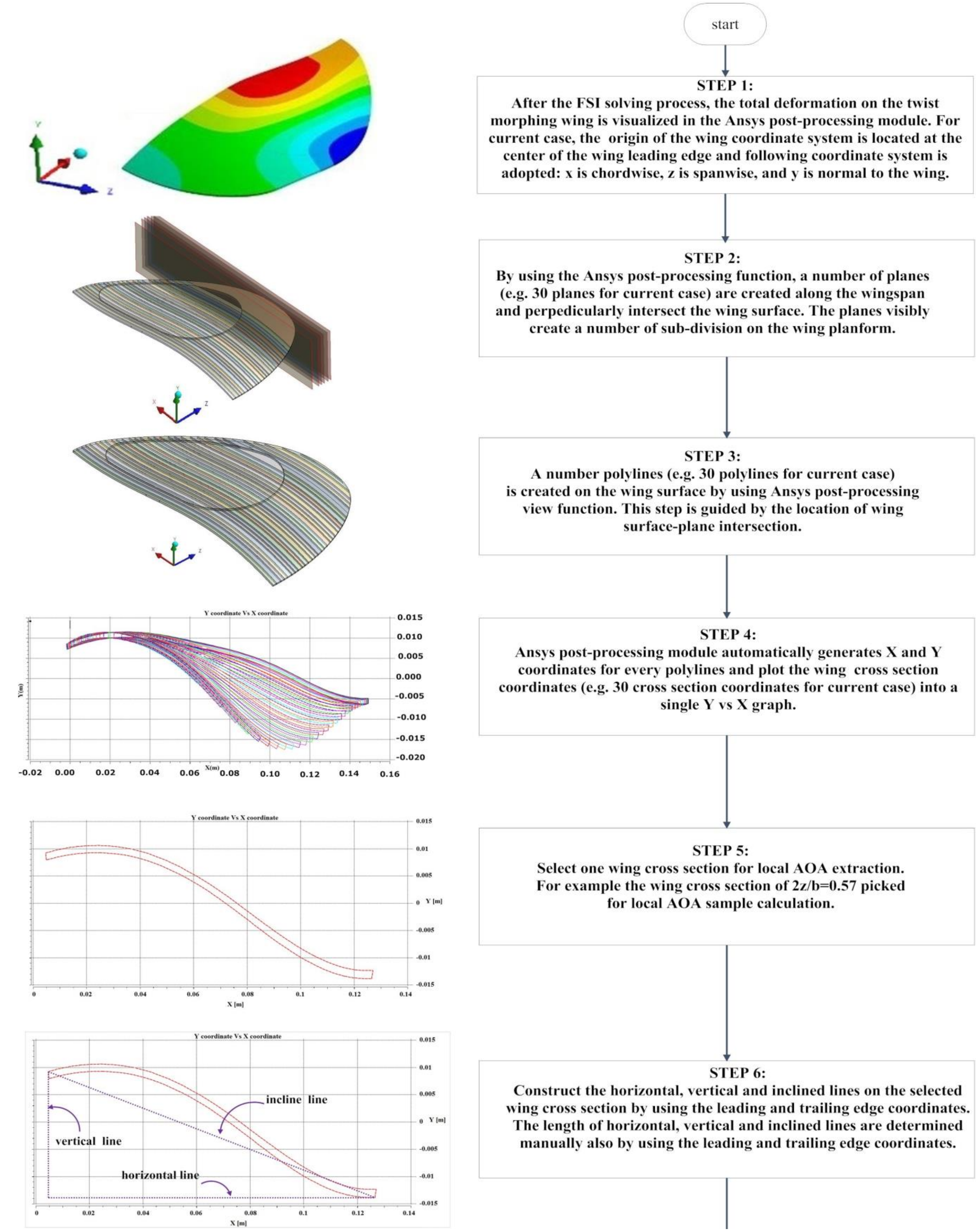


Figure 2 The summary of local AOA extraction method for twist morphing MAV wing.

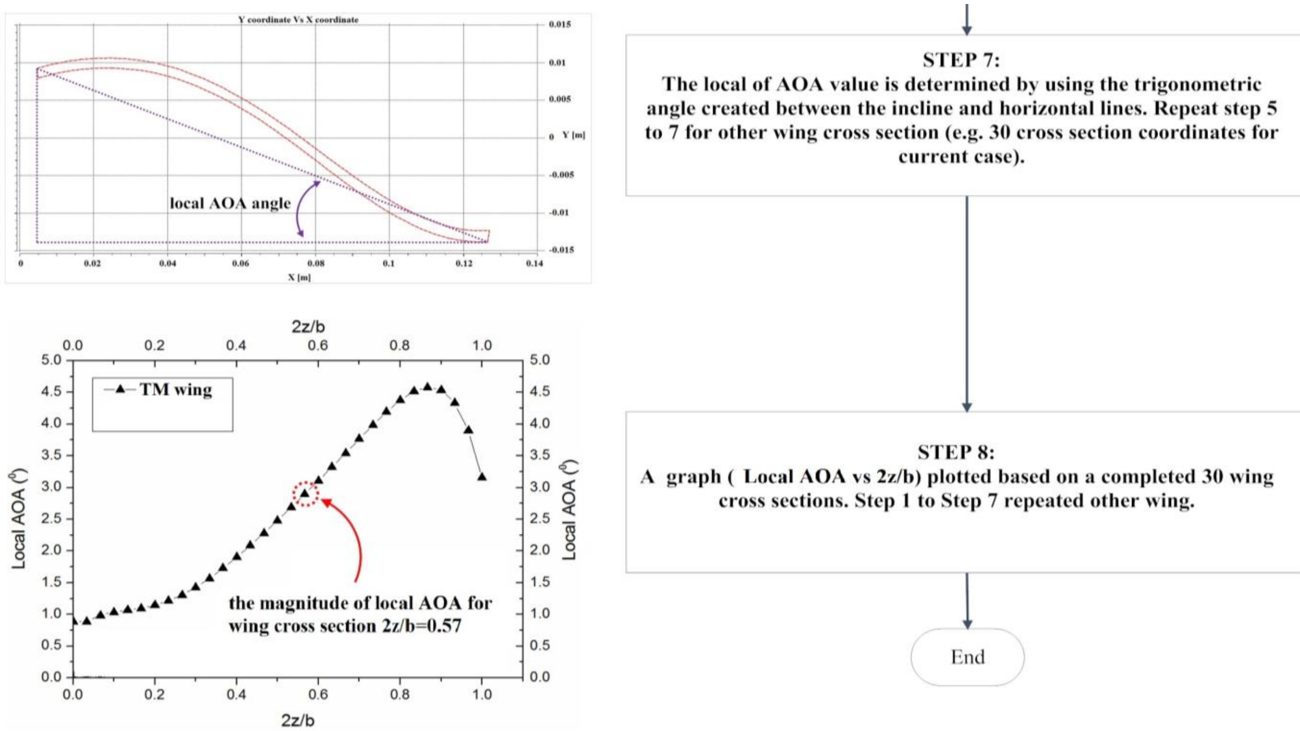


Figure 3 The summary of local AOA extraction method for twist morphing MAV wing (continue).

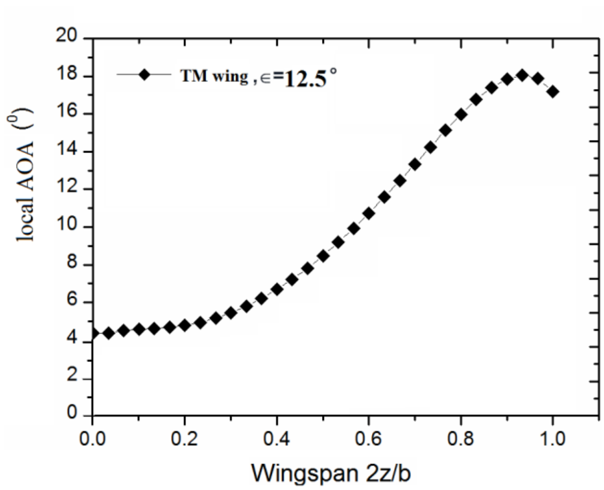


Figure 4 Local AOA (°) vs. wingspan (2z/b) graph.

4.0 CONCLUSION

Current works are mainly conducted to introduce a new method in extracting the local AOA value on a twist morphing MAV wing. The method manipulates the automated coordinate generation produced by Ansys software and combined the generated coordinates with manual determination of local AOA magnitude. The main principle behind the method is combining the automated coordinate generation obtained in Ansys commercial software with manual determination of local AOA process. The process started in the post-processing unit in Ansys FSI module to produce a generated coordinates created across the wing span. Then, the local AOA is manually determined based on the plotted wing profile. Based on the example, 30 local AOA values were obtained from 30 wing cross sections. By using the local AOA value at the root chord and wing tip, the geometric twist magnitude or twist intensity for a twist morphing wing is determined at ϵ = 12.5°. The result representes the capability of current local AOA extraction method in providing the geometric twist magnitude for a twist morphing MAV wing.

Acknowledgement

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