Modeling and Aerodynamic Characteristics Analysis of Morphing Aircraft

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Abstract: In recent years, military and civil aviation have put forward higher and higher requirements to the performance of the aircraft. The morphing aircraft can adapt to a variety of environments, perform a variety of tasks and meanwhile maintain excellent flight performance. This paper researches the dynamic modeling method, aerodynamic parameter analysis and the dynamic characteristic response of morphing aircraft. The physical model of a variable-span variable-sweep morphing aircraft was simplified so as to use Kane Equation modeling. In this paper, the software Datcom is used to analyze the aerodynamic parameters of the morphing aircraft. Then the aircraft's longitudinal dynamic responses during the morphing process are simulated and analyzed. The simulation results show that the speed, height and pitch angle of the morphing aircraft will be greatly changed.

Key Words: Morphing Aircraft, Modeling, Aerodynamic Characteristics Analysis, Kane's Equation

1 Development of Morphing Aircraft

In recent years, military and civil aviation aircraft have put forward higher and higher requirements to the performance of the aircraft. The aircraft not only adapt to different flight environment to perform different tasks, but also ensure the flight performance. Obviously the fixed wing aircraft cannot satisfy these requirements. Under the circumstance, morphing aircraft technology becomes research hotspots. This kind of aircraft is designed to change the aerodynamic shape in a large scale so that the aircraft can perform multiple tasks [1-3].

In the past few decades, the world carried out a lot of research about morphing aircraft technology. Mainly includes: AFTI/F 111 adaptive wing project in 1979 [4], active flexible wing (AFW) project in 1985 [5], smart wing project in 1995 and morphing aircraft structures (MAS) project in 2003 [6]. These research projects did a large number of theoretical analysis and experiment and made valuable achievements aiming at dynamic performance, structure design, control technology, intelligent materials and multidisciplinary technology and many other aspects.

The morphing aircraft need to change aerodynamic shape in a wide range. Therefore, dynamic modeling is not like conventional aircraft, instead, establishes a dynamic model including morphing structure. Ref. [7] provides a flight dynamics modeling method of morphing aircraft, and simulated in a gull wing aircraft; Ref. [8] presents a dynamic modeling and flight control method for the morphing aircraft with large scale deformation; Ref. [9] establish dynamic model for a variable length aircraft. The modeling process noted above is based on the classical Newtonian mechanics method.

The change of morphing aircraft's span and sweep will cause the aerodynamic parameters change. Firstly this paper used the software Datcom to analyze aerodynamic parameters. Then this paper simplifies the variable length, variable sweep morphing aircraft as a multi rigid body system and establishes the dynamic model using Kane method. Based on the dynamic model, the longitudinal motion response during the morphing process of the aircraft are simulated and analyzed.

2 Aerodynamic Parameter Analysis

For the analysis of the aerodynamic characteristics, the aerodynamic Parameter of the morphing aircraft must be acquired.

2.1 Datcom Calculated Aerodynamic Parameters

At present, the method of aerodynamic parameters acquisition includes: wind tunnel experiment based on engineering experiment, computational fluid dynamics (CFD) method and engineering estimation method Datcom.

The following table gives the comparison of three commonly used calculation method of aerodynamic parameters.

Tab 1. Comparison of aerodynamic parameters calculation methods

Aerodynamic parameters calculation methods	Advantages	Disadvantages

Sponsored by Aviation Science Foundation:20135751040

Wind tunnel experiment	High accuracy, the most close to the real situation	High experiment cost, long period
CFD	Small data error, close to the real situation	Complex analysis process, huge calculation quantity
Datcom	Calculate aerodynamic parameters quickly, small calculation quantity	Some errors in calculation

As is seen in the table, the results of the calculation of Datcom has a certain error, but the results are still credible in the error range. Considering that the Datcom can get a lot of effective data in a short time, moreover, Datcom has a high accuracy in the range of less than 10° attack angle and is used in many studies. So this paper uses Datcom to carry on the aerodynamic analysis.

Input angle of attack, wing span, wing sweep in the Datcom to calculate aerodynamic parameters. This paper sets the flight conditions are as follows: the flight height is 10km, the flight speed is 0.6Ma. The wing sweep is 0° ,15°,30°,45°, and the corresponding span is 2m, 4/3m, 2/3m, 0m.

2.2 Analysis of Aerodynamic Parameters

Import the aerodynamic parameters obtained by Datcom into Matlab and plot the lift coefficient, drag coefficient, lift drag ratio and pitching moment coefficient curves along with the angle of attack. The curves are as follows:

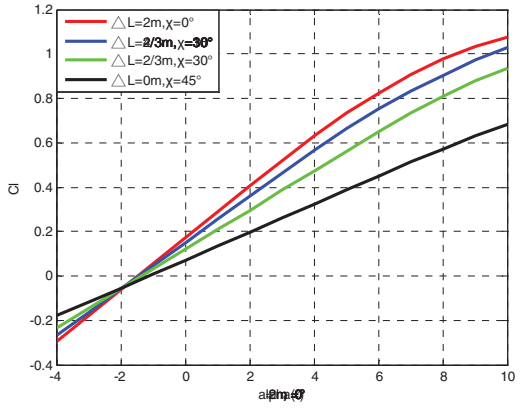

Figure 1: The change of lift coefficient along with the angle of attack

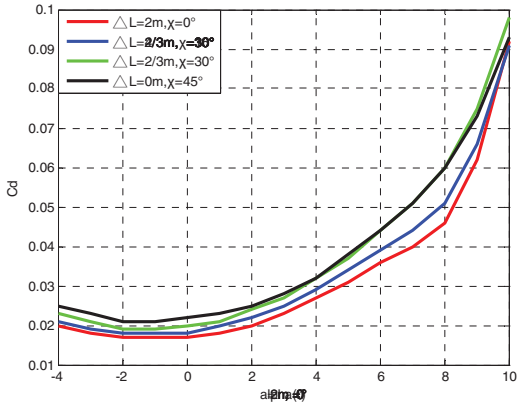

Figure 2: The change of drag coefficient along with the angle of attack

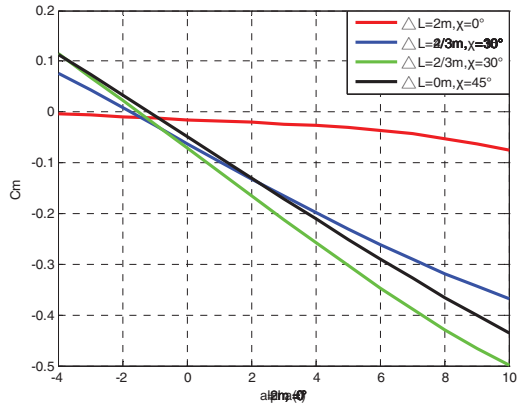

Figure 3: The change of pitching moment coefficient along with the angle of attack

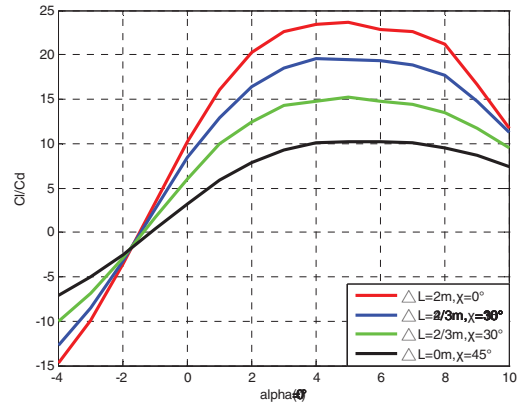

Figure 4: The change of lift drag ratio along with the angle of attack

In the figure, χ means the wing sweep and ΔL means the corresponding span. It can be seen from the figure that the aerodynamic parameters change a lot before and after the morphing. Taking Figure 1 as an example, when the morphing aircraft