Design and Analysis of Multi-Section Variable Camber Wing

Anita Nadar, Rizwan Khan, Parag Jagnade, Preshit Limje, Nishant Bhusari & Kushal Singh

AE Department, PCE, RTM Nagpur University, Nagpur
E-mail: annunadar@gmail.com, rizwankhan91cool@gmail.com, paragjagnade.click@gmail.com, nishant_bhusari@rediffmail.com, sharealittle719@gmail.com, kushalsingh101@gmail.com

Abstract – Minimizing fuel consumption is one of the major concerns in the aviation industry. In the past decade, there have been many attempts to improve the fuel efficiency of aircraft. One of the methods proposed is to vary the lift-to-drag ratio of the aircraft indifferent flight conditions. To achieve this, the wing of the airplane must be able to change its configuration during flight, corresponding to different flight regimes. Conventionally high lift devices like Flaps are used for this purpose but the functioning system is quite costly, heavy and noisy. In this project the aerodynamic characteristics of a multi-section, variable camber wing will be investigated. The model to be used in this project will have a 19.7cm chord and a 20cm wingspan, with the ribs divided into 3 sections such that section will be made to rotate approximately 1 degree without causing significant discontinuity on the wing surface manually. The multi-section variable camber wing model is expected to provide up to 10 per cent change in camber from the baseline configuration.

Keywords – Multi Section, Variable Camber wing, Rigid wing, Flaps, Wingspan, Ribs.

1. INTRODUCTION

A small percentage reduction in the fuel consumption of an airplane can lead to major savings in aircraft operational costs. Since the amount of fuel stored in the aircraft is limited, lower fuel consumption means greater range or endurance in flight. There has been a great deal of research focused on achieving this goal. One promising concept is the use of a variable camber wing. This wing can change its configuration and provide variations in lift and drag that satisfy different flight conditions so fuel can be consumed efficiently.

Variable camber wing concepts have been explored and developed extensively since the beginning of flight. The wing warping of the Wright Flyer, which used the pulling of cables to change the configuration of the wing tips was considered the first variable camber wing concept. The most significant variable camber devices currently used in most transport aircrafts are high-lift devices such as leading-edge slats and trailing-edge flaps. Those devices have demonstrated very promising results in reducing fuel consumption. Throughout this thesis, a wing with high-lift devices will be referred to as a conventional variable camber wing.

Even though traditional high-lift devices have shown the capability of improving the aerodynamic performance of the aircraft, these systems involve discontinuities or sudden curvature changes in the aerofoil cross-section and also involve complex and bulky actuation systems. Thus, the variable camber wing concept that can improve aerodynamics properties of the plane in different flight conditions and at the same time be simple and lightweight must be investigated.

This research focuses on designing and testing a variable camber wing model using multi section ribs. The model consists of four sets of three NACA 0015 aerofoil rib-sections connected through sub-spars; each section of the rib can rotate up to 5 degrees upwards or downwards without causing major discontinuity on the aerofoil cross-section.

Fig. 1 : Multi-Section Variable Camber Wing
The skin of the wing is made of the insignia cloth (an adhesive backed polyester fabric for making banners and flags) and silicon rubber sheet bonded together. Both materials provide sufficient strength and elasticity for the wing in both baseline and morphing configuration. Figure 1 shows the multi-section variable camber wing used for wind tunnel testing.

II. VARIABLE CAMBER WING DESIGN

Three wind tunnel models were constructed for this research: one multi-section variable camber wing and two rigid wings of the baseline (Symmetrical) configuration and of the cambered configuration of the variable camber wing. Detailed information of these wing models are described as follows.

The initial inspiration of this wing concept began with the desire to change the camber of the wing by deflecting only the leading edge and trailing edge portion of the wing without having any gap between each portion. Using a three-section wing concept, the provided a smooth change during cambered configuration. Dividing the wing into section provided ease in varying the shape of the aerofoil since each section could rotate freely relative to the nearby sections.

Due to lack of space in the wing sections and due to wind tunnel constraints the sections were rotated manually and held at that position by using mechanical means.

2.1 Multi-Section Variable Camber Wing

2.1.1 Wing Ribs and Spars

The wind tunnel model was a 20 cm span and 19.5 cm chord NACA0015 based aerofoil with 4 wing ribs. Each rib was divided into 3 sections with circular cuts at both ends except for the leading and trailing edge sections, which had a circular cut at only one end. The ribs were made of plywood and the sub-spars were made of stainless steel spokes.

Each rib section and the corresponding spar were secured together by setscrews, which allowed for convenient adjustment. Balsa wood links were used to connect the rib sections together and allowed them to rotate freely. Each rib section could rotate up to 5 degrees around its own spar without providing significant discontinuity in the wing surfaces. The process of wing rib fabricating began with determining the suitable number rib sections and the location sub-spars. The circular curves were then created by having a centre at the centre of the spar location and had a radius of 0.1 inch less than the distance between the centre of the spar and the point on the contour of the aerofoil perpendicular to the camber line. Each section of the ribs was cut with the Saw machine. Rib sections were manufactured with 3 multi-sections joined by sub-spars with other sections. Figure 2 shows the drawing of wing rib cross-section.

2.2 Wing Structures Assembly

The rib sections are connected together by the chain-like connection links, which allow each section to rotate around its own spar and to rotate relative to the nearby sections. The ribs and the links are secured together by balsa wood links. The ribs sections are joined together by stainless steel spokes which acts like sub-spars and then the sections are joined together by links made by balsa wood and all these are fastened by using nuts and screws.

2.3 Wing Skin

The materials used for covering the wing model were insignia cloth, an adhesive backed polyester fabric used for banners and flags, and silicon rubber sheet. The insignia cloth is a very light, smooth, and windproof material. A layer of insignia first glued onto the wing ribs covering both top and bottom surface of the wing. The area on the rib where two rib sections meet is covered with the silicon rubber strip only because this area change its size when the wing is cambered so the elastic covered for this area is required. The strips of insignia cloth are glued on the wing surface anywhere else away from the joint of rib sections. Figure 4 shows the wing with skin material; silicon rubber is at the section attachment points and insignia cloth is elsewhere.
2.4 Rigid Wing Models

Two rigid wing models for the baseline configuration and for the cambered configuration were constructed to compare the test results with those of the variable camber wing. Both the wings are constructed by using Wooden Material. First wing is the Baseline configuration that is the symmetrical configuration wing of NACA 0015 Configuration this rigid model was made by Wood with 19.5 cm Chord length and 20 cm span length. Figure 5 shows Baseline Rigid Wing (NACA 0015)

Second Wing is the Cambered Configuration wing that is wing with NACA 6615 Configuration this rigid model was made by Wood with 19.7 cm Chord length and 20 cm span length. Figure 6 shows Cambered Rigid Wing (NACA 6615)
2. Cambered rigid configuration

Aerofoil selected for cambered rigid configuration is NACA 6615 with chord length 19.7 cm and span 20 cm.
IV. EXPERIMENTAL TESTING OF MULTI-SECTION VARIABLE CAMBER WING AND RIGID WINGS

5.1 Comparison of Experimental Data of MVCW and Baseline rigid wing with data of Software Analysis of Wing:

![Graph of Coefficient of lift Vs. Alpha](image)

Fig. 16: Calculation of drag force in Ansys software

Fig. 17: Catia model of structure assembly of Multi-Section Wing

Fig. 18: Wind Tunnel used for Testing

Fig. 19: Variable Camber Wing while Testing in Wind Tunnel

Fig. 20: Six Component Test Set-up showing the variation of lift and drag

Fig. 21: Graph of Coefficient of lift Vs. Alpha
Fig. 22: Graph of Coefficient of drag Vs. Alpha

Fig. 23: Graph of Cl/Cd vs. Alpha

Fig. 24: Graph of Coefficient of lift Vs. Alpha

Fig. 25: Graph of Coefficient of drag Vs. Alpha

Fig. 26: Graph of Cl/Cd vs. Alpha

Fig. 27: Graph of Coefficient of lift Vs. Alpha
VI. CONCLUSION AND FUTURE WORK

A Lift derived from the variable camber wing is higher than that of the rigid wing; this is possibly due to the vibration of the wing skin that keeps the flow attached to the wing. For the cambered configuration, the flexibility of the skin helps to reduce the drag on the variable camber wing.

The wing skin on top surface of the wing becomes tighter and smoother as it is being forced to curve. The bottom surface of wing also becomes tighter due to high pressure. The software drag derived from the Ansys software lesser than those derived from the experiment because of errors occurring during experimental testing. The increase in lift and decrease in drag of the variable camber wing in cambered configuration results in a higher lift-to-drag ratio than that of cambered rigid wing.

The future of the project will be to implement electric actuators and a simple linkage system embedded inside the wing, will be designed as another means to vary the shape of a wing. Same type of skin material should be applied to both variable camber wing and rigid wing to provide fair comparison.

VII. REFERENCES


