STRUCTURAL ANALYSIS OF BASALT AND GLASS FRP COMPOSITE HIGH LIFT DEVICES OF CIVIL TRANSPORT AIRCRAFTS

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Abstract—

Composites are widely used for the constructions of various components of aircraft due to its appreciable properties than its counterpart conventional metals. This research work focuses on stress analysis of flaps (high lift device) used in the high rage aircrafts. NACA AG09 and SC20610 airfoils are used for developing such flaps. Two different flaps(plain flap and slotted flap) are chosen for this analysis. The loads acting on these flaps during flight conditions are determined using ANSYS-CFD software and the structural analysis are done by using NASTRAN and PATRON software. For structural analysis two different materials, Basalt Fibre Reinforced plastic(BFRP) composite and Glass Fibre Reinforced plastic(GFRP) composites are used. The stress at various layers of the BFRP flap is higher than that of GFRP flap.

I. INTRODUCTION

Composite materials are called lion of materials due to its high strength to weight ratio and stiffness to weight ratio. These materials are widely used for various structural applications like marine, Automobile, civil, Automotive, Space and Aeronautical Industries. Verities of natural and artificial fibres are used for the development of new composite materials for diverse applications. Nowadays The major components of most of the aircrafts are manufactured using Carbon Fibre Reinforced Plastic (CFRP) composites. But the auxiliary components like control surfaces,flaps,wing trailing edges, nose cone, flooring ect are manufactured using aramid fibre composites and GFRP composites. Basalt Fibre Reinforced Plastics(BFRP) composites are new composites developed from basalt rock. These materials are having very good mechanical and thermal properties slightly greater than its counterpart GFRP composites. This materials also can be used for the construction of auxiliary aircraft components. Many people have done various work on structural analysis of various components using various materials. [1] Anand.H.R et.al have done structural analysis of wing box using GFRP. [2],[3]Di.Matteo et.al have developed flaps for high lift wing using GFRP materials. [4] Durksteenhuizen et.al have introduced automated actuators for high lift devices.[5]Morishima, R et.al have developed morphing technique for flaps. In this present work morphing flaps are developed using BFRP materials and GFRP materials.

II. MATERIAL PROPERTIES

Basalt unidirectional fabric (density 550 Kg/cm^2) is the mandatory reinforcement material for our experimental work. Epoxy LY556, the hardener. Aradur Hy 951 was purchased from Javanthy Enterprises; Chennai is used as matrix material. BFRP and GFRP laminates were fabricated by using hand lay up process. Specimens were prepared for mechanical tensile test as per ASTM D3039 standards using computerized abrasive water jet cutting machine in order to avoid delamination and to get perfect dimension. Material properties of GFRP and BFRP composites are shown in Table.1.

Table 1. Material properties of glass/epoxy and basalt/epoxy

Materials	E_1 (Gpa)	E_2 (Gpa)	G_{12} (Gpa)	$\square_{12}$	X_t (Mpa)	Y_t (Mpa)
Glass/epoxy	40.49	6.91	2.667	0.269	1000	30
Basalt/epoxy	46.49	6.54	2.512	0.251	1120	25

III. MODELLING AND ANALYSIS

For analysis of flaps two different airfoils were selected. Plain flap NACA AG09 and slotted flap SC20610. Modeling were done using CATIA software. The length of the flap is 1m and the width is 1m.. The skin thickness is 2mm and is reinforced by a six-I shaped stringers. The stringers flange and web are 12mm in length, placed on both upper and lower surfaces in order to reinforce the skin and to allow the external and internal loads transfer through the skin structure.. 2D QUAD4 shell elements were used for both skin and stringers. A meshed model of flap is shown in the Fig.1. The major loads acting on the flaps are actuating load and the aerodynamic loads. The aerodynamic loads are determined using CFD analysis. An actuating load of 861N is applied at the leading edge of the flap. Pressure distributions are uniformly distributed loads.

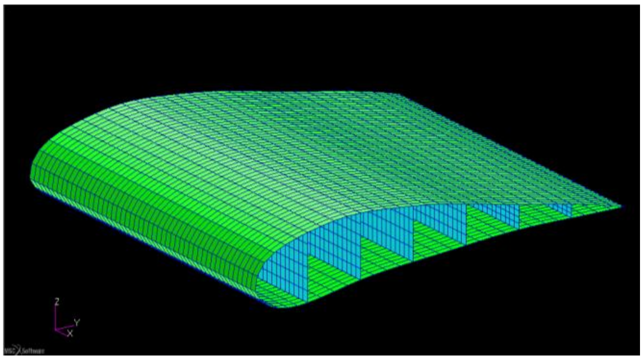

Fig.1. Meshed model of flap

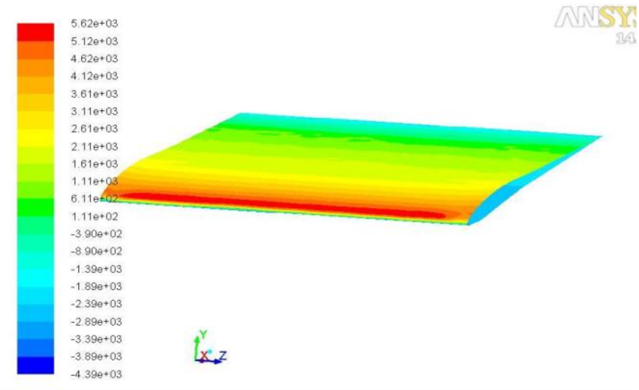

Fig.2. Pressure distribution over plain flap

IV. RESLTS AND DISCUSSIONS

Structural analysis of the two flaps were carried out using NASTRAN and PATRON software. The aerodynamic loads are calculated using CFD analysis. During flight there is a flow over the flaps .The pressure distribution over the plain flap is shown in fig.2.From the pressure distribution the aerodynamic loads, lift and drag forces of the two flaps were determined and the corresponding coefficients are shown table.2. From the CFD analysis it is observed that the aerodynamic efficiency of slotted flap is 6 times than that of plain flap. But the lift developed in the plain flap is 1.5 times that of slotted flap. Since the purpose of flap is to develop high lift during flight take off. Therefore the plain flap is selected for the structural analysis.

For structural analysis of the plain flap is chosen. The boundary conditions are, the leading edge is hinged and the trailing edge is free. The lift and drag forces evaluated using CFD software is considered as Uniformly Distributed load over the entire flap. Apart from that an actuation load of 861 N is applied at the leading edge that is applied by the pilot. The material properties of BFRP and GFRP composites shown in Table.1. are used for the analysis. The stress distribution over the flap for GFRP and BFRP materials are shown in fig.3 and Fig.4.The comparison between the layer by layer average stress values of the two flaps with BFRP and GFRP materials are shown in fig.5. For GFRP, the stress curve increases gradually from 1st layer to 8th layer from 2.27 to 0.858.At 45^0 orientation, the stress at 1st layer is 2.27 and 2nd layer is 1.97.Then at 0^0 orientation for the next three layer, the value is 1.39, 1.24, 1.09 and the next two layers at 90^0 the stress value is 0.96 and 0.892. Then, in 8th layer at 0 □ orientation , the stress decreases suddenly and again from 9th layer to 12th layer, it increases gradually. So, the maximum failure occurs at 8th layer (0.858GPA). so, it fails first and then 1st layer(2.27GPA).For For BFRP, the stress curve increases gradually from 1st layer to 6th layer (i.e) from 2.50 to 1.38.At 45^0 orientation, the stress at 1st layer is 2.50 and 2nd layer is 2.24.Then at 0^0 orientation for the next three layer, the value is 1.57, 1.64, 1.38 and the 6th layer at 90^0 the stress value is 1.38. Then, in 7th layer at 90 □ orientation , the stress decreases to 1.25 and from 8th layer increases suddenly to 1.74 and from 9th layer to 12th layer stress increases gradually. The first ply failure occurs at the 7th layer (1.25GPA) and last ply failure occurs at the 12th layer(2.84GPA).The average strain in the X-direction is 0.0000017 for BFRP composites and 0.0000083 for GFRP composites.

Table.2. Cl and Cd values of plain flap and slotted flap calculated using CFD analysis

Type of flap	C_L	C_D
Plain flap	1.014	0.724
Slotted flap	0.7487	0.149

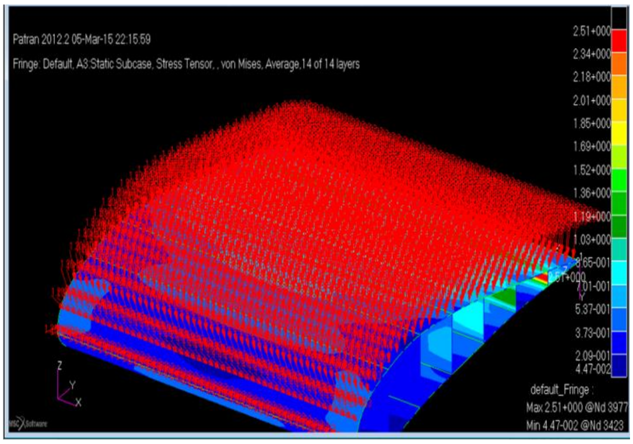

Fig.3.Averge stress distribution of GFRP Flap

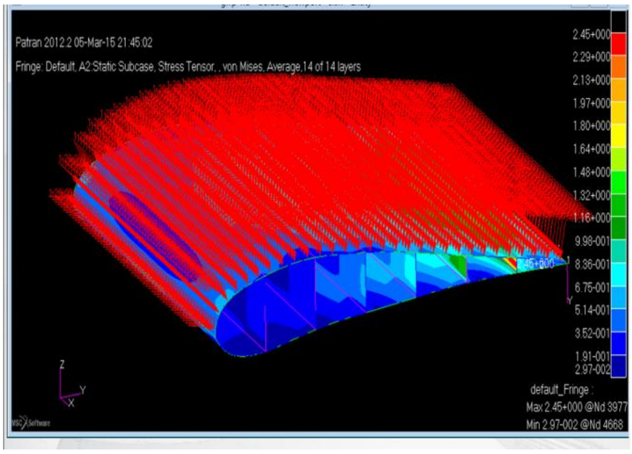

Fig.4. Average stress value of BFRP Flap

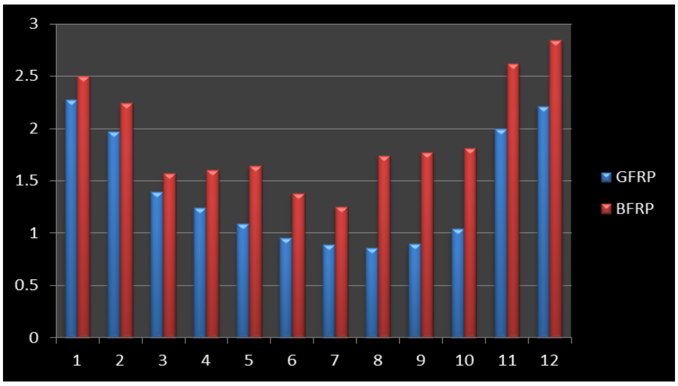

Fig.5 Layer by layer Comparative stress distribution of GFRP and BFRP flaps

V. CONCLUSION

Due to high lift generation, the plain flap is selected for analysis. From the ply by ply stress distribution and failure analysis, the flap with basalt/epoxy composite is better than the flap with glass/epoxy composites. Therefore, the basalt fibre plastic composites are suggested for the construction of auxiliary components of aircrafts in the place of GFRP composites.

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