DESIGN AND ANALYSIS OF A CANARD OF AN UAV

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Abstract

A canard is used to balance loads, to improve lift characteristics at the nose, to improve overall stability and to improve stalling characteristics of the UAV. ADE DRDOs ARCHER UAV utilizes a canard design to help with balancing of the control systems situated in the nose section. An UAV is expected to be highly stable even during turbulent conditions as they are mainly used for surveillance and reconnaissance. A canard design UAV helps with this application. The Canard is composed of composites in majority and the fasteners used to fasten the canard and the fuselage are metals. Composites have a major advantage over metals that is they have excellent mechanical properties in the direction of the fibre enabling for an excellent design characteristic. Composites are also much lighter than metals reducing the structures weight. They also can be made into any form or shape without complex fabrication process. Their main disadvantage is transverse loading conditions and high cost of material. Technology of composites used in aircraft structures highly benefits in weight reduction and increasing overall stiffness of the structure. The present work focuses on optimizing the design of the canard to reduce weight while sustaining the same loading conditions. Various iterations are run to achieve these objectives by varying the composite layer thickness, fibre orientations and number of composite layers in the canard structure. The canard being used in the UAV has been modelled on CATIA from the given aerofoil profile. A hybrid design between part modelling and surface modelling is used to model it. The finished CAD model is imported into HYPERMESH for meshing. The material properties thicknesses, orientations and failure criteria are added to the components. This meshed model is then imported into PATRAN for processing it. The boundary conditions and loads are applied in this software. This file is then imported into a solver- NASTRAN for solving the FEA problem. This analysed model is then imported into HYPERVIEW to view the results.

Keywords: Composites; Canard; UAV; Analysis; FEM.

Introduction

Composites consist of multiple constituents, usually a fibre and matrix mixed to form a ply. Multiple plies stacked one on top of the other creating a structure called laminate. These laminates can be formed into any shape and size. The material orientation can be selected as per design requirements allowing for a very flexible design. Strength and weight can be varied to achieve desired outputs.

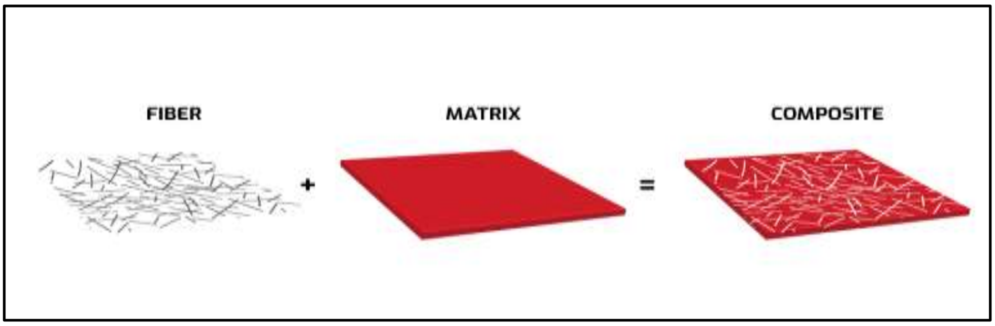


Figure 1: General Composite Structure

Composites have multiple advantages over isotropic materials such as density being much lower, high tensile modulus in direction of fibre, excellent corrosion resistance etc. they also have a few disadvantages such as failure under transverse loading conditions, cost, reusability and disposal is not possible, difficult to attach multiple parts etc. Figure 1 shows General Composite Structure

Figure 2: Various composite materials

Figure 2 shows Various composite materials There are various failure criteria used to understand failure in composites. Namely they are – maximum stress criterion, maximum strain criterion, Tsai-Hill criterion, Tsai-Wu criterion, Classical laminate theory, etc. methods to identify failure are fiber breaking, matrix crazing, matrix cracking fiber debonding and delamination. Because of their excellent mechanical properties and corrosion resistance they are widely used in aerospace industries. The main advantages of using composites in aircrafts are weight reduction, easier to assemble complex components, monocoque molding, thermal stability, high impact resistance and galvanic corrosion is not present A canard is an arrangement wherein a small forewing is placed ahead of the main wing. Canard wings are also extensively used in guided missiles and smart bombs. The designer may adopt the canard configuration to reduce the main wing loading, to better control the main wing airflow, or to increase the aircraft's maneuverability, especially at high angles of attack or during a stall. Canard foreplanes, whether used in a canard or three-surface configuration, have important consequences for the aircraft's longitudinal equilibrium, static and dynamic stability characteristics. There are multiple configurations of the canard such as close coupling, free floating canard, variable geometry, ride control and stealth. The main advantage of a canard is, it allows for good stalling characteristics without elevator stops. The main disadvantage is, the design creates a large CG range and directional stability for the vertical surfaces are reduced.

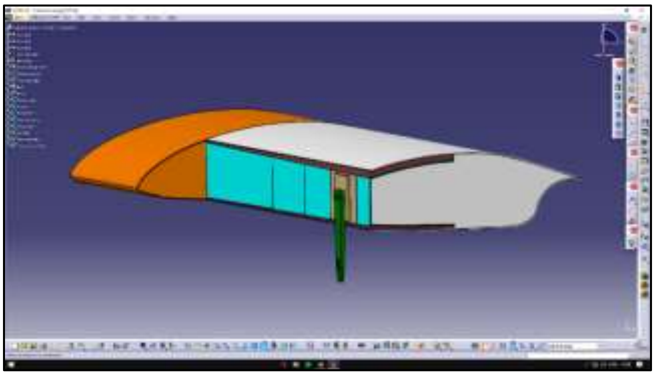


Figure 3: Archer UAV with Canard configuration

Figure 3 shows Archer UAV with Canard configuration DRDO uses an UAV for surveillance and reconnaissance called Archer, previously known as Rustom-1. It is a MALE UAV. MALE stands for Medium Altitude Long Endurance. The Archer utilizes a canard to help balance the CG which is ahead of the main wing.

Method & Material

Literature survey was conducted to know about previous studies and research gaps were identified. The aerofoil coordinates were imported into CATIA and the model was made using multiple tools in surface modelling. It consists of multiple layers such as glass skin, shear web, spar cap, nine plies and one ply. It also has isotropic materials such as high density Styrofoam and aluminum.

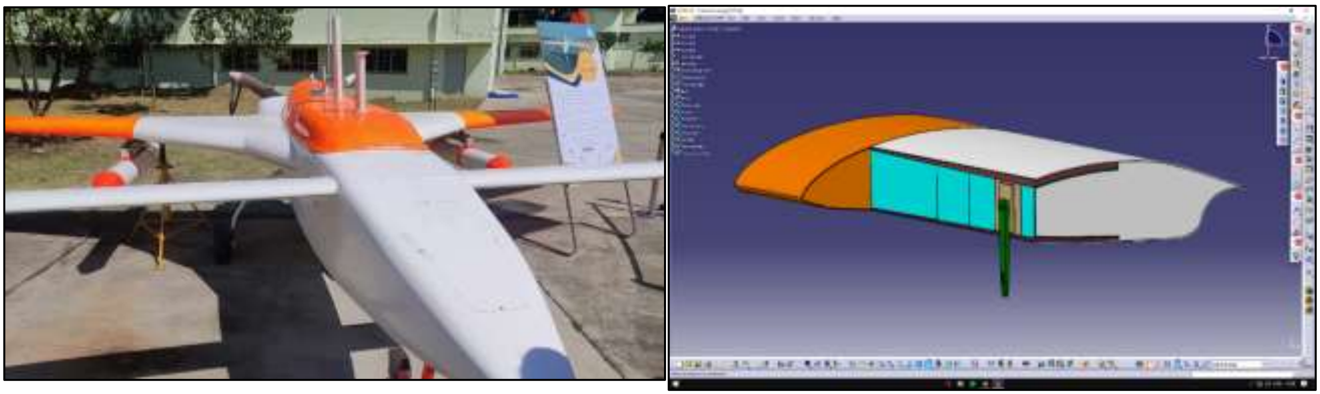


Figure 4: Cross Sectional View of Canard consisting of outboard and inboard

Meshing of the model is done on Hypermesh for FEM analysis. The composite materials were 2D meshed and isotropic materials were 3D meshed. The materials were assigned as needed to the parts. The materials consist of GFRP, CFRP Bi-Directional, CFRP Uni-Directional, High-density Styrofoam and aluminum.

The meshed model was imported into Patran for analysis where the loading and boundary conditions were applied and the model was constrained. The required output results were specified. The output file was run on a solver – Nastran. After solving the output file from Nastran is checked for fatal errors and then imported into HyperView. HyperView is a post processor and is used to view the analysis results. Figure 4 shows the Cross Sectional View of Canard consisting of outboard and inboard

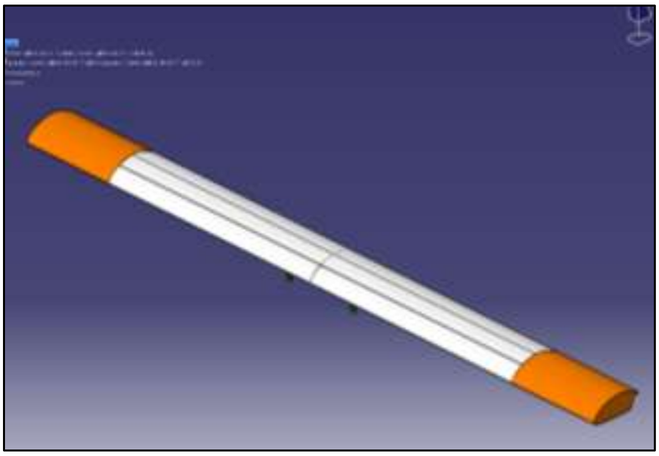


Figure 5: Final Canard model

Figure 5 shows Final Canard model shows the multiple iterations were run to optimize the design in such a manner so the weight of the canard is reduced under same loading conditions without failure. This was done was varying the number of composite layers, thickness of composite layers and orientation of these layers in different parts of the canard.

Table 1,2,3 shows the material properties and its characteristics

Table 1: Materials properties

Properties	Styrofoam	Glass fibre composite	Carbon fibre composite Bi-Directional	Carbon fibre composite Uni-Directional	Aluminium
E (MPa)	70	-	-	-	70000
E1 (MPa)	-	18000	52000	115000	-
E2 (MPa)	-	18000	52000	7250	-
G (MPa)	21	-	-	-	29000
G12 (MPa)	-	2200	2300	2900	-
G23 (MPa)	-	2200	2300	2900	-
G13 (MPa)	-	2200	2300	2900	-
NU	0.2	-	-	-	0.2
NU12	-	0.2	0.2	0.2	-
ST (MPa)	1.9	-	-	-	-
SS (MPa)	0.8	-	-	-	-
SC (MPa)	1.9	-	-	-	-
X_t (MPa)	-	-	305	690	-
X_c (MPa)	-	-	170	275	-

Y_t (MPa)	-	-	305	14	-
Y_c (MPa)	-	-	170	51	-
S (MPa)	-	-	31	43	-
RHO (Kg/mm^3)	5 e-08	2 e-06	1.9 e-06	1.6 e-06	2.7 e-06

Iteration – 1

Table 2: Material variation in Iteration 1

Sl No.	Layers	No. of Layers	Orientation	Thickness (mm)	Angle (degree)
1.	Glass skin Top (Glass Fibre)	4	Bi-Directional	0.25	45
2.	Glass skin bottom (Glass Fibre)	3	Bi-Directional	0.25	45
3.	Shear web (Carbon Fibre)	6	Uni-Directional	0.2	45
			Uni-Directional	0.2	-45
			Uni-Directional	0.2	-45
			Uni-Directional	0.2	-45
			Bi-Directional	0.2	45
			Bi-Directional	0.2	45
4.	Spar cap (Carbon fibre)	11	Uni-Directional	0.2	0
5.	Nine plies (Carbon fibre)	9	Bi-Directional	0.2	45
6.	One ply (Carbon fibre)	1	Bi-Directional	0.2	45

Table 3: Material variation in Iteration 2

Sl No.	Layers	No. of Layers	Orientation	Thickness (mm)	Angle (degree)
1.	Glass skin Top (Glass Fibre)	3	Bi-Directional	0.2	45
2.	Glass skin bottom (Glass Fibre)	2	Bi-Directional	0.2	45
3.	Shear web (Carbon Fibre)	6	Uni-Directional	0.2	0
			Uni-Directional	0.2	90
			Uni-Directional	0.2	0
			Uni-Directional	0.2	90
			Uni-Directional	0.2	0
			Uni-Directional	0.2	90
4.	Spar cap (Carbon fibre)	13	Uni-Directional	0.2	0
5.	Nine plies (Carbon fibre)	9	Bi-Directional	0.2	45
6.	One ply (Carbon fibre)	1	Bi-Directional	0.2	45

Results and Discussions

Load distribution on wing-

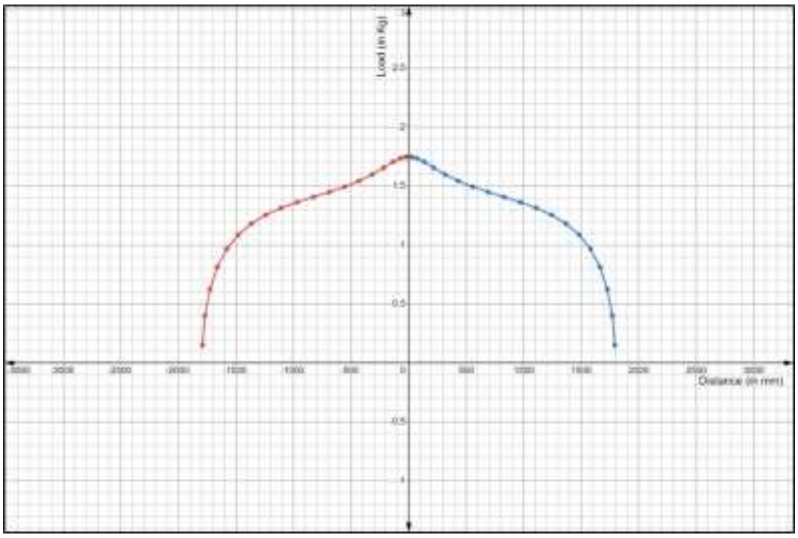


Figure 6: Load distribution graph

Figure 6 shows A detailed study on the design and analysis of a Canard is completed. First the canard was modelled using ‘CATIA’ software and meshed for analysis using ‘Hypermesh’ software. The number of composite layers, thickness and these layers and orientations of these layers were varied during the meshing process for different iterations. ‘Patran’ and ‘Nastran’ software were used to analyze and obtain results for these iterations. Figure 7,8,9,10,11,12,13,14,15,16,17,18 shows the analysis of composite material and its characteristic.

Table 4: Physical parameters obtained

	Iteration – 1	**Iteration – 3**
Total Volume (mm^3)	4.1 e+07	4.058 e+07
Total mass (kg)	6.881	6.138
Total Area (mm^2)	4.052 e+06	4.052 e+06
Total number of nodes	57399	57399
Total number of elements	68496	68496

Table:5 Results of analysis

	Iteration – 1		**Iteration – 3**	
	Max	Min	Max	Min
Failure Index	8.91e -01	-2.80e-01	3.32e-01	-5.03e-02
Displacement (mm)	2.14e+01	2.38e+00	2.14e+01	2.38e+00

Direct Stress (N/mm)	4.31e-02	-7.24e-02	5.91e-02	-7.35e+02
Direct Strain	5.75e-04	-1.11e-03	1.20e-03	-1.16e-03
Composite Stress (N/mm)	1.30e+02	7.32e-03	1.24e+02	1.43e-02
Composite Strain	2.03e-03	7.36e-07	2.82e-03	1.44e-06

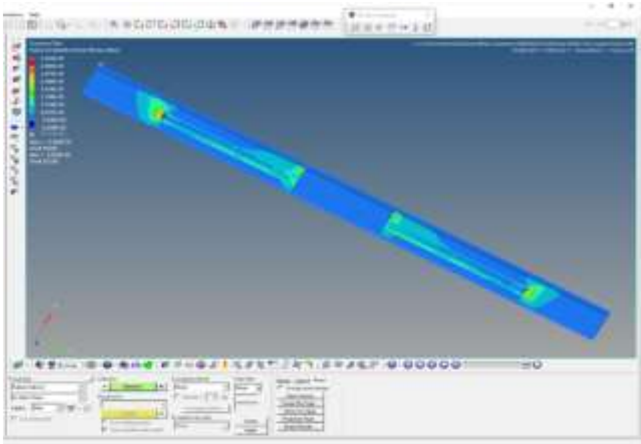


Figure 7: Failure Index

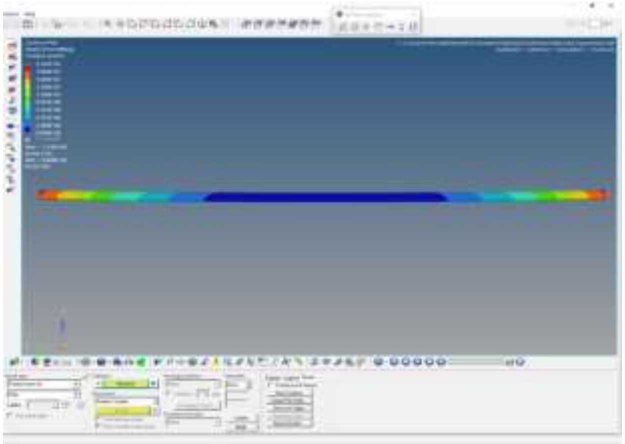


Figure 8: Displacement

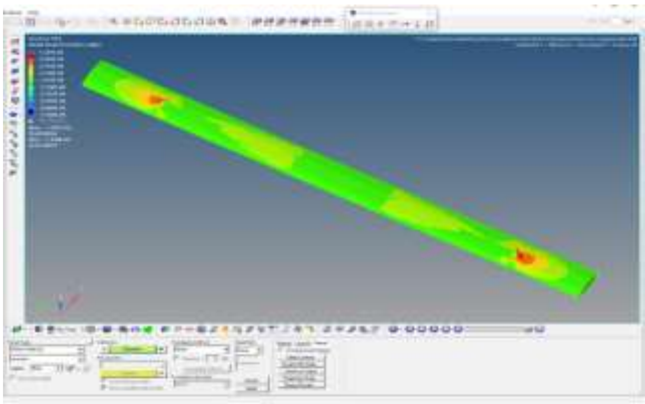


Figure 9: Direct Strain

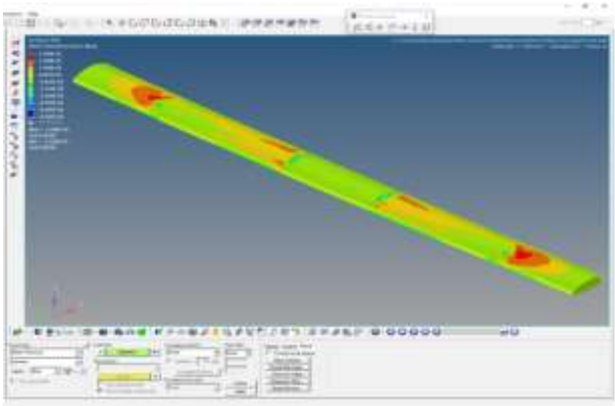


Figure 10: Direct Stress

Figure 11: Composite Strain

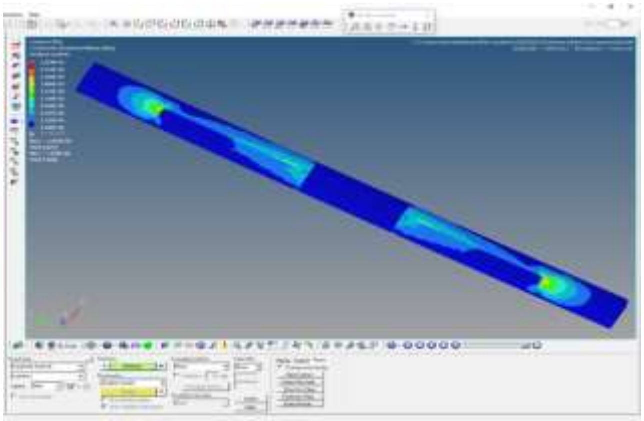
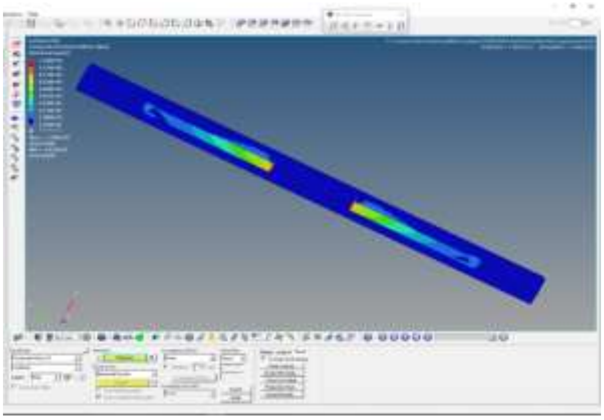
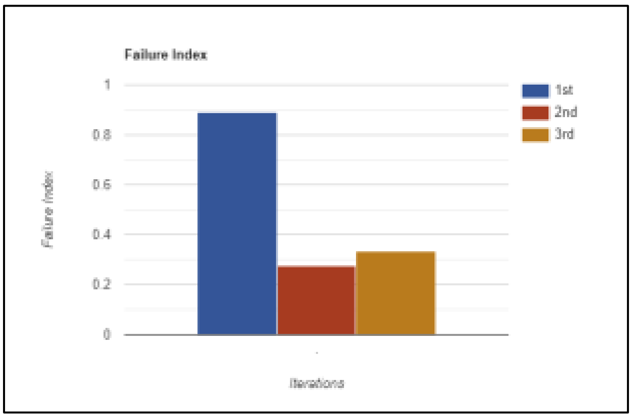


Figure 12: Composite Stress





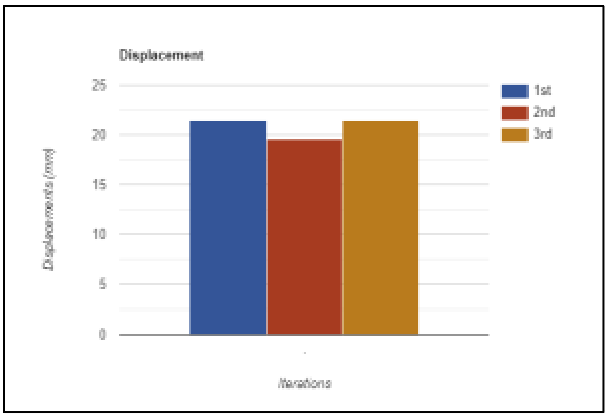
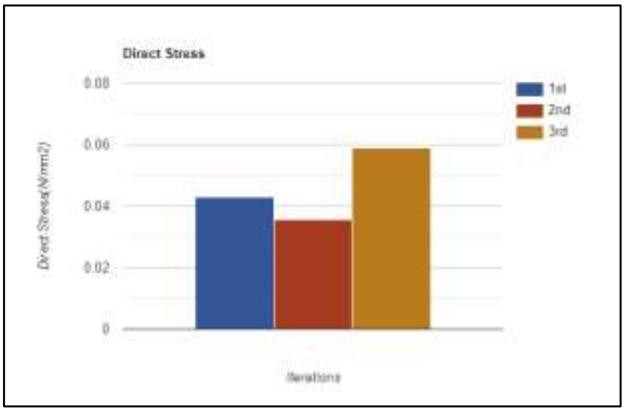


Figure 13: Failure index graph

Figure 14: Displacement graph



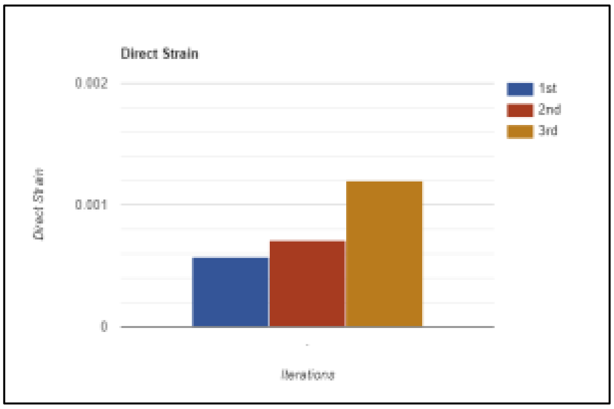


Figure 15: Direct Stress graph

Figure 16: Direct Strain graph

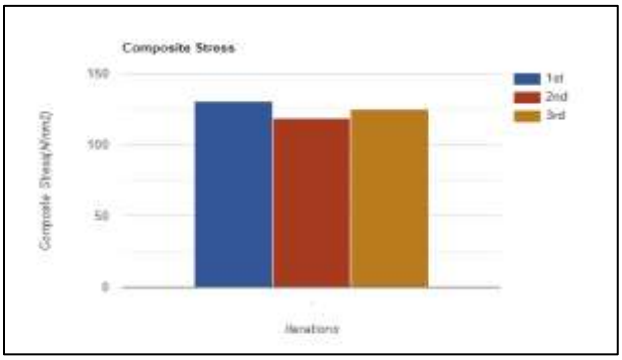


Figure 17: Composite Stress graph

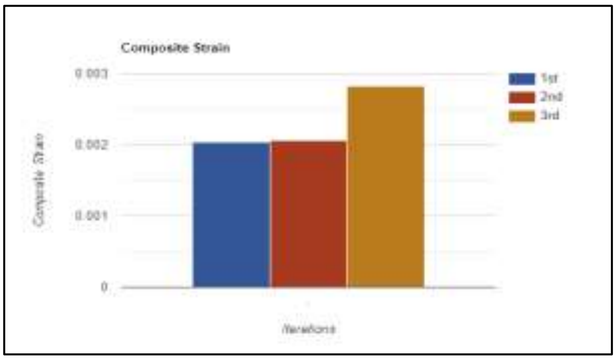


Figure 18: Composite Strain graph

Conclusions

The following inferences were drawn from the Finite Element Analysis of the Canard Structure –
i) Optimization studies on the canard layup was carried out and it was found that the overall the weight of the canard was reduced from 6.881 kg in the first iteration to 6.138 kg in third iteration which was done by varying thickness, layers and orientation of various composite layers in the canard structure. In total 11.44 % reduction of weight was obtained.
ii) It was found that the failure index of the structure was reduced from 8.91e-01 in the first iteration to 3.326e-01 in the third iteration which increased the overall stiffness of the canard
iii) The overall weight to failure index ratio of the canard structure was improved after the final iteration.
iv) The composite stress concentration was shifted from the glass skin layer to the spar caps after the final iteration which helped to improve load distribution inside the canard structure

The overall design of the canard was optimized for weight reduction and safety and the proposed objectives were obtained.

Future Scope

In the future, the design of the canard will be changed to a sandwich foam design. This design will allow for a stiffer canard. This design will also be much lighter.

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