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OPTIMIZATION OF UNMANNED AERIAL VEHICLE WING STRUCTURE

M.S.Prabhu[1], J. Naveen Raj[2] and G.Vignesh[3]

[1] Assistant Professor, Department of Aeronautical Engineering, Hindusthan Institute of Technology, Coimbatore-32, Tamilnadu, India

[2] Final year (2011-15), Department of Aeronautical Engineering, Hindusthan Institute of Technology, Coimbatore-32, Tamilnadu, India

[3]Final year (2011-15), Department of Aeronautical Engineering, Hindusthan Institute of Technology, Coimbatore-32, Tamilnadu, India

Abstract

The optimum structural design of an Aircraft wing is an important factor in the performance of the airplanes i.e. obtaining a wing with a high stiffness/weight ratio and sustaining the unexpected loading such as gust and maneuvering situations. This is accomplished by minimization of structural mass by varying member composition or material usage in the model. In this article optimization method for wing structure of an UAV is proposed through better analysis. This article mainly concentrates on usage of composites on the skin panel of the wing and the rest of the structures with aluminum material. It also involves the study of various composition of sub structures like stringers, ribs contributing the optimization involved. The results are given such that to prove that usage of composites together with the aluminum greatly contributes for the reduction in overall structural weight.

Keywords: *stiffness, gust, maneuvering, optimisation*

1. Introduction

When applied to aircraft structures, carbon composites are generally supplied in unidirectional (UD) form: thin (~0.125 – 0.25 mm thick) sheets or tapes of parallel fibres that have been pre-impregnated with resin that has yet to set. This form of the material is ideal for the manufacture of thin plates that are used so extensively in airframe structures. Manufacturers use tape laying machines to lay down layers, or plies, of this material, one on top of the other, to form single piece sub-components. By laying successive plies in different directions, the strength and stiffness of the component can be tailored to match the demands of the engineer, allowing adequate structural properties to be attained for minimum weight.

Modern tape-laying machines can fabricate an entire wing skin in one piece, eliminating the fasteners that are routinely used in metallic designs and thus saving manufacturing cost and further reducing overall weight. To complete the manufacturing process, the component is cured within an autoclave, which subjects the component to pressure at an elevated temperature to consolidate and harden the layers of plies into a single monolith of carbon/epoxy laminate.

2. Project Description

From the literature survey studies it is understood that the optimization of the wing on an aim to reduce the weight of the wing structure, the variation of sub structures like stringers, ribs and also the material used greatly influence. Hence from this, we suggest the use of composites with the aluminium for the wing structure can be used as another optimization technique. In this article the effect of composite together with the variation of structural parts are also considered.

2.1 Description

For the better suggestion through the result, a wing of an UAVs that contains taper wing and rectangular wing is chosen. Rectangular wing from UAV called Predator and taper wing from UAV called Luna is chosen. Further with the actual parameters results can be found using structural analysis. Structural analysis is probably the most common application of the finite element method. The static analysis is used to determine displacements, stresses, etc. under static loading conditions. In this work the structural static analysis was achieved by using the Ansys in order to obtain stress and displacement distribution in the wings by using isotropic and composite material for selected unmanned aircrafts. The Ansys program has many finite element analysis capabilities, ranging from a simple, linear, static analysis to a complex, non linear, transient dynamic analysis. A typical Ansys analysis has three

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distinct steps: Building the model, Apply loads and obtain the solution.
and review the results.

3. Raw Data

Historically, aluminum materials have been the primary material for aircraft and spacecraft construction. Today, structural weight and stiffness requirements have exceeded the capability of conventional aluminum, and high-performance payloads have demanded extreme thermo-elastic stability in the aircraft design environment. During the past decades, advanced composite materials have been increasingly accepted for aircraft and aerospace structural materials by numerous developments and flight applications. Composite materials are those containing more than one bonded material, each with different structural properties.

For the optimization of wing of the selected UAV, two wings one with actual usage of aluminium and other with combination as where substructure (spars, flanges, Ribs, and stringers) is made up of isotropic material whereas the skin panels of wing are made up of composite material such as graphite/epoxy. The properties of those selected composites are,

TABLE 1 (a) MATERIAL PROPERTIES

Material	7075-T6 aluminium	H.M Gr/EP	Gr/Ep	Sg/Ep
E(N/m^2)	71E9	137.9E9	145	55
ν	0.33	0.21	0.25	0.28
ρ(Kg/m^3)	2800	1743	1580	1593

TABLE 1 (b) MAIN CHARACTERISTICS OF THE WINGS

CHARACTERISTIC	TAPER WING	RECTANGULAR WING
Wing span(m)	3.05	3.35
Gross Area(m^2)	1.4	1.53
Aspect ratio	6.64	7.33
Taper ratio	0.53	1
Tip Chord(m)	0.32	0.45
Root Chord(m)	0.6	0.45
Sweep angle(deg)	5.24	0
section Profile	NACA 0012	NACA 2412

Using the above data the model is designed using the catia modelling software for various composition of stringers and ribs.

The wing structural design problem is composed into two levels in a hierarchical structure at the first level, the wing configuration is completely made up of isotropic material and the following design parameters were investigated such as number of stringers, number of ribs. The second level wing substructure (stringers, ribs) is made of isotropic material and the skin panel is made of composite material. For composite material, the work covers the investigation of the effect of changing 3 type of composite material. Then from the results we take the optimum design.
To insert “Tables” or “Figures”, please paste the data as stated below. All tables and figures must be given sequential numbers (1, 2, 3, etc.) and have a caption placed below the figure (“FigCaption”) or above the table(“FigTalbe”) being described, using 8pt font and please make use of the specified style “caption” from the drop-down menu of style categories

4. Loads and Supports

The model designed in CATIA is taken to ansys for analysis, here the loadings are given such that the pressure force on upper surface is lower than the lower surface of the wing. That is on upper surface pressure P =1e7 pa and lower surface P =2e7pa.The wing is provided with frictionless support. The structural analysis was achieved by using the Ansys, in order to obtain stress and displacement distributions in the wings by using isotropic and composite material for find the optimum design.

The analysis results are tabulated to compare and isolate the efficient one,

TABLE 2- RESULTS OF RECTANGULAR WING

MATERIAL	COMPOSITION (STRINGERS × RIBS)	MAX. VON MISES STRESS(Gpa)	DEFORMATION (m)	MASS (kg)
Aluminium	5×3	1.9167	0.0071097	38.2
Composite composition 1 (High modulus epoxy+aluminium)	5×3	2.0706	0.00406518	34.98
	4×3	2.5547	0.008045	27.132
	3×3	2.5922	0.0091942	23.464
	5×4	1.9546	0.0039022	34.873
	5×5	1.9873	0.0039656	34.988
Composite composition 2 (graphite epoxy+aluminium)	5×3	2.0674	0.0044665	34.47
	4×3	2.5412	0.0076648	26.627
	3×3	2.5791	0.0087299	22.96
	5×4	1.9007	0.0037441	34.368
	5×5	1.9818	0.003785	34.484
Composite composition 3 (Hg epoxy+aluminium)	5×3	1.887	0.008637	34.518
	4×3	2.4546	0.0156.1	26.669
	3×3	2.7853	0.02011	23.01
	5×4	2.5094	0.007288	34.41
	5×5	2.0926	0.0075714	34.525

TABLE 3- RESULTS OF TAPER WING

MATERIAL	COMPOSITION (STRINGERS× RIBS)	MAX. VON MISES STRESS(Gpa)	DEFORMATION (m)	MASS (kg)
Aluminium	5×3	7.7821	0.002412	52.92
Composite composition 1 (High modulus epoxy+aluminium)	5×3	10.42	0.001808	43.8
	4×3	5.9422	0.00322	41.9
	3×3	5.9761	0.002706	40.6
	5×4	9.2487	0.001643	43.9
	5×5	11.354	0.002273	44.1
Composite composition 2 (graphite epoxy+aluminium)	5×3	10.683	0.001756	42.4
	4×3	6.0357	0.003135	41.3
	3×3	6.0784	0.002634	39.1
	5×4	9.4907	0.00159	42.5
	5×5	11.595	0.00219	42.6
Composite composition 3 (Hg epoxy+aluminium)	5×3	6.8616	0.002761	42.5
	4×3	4.3375	0.00485	41.1
	3×3	4.1291	0.00405	39.2
	5×4	5.9111	0.0026	42.6
	5×5	7.295	0.00385	42.7

EFFICIENT ANALYSIS RESULTS FOR RECTANGULAR WING

These are found efficient composition when compared with actual aluminium from the values of von mises stress, deformation and mass obtained from the ansys results. Hence for composite composition 1,2 and 3 the structural compositions(stringers x ribs) 5x4,5x4,5x3 respectively holds good and efficient.

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RESULTS FOR ALUMINIUM:

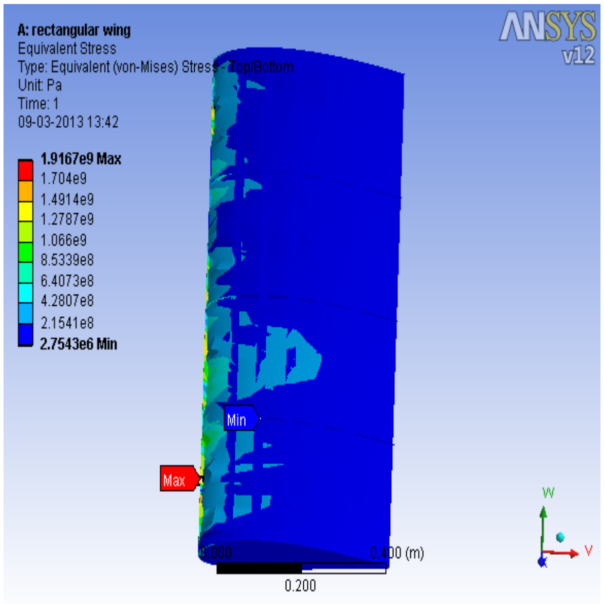

FIG 1 VON MISES STRESS FOR ALUMINIUM

COMPOSITE COMPOSITION 1 FOR (5 STRINGERS × 4 RIBS)
SKIN SURFACE: H.M.Gr/Ep
SUB STRUCTURE: ALUMINIUM

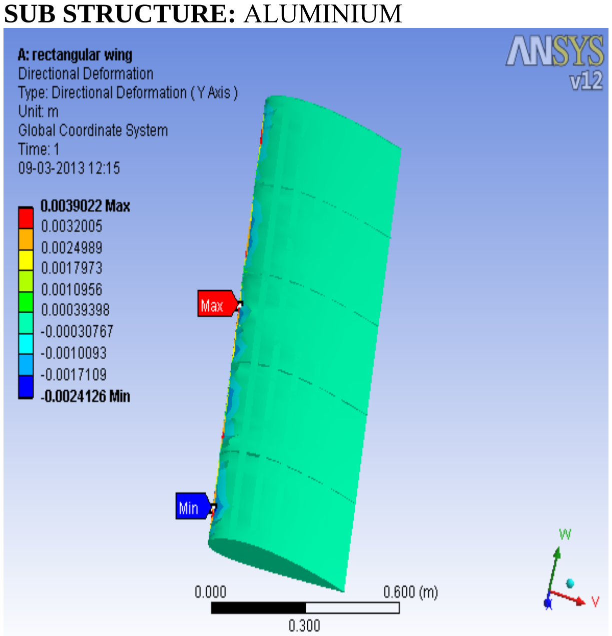

FIG 2 DEFORMATION FOR COMPOSITION 1 FOR (5×4)

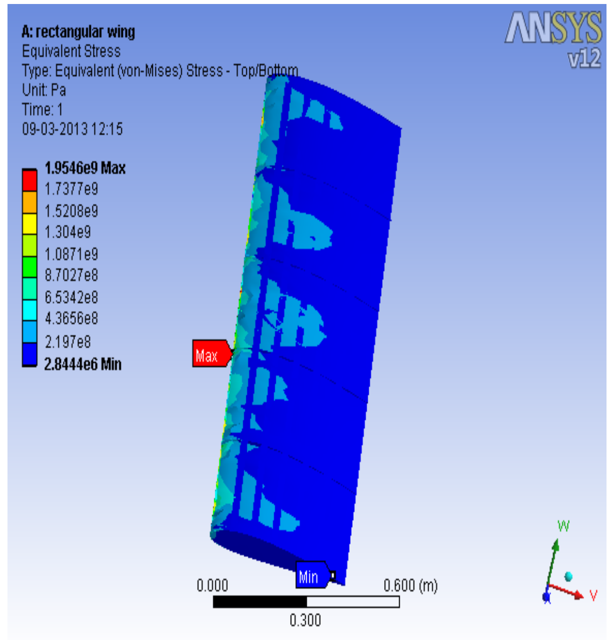

FIG 3 VON MISES STRESS FOR COMPOSITION 1 (5×4)

COMPOSITE COMPOSITION 2 FOR (5 STRINGERS × 4 RIBS)
SKIN SURFACE: Gr/Ep
SUB STRUCTURE: ALUMINIUM

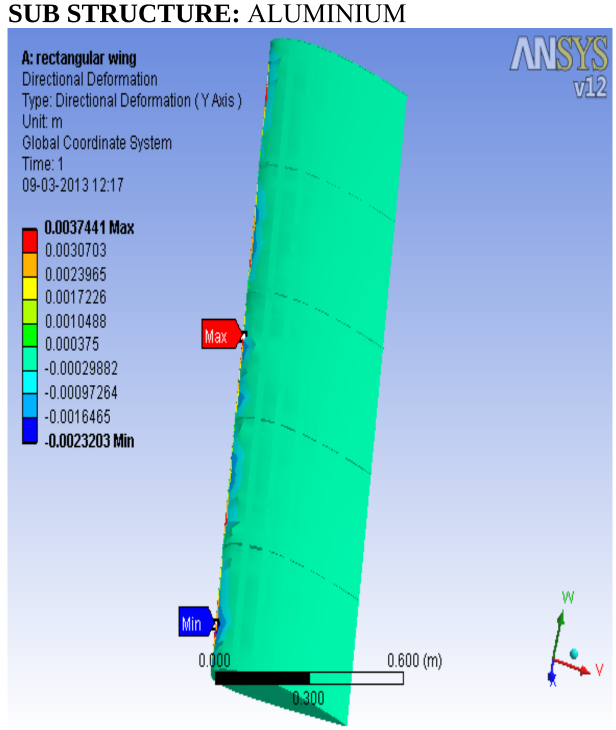

FIG 4 DEFORMATION FOR COMPOSITION 2 FOR (5×4)

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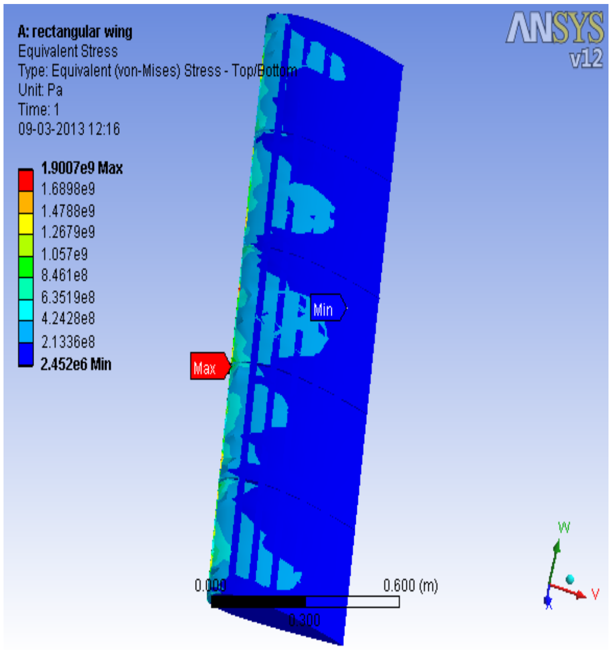

FIG 5 VON MISES STRESS FOR COMPOSITION 2 (5×4)

COMPOSITE COMPOSITION 3 FOR (5 STRINGERS × 3 RIBS)

SKIN SURFACE: Sg/Ep

SUB STRUCTURE: ALUMINIUM

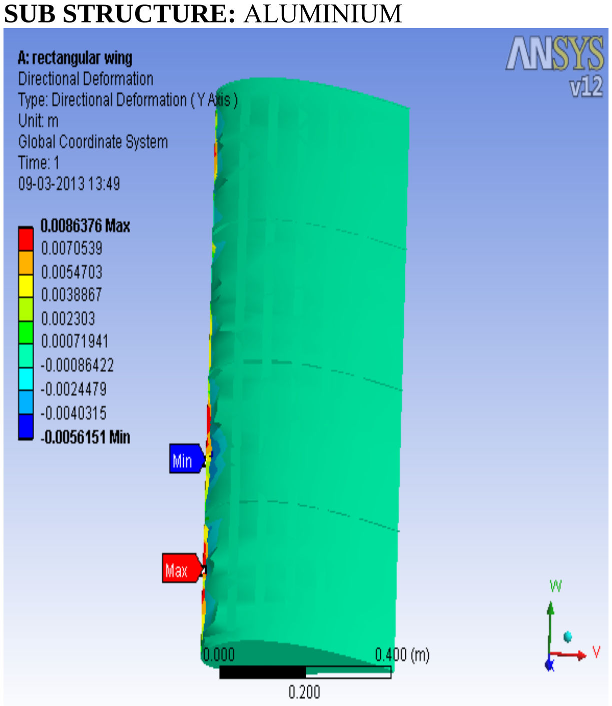

FIG 6 DEFORMATION FOR COMPOSITION 3 FOR (5×3)

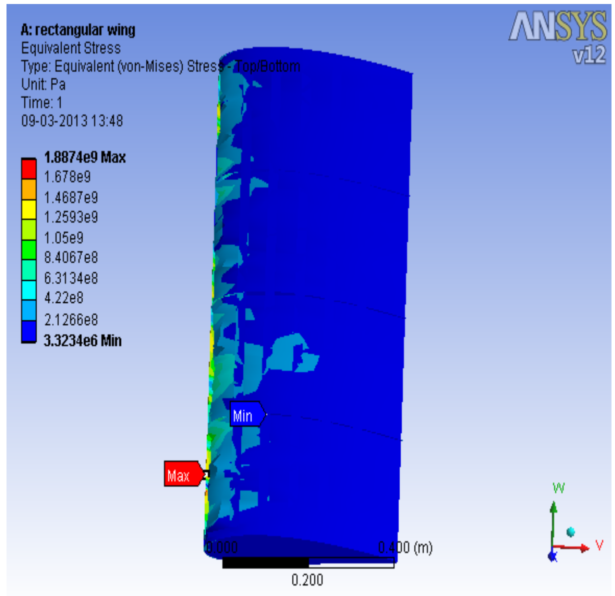

FIG 7 VON MISES STRESS FOR COMPOSITION 3 (5×3)

<u>EFFICIENT ANALYSIS RESULTS FOR TAPER WING</u>

These are found efficient composition when compared with actual aluminium from the values of von mises stress, deformation and mass obtained from the ansys results. Hence for composite composition 1,2 and 3 the structural compositions(stringers x ribs) 4x3,4x3,3x3 respectively holds good and efficient.

RESULTS FOR ALUMINIUM:

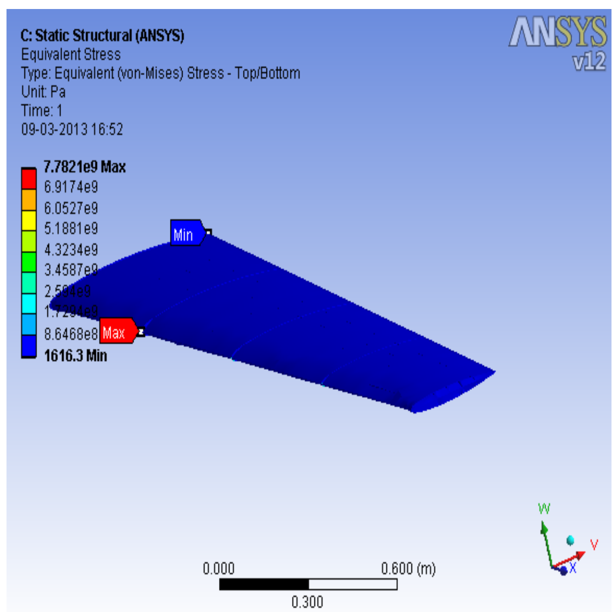

FIG 8 VON MISES STRESS FOR ALUMINIUM

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COMPOSITE COMPOSITION 1 FOR (4 STRINGERS × 3 RIBS)
SKIN SURFACE:H.M. Gr/Ep
SUB STRUCTURE: ALUMINIUM

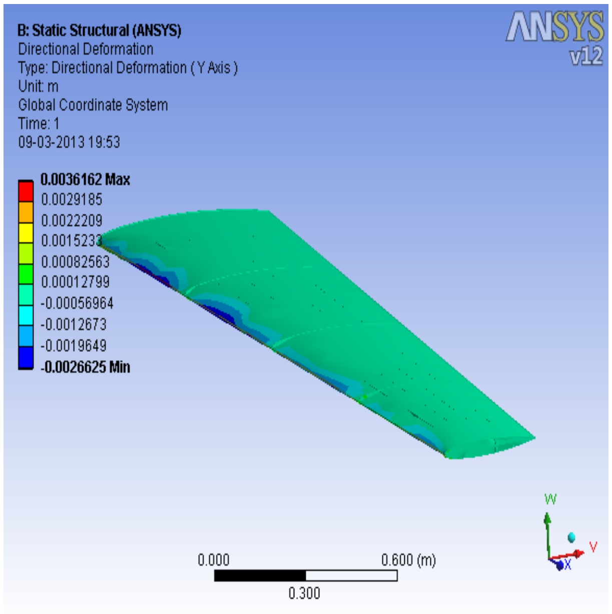

FIG 9 DEFORMATION FOR COMPOSITION 1 FOR (4×3)

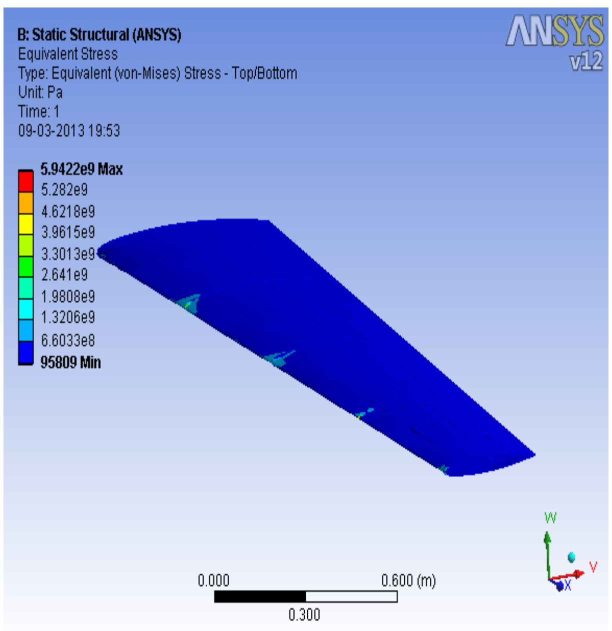

FIG 10 VON MISES STRESS FOR COMPOSITION 1 (4×3)

COMPOSITE COMPOSITION 2 FOR (4 STRINGERS × 3 RIBS)
SKIN SURFACE: Gr/Ep
SUB STRUCTURE: ALUMINIUM

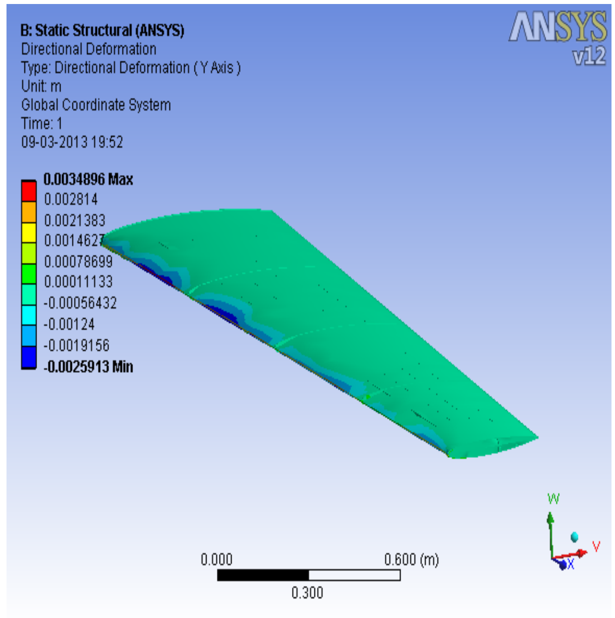

FIG 11 DEFORMATION FOR COMPOSITION 2 FOR (4×3)

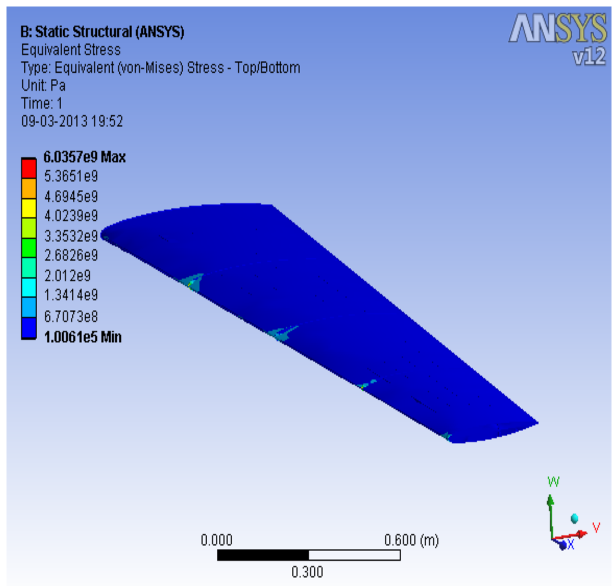

FIG 12 VON MISES STRESS FOR COMPOSITION 2 (4×3)

COMPOSITE COMPOSITION 3 FOR (3 STRINGERS × 3 RIBS)
SKIN SURFACE: Sg/Ep
SUB STRUCTURE: ALUMINIUM

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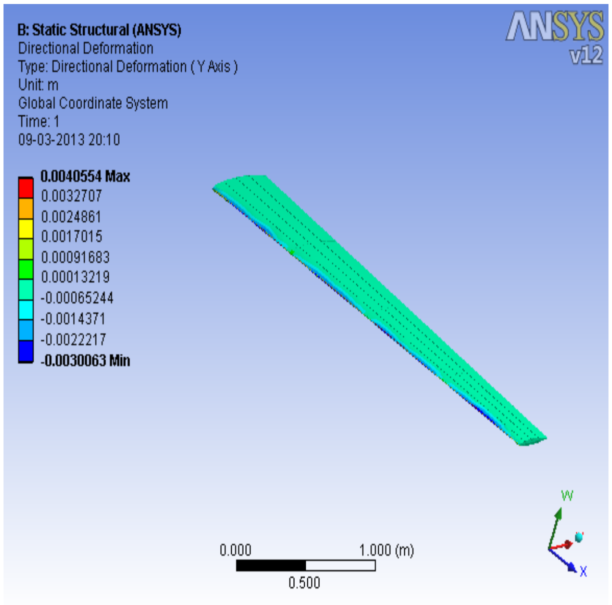

FIG 13 DEFORMATION FOR COMPOSITION 3 FOR (3×3)

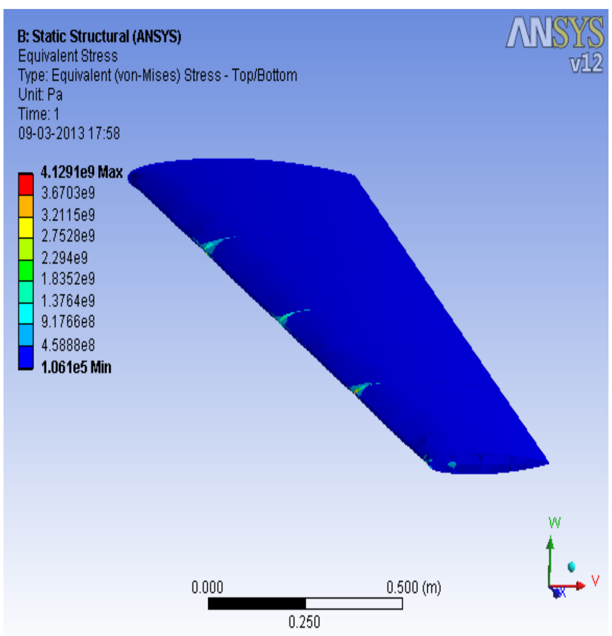

FIG 14 VON MISES STRESS FOR COMPOSITION 3 (3×3)

5. CONCLUSION

For both the taper and rectangular wing the results of the analysis reveal that using composites poses very good reduction in weight of the overall wing structure. And it also reveals that the components of wing like stringers and ribs greatly contributes to the stress action of the wing structure. Even the combination of stringers and ribs differs for various composite composition in respect to both taper and rectangular wing. It means it differs for both taper and rectangular wing.

6 FUTURE ENHANCEMENT

In this study we used analysis for both taper and rectangular wing and found which is efficient. In future attempts can be taken to replace the structural design if the composites usage and analysis. Hence future analysis can be done to use the structural variation like replacing the UAV which has taper wing to rectangular or vice versa, for which the analysis holds efficient and good.

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