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Ribs Strength and Topology Optimization with Low Weight

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***Abstract*— This article deals about Ribs strength optimization with low amount of weight. By this project we have to decrease the ribs weight as wells as same amount of strength and also decrease the aircraft wing structural weight and structural load of the aircraft. For this work, we have to take three different types of ribs with comparing the base models. From this three ribs section we have to take and choose the best one according to the self-weight and structural strength. By this rib section we have to create wing structures to 15 and 6 ribs construction and find out the structural strength (Deformation and stress) for the (4 & 7.25) degree of angle of attack to this two wing structure.**

Keywords--- Angle of attack, Deformation, Ribs, Structural strength, Wing structure.

I. INTRODUCTION

The Ribs is one of the major component of the aircraft wing structure. The ribs are also called the vertical section of the aircraft wing structure. The ribs are creating the airfoil structure for the aircraft wing. The aircraft wing strength and weight are depending upon the wing ribs.

Topology optimization is a useful tool for a designer which generates the optimal conceptual shape of a structure. It is a method that optimizes material layout within a given design space under boundary conditions. The structural shape is generated within a predefined design space. Through topology optimization; engineers can find the best conceptual design that can satisfy the objective design. In addition, the user defines structural supports and loads. Without any further decision and guidance of the user, the method will give the structural shape thus provides a first idea of an optimum geometry. A desired property of the structure is maximized by changing the shape of the given material. Usually this maximized property is stiffness. Another usage of topology optimization is minimizing the weight, subjected to a given constraint (such as stress). Topology optimization is used for many different engineering applications such as thermodynamic problems, fluid mechanics, electro mechanics, acoustic problems, problems, and solid mechanics. By using topology optimization, designers can easily solve very difficult and complex problems; hence, usage of this method is increasing day by day. The simple idea of the topology optimization is the removal of less efficient materials from a structure.

The aircraft wing design, which relies on internal struts and spars for aerodynamic load bearing, is limited primarily by traditional manufacturing techniques. If manufacturing constraints are removed, the design focus shifts towards providing an improved distribution of loads throughout the structure, subsequently eliminating unnecessary material. To design an optimized component, an increasingly more common method in structural design is the implementation of Topology Optimization (TO).

II. PROBLEM DESCRIPTION

A. *Analysis (BC, CAD, etc.)*

The following boundary conditions are to be used for analysis and 2D mesh has to be carried out on the wing optimization which is given below.

Boundary condition:

One end fixed and other end force acting upward direction.

Analysis type:

Linear static model analysis

Modal analysis

Mesh type: Tetrahedrons

TABLE I. PROPERTIES OF MATERIAL

S.No	Structural Properties	Values
1	young’s modulus (N/m2)	7e^010
2	Poisson’s ratio	0.346
3	Density (kg/m3)	2710
4	yield strength (N/m2)	9.5e^007

B. *Types of Rib Sections*

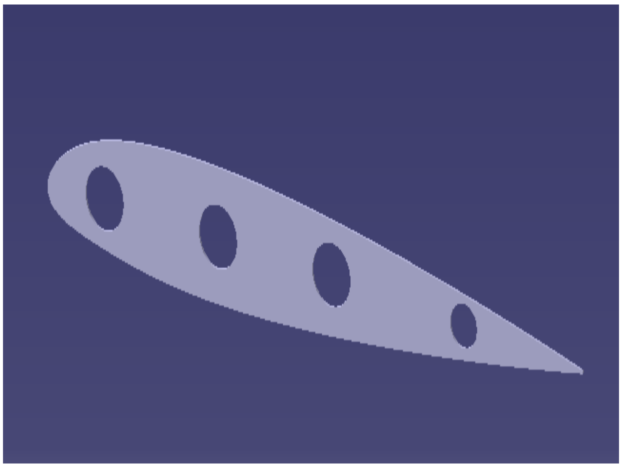

Fig. 1. Base model

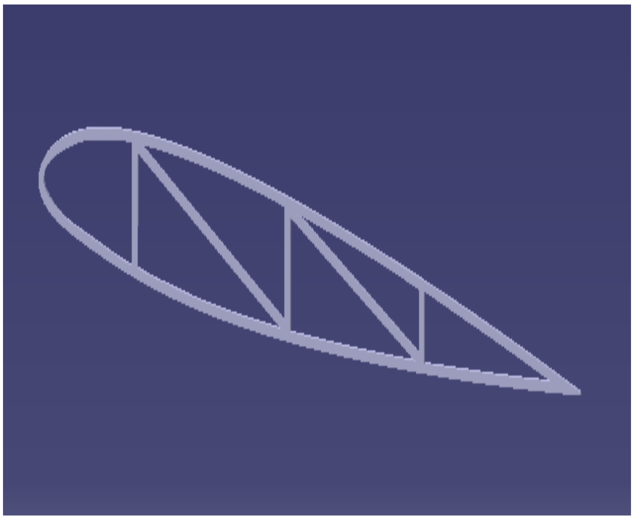

Fig. 2. Shell/beam model

Fig. 3. Refined panel model

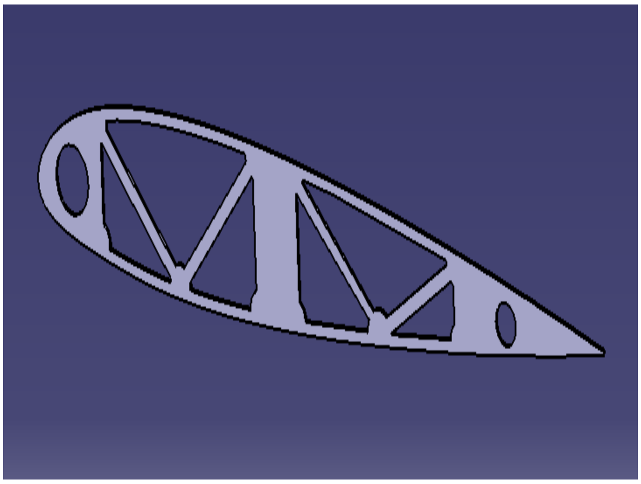

Fig. 4. Aerodynamic model

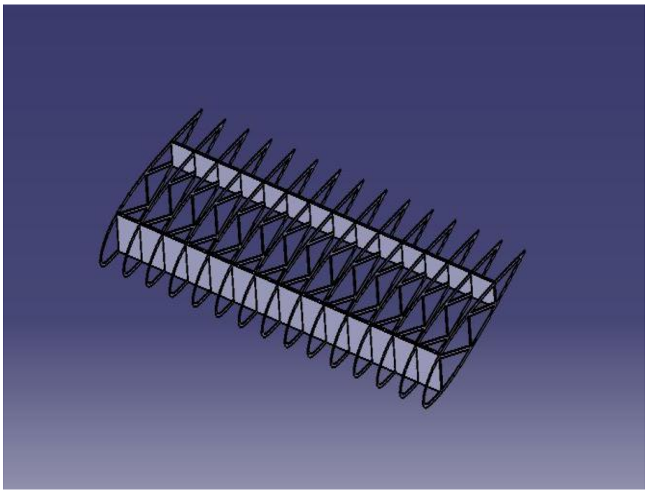

Fig. 5. 15 Ribs constructions

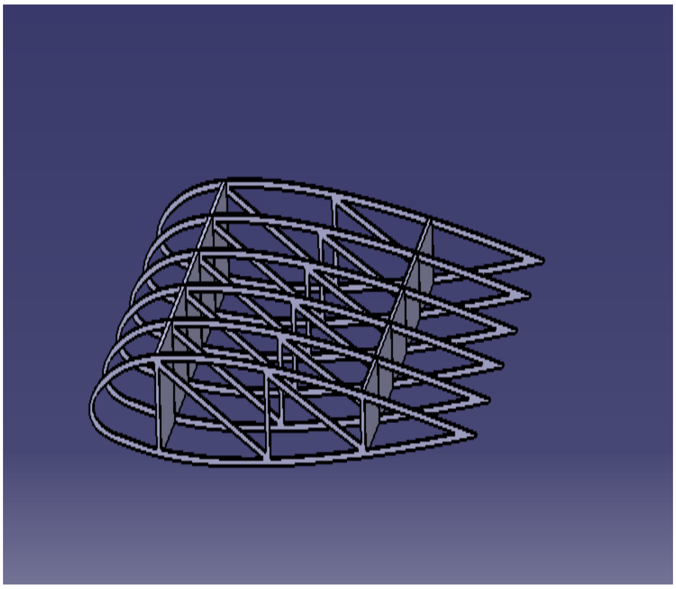

Fig. 6. 6 Ribs constructions

III. RESULT AND DISCUSION

The baseline wing structure analysis was conducted on the RV-10 wing structure with required load condition which is compared with the topology optimized of finalized wing rib design. The optimization was conducted to reduce the volume and to increases the strength of the wing by using FEA optistruct analysis. The load is applied on the face of the rib section and constraints were applied on the wing structure. The different rib section has been analyzed by using optistruct tool in which the best and low deformation rib section was selected for analysis then the results are compared with baseline structure. The given table shows the maximum stress, deformation and weight for base model and different rib section and the wing structures.

A. *Rib Cut Sections*

The ribs are designed with different cut sections. Because cut sections profiles are depends upon structure weight. So we have optimized by rib cut sections& rib's spacing and as well as give weight reduction.

The displacement and stress variation shown in below figures for different types of rib section.

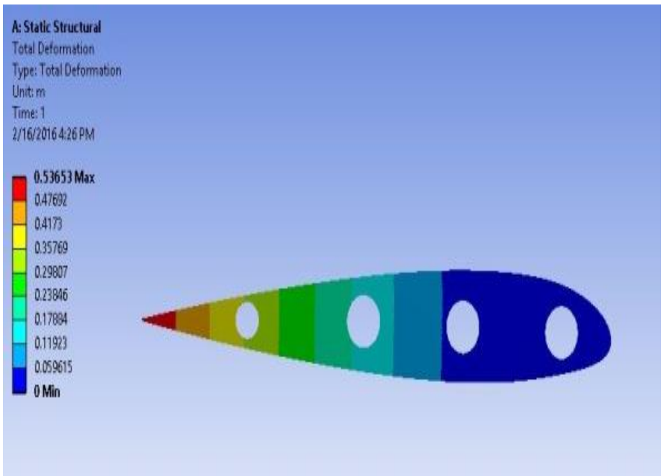

Fig. 7. Displacement for Base model Rib section

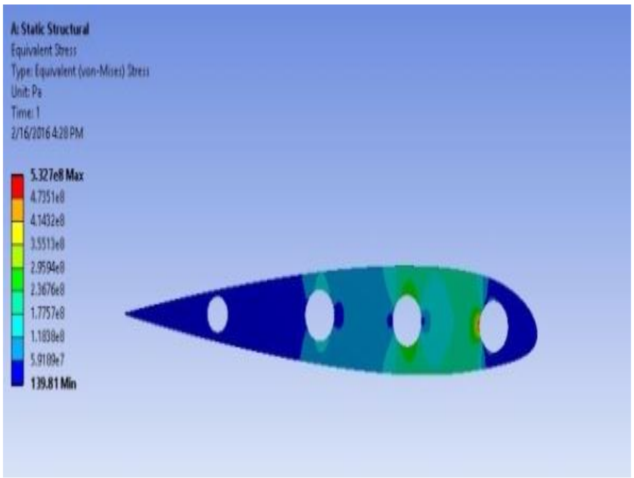

Fig. 8. Stress variation for Base model Rib section

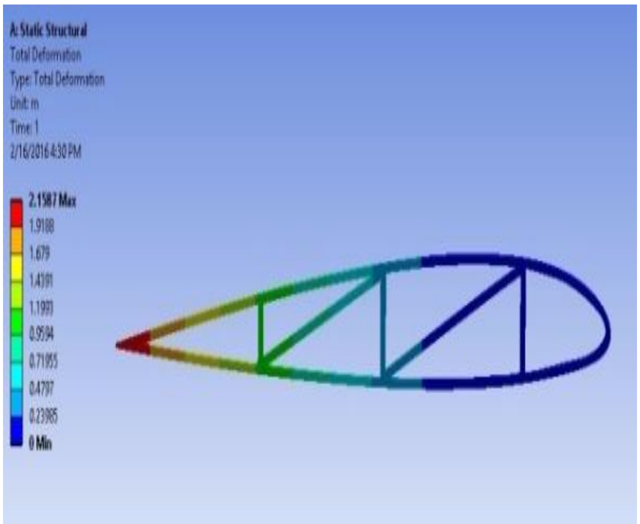

Fig. 9. Displacement for Shell/beam model Rib section

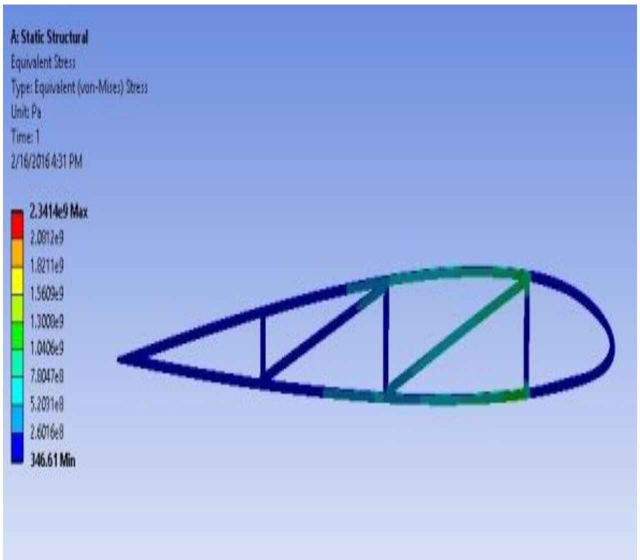

Fig. 10. Stress variation for Shell/beam model Rib section

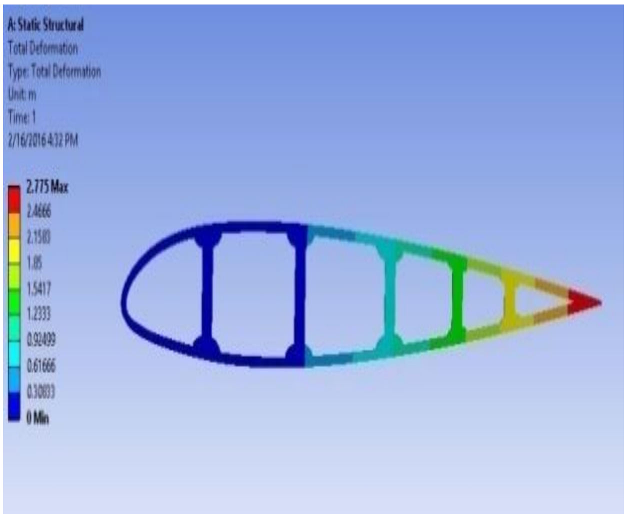

Fig. 11. Displacement for Refined panel model Rib section

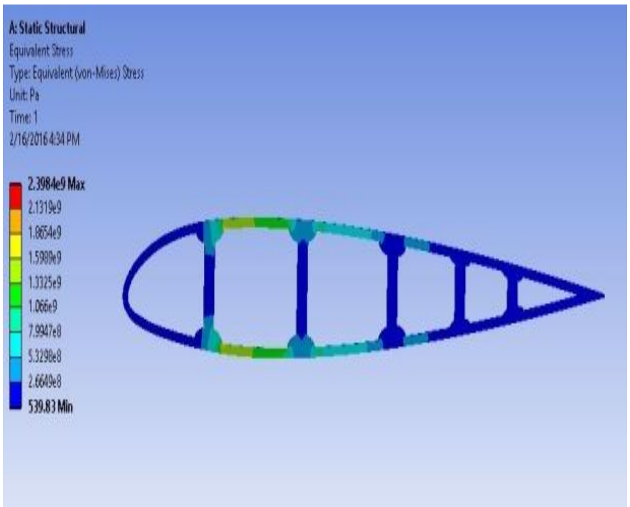

Fig. 12. Stress variation for refined panel model Rib section

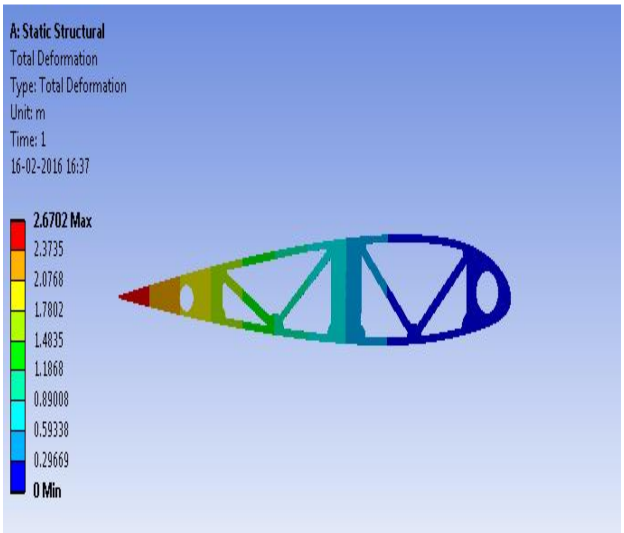

Fig. 13. Displacement for Aerodynamic model Rib section

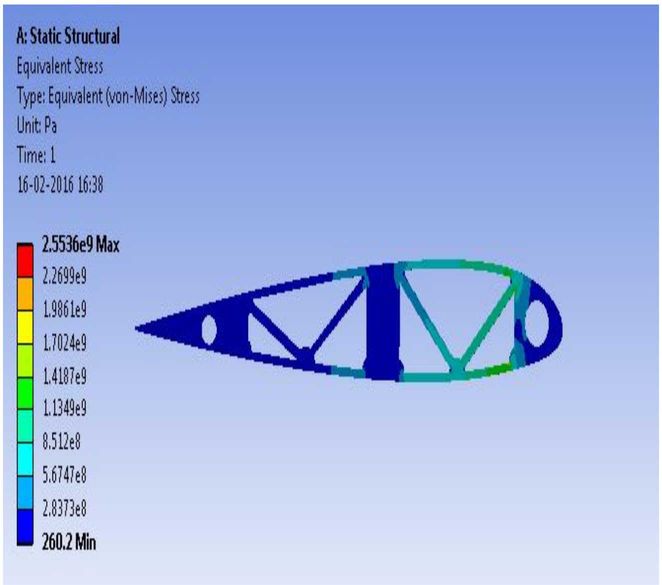

Fig. 14. Stress variation for Aerodynamic model Rib section

The ribs various cut sections are following below with that results also.

TABLE II. COMPARISON OF MAXIMUM DEFORMATION AND MAXIMUM STRESS FOR DIFFERENT TYPES OF RIB SECTION

S.no	Rib section	Weight(kg)	Maximum Deformation(mm)	Maximum stress (N/mm^2)
1	Base profile	8.76	0.5365e3	5.327e8
2	Profile 1	2.962	2.1587e3	2.341e9
3	Profile 2	3.266	2.775e3	2.398e9
4	Profile 3	5.003	2.6702e3	2.553e9

B. *Wing construction*

TABLE III. PROPERTIES OF 15 RIBS WING CONSTRUCTION AND 6 RIBS WING CONSTRUCTION

No. Of Ribs	Mass (Kg)	Volume (mm3)	Surface Area (mm2)	Material	Density
15	43.366	4.337e^7	2.138e7	Aluminum	2710 m3
6	6.659	6.659e6	1.716e6	Aluminum	2710 m3

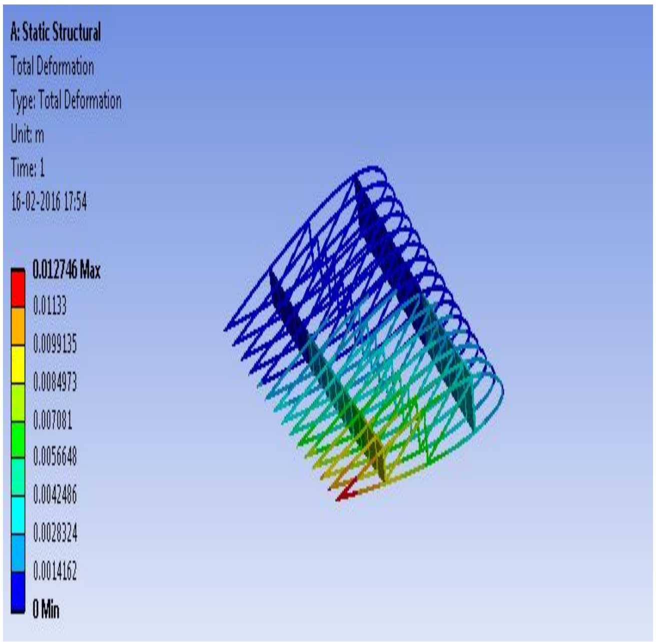

Fig. 15. Displacement for 15 Ribs constructions

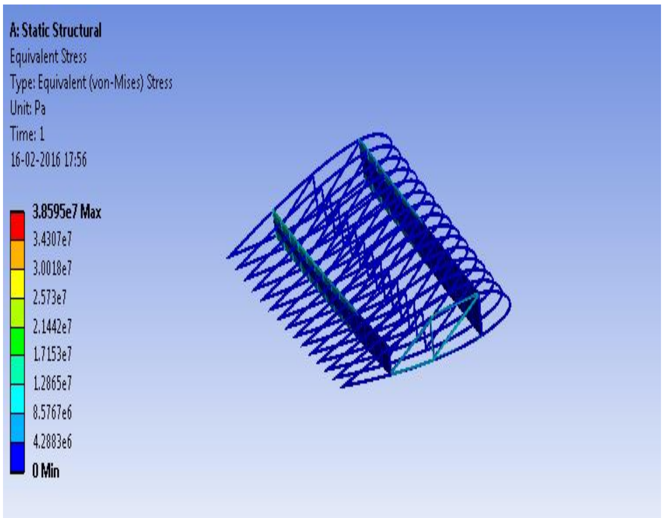

Fig. 16. Stress variation for 15 ribs construction

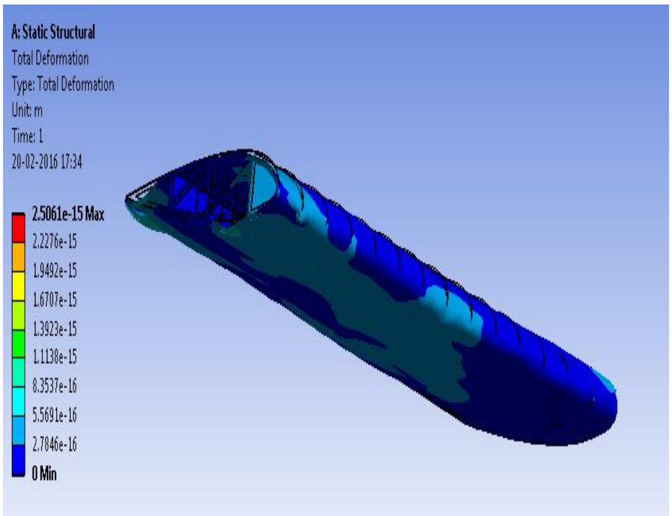

Fig. 17. Deformation to the 4degree AOA for 15 Ribs Wing construction

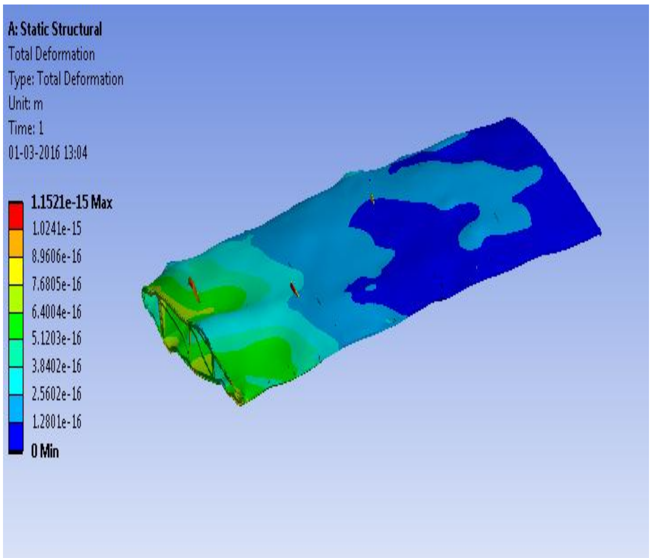

Fig. 18. Deformation to the 7.25degree AOA for 15 Ribs Wing construction

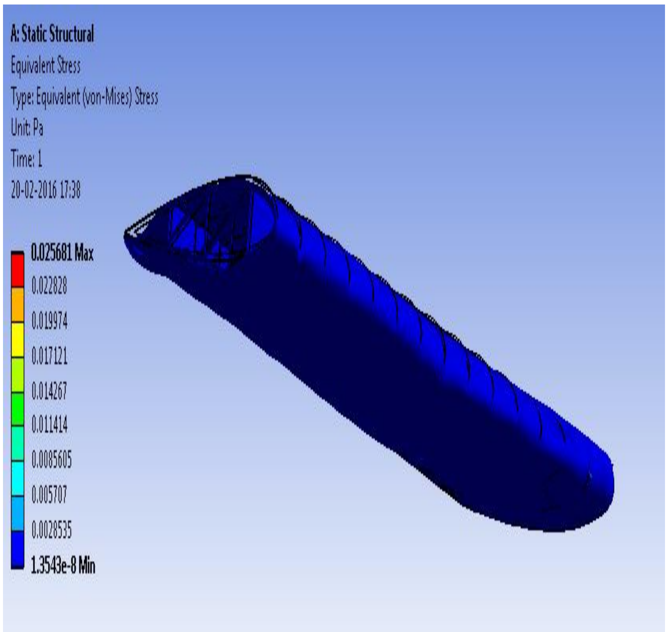

Fig. 19. Stress to the 4degree AOA for 15 Ribs Wing construction

TABLE IV. COMPARISON BETWEEN 4 AND 7.25 DEGREE OF ANGLE OF ATTACK (15 RIBS)

S. No	Description		Case1 (At AOA 4)	Case2 (At Maximum AOA7.25)
1	Boundary condition		One end fixed and other end force acting upward direction	One end fixed and other end force acting upward direction.
2	Mesh type		Tetrahedrons	Tetrahedrons
3	Displacement	Maximum (mm)	2.5061e-15	1.1521e-15
		Minimum (mm)	0	0
4	Stress	Maximum (N/mm^2)	0.025681	0.0074555
		Minimum (N/mm^2)	1.3543e-8	3.6931e-9
5	Mass=43.366kg		Volume=4.337e+7 mm^3	

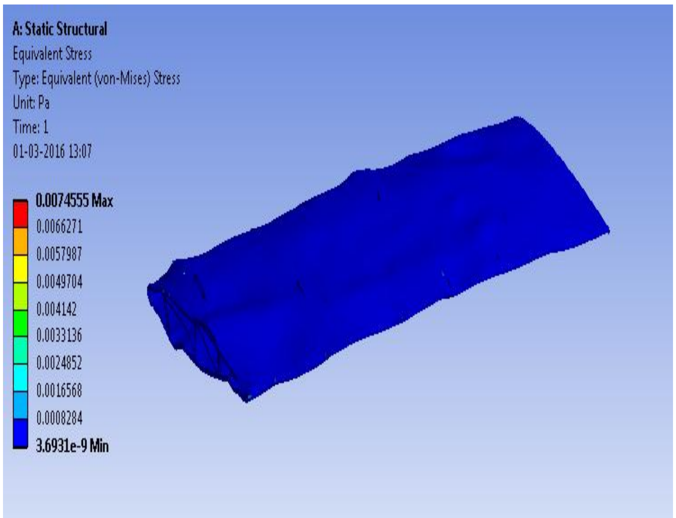

Fig. 20. Stress to the 7.25degree AOA for 15 Ribs Wing construction

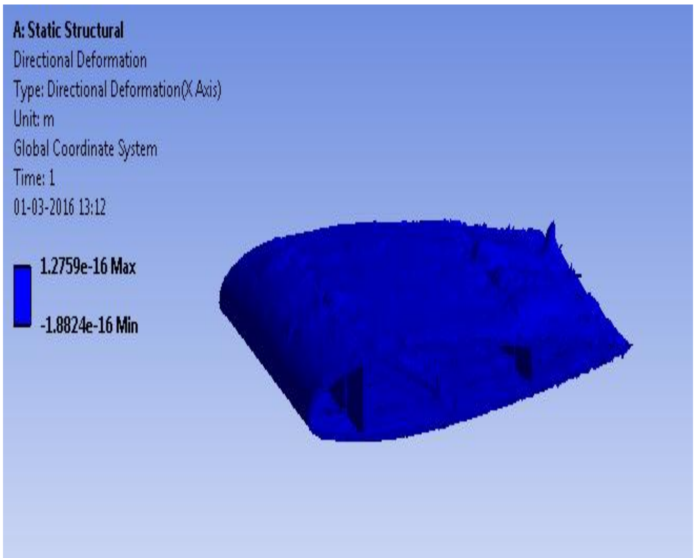

Fig. 21. Deformation to the 4degree AOA for 6 Ribs Wing construction

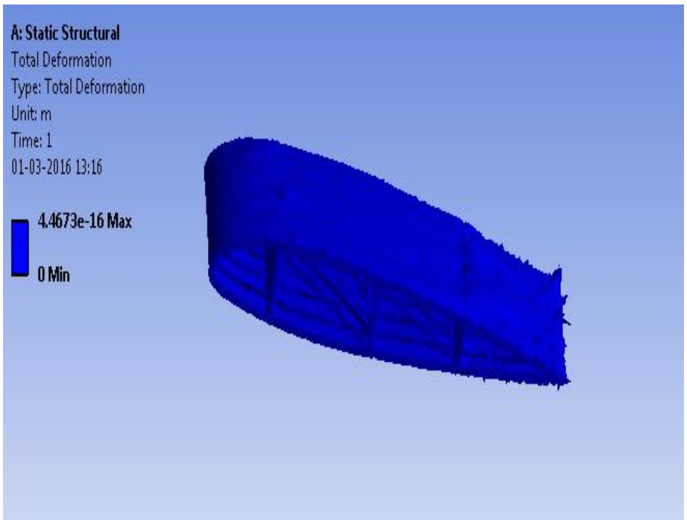

Fig. 22. Deformation to the 7.25degree AOA for 6 Ribs Wing construction

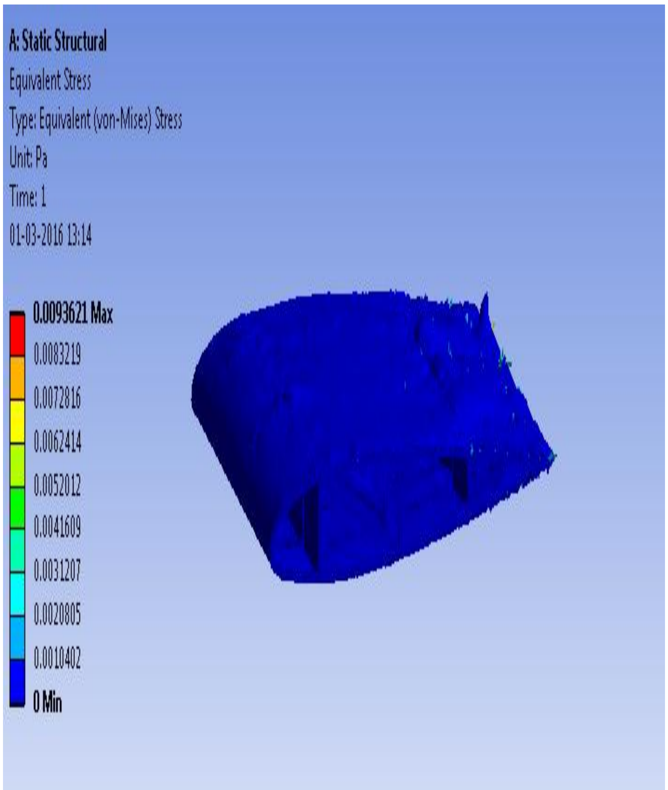

Fig. 23. Stress to the 4degree AOA for 6 Ribs Wing construction

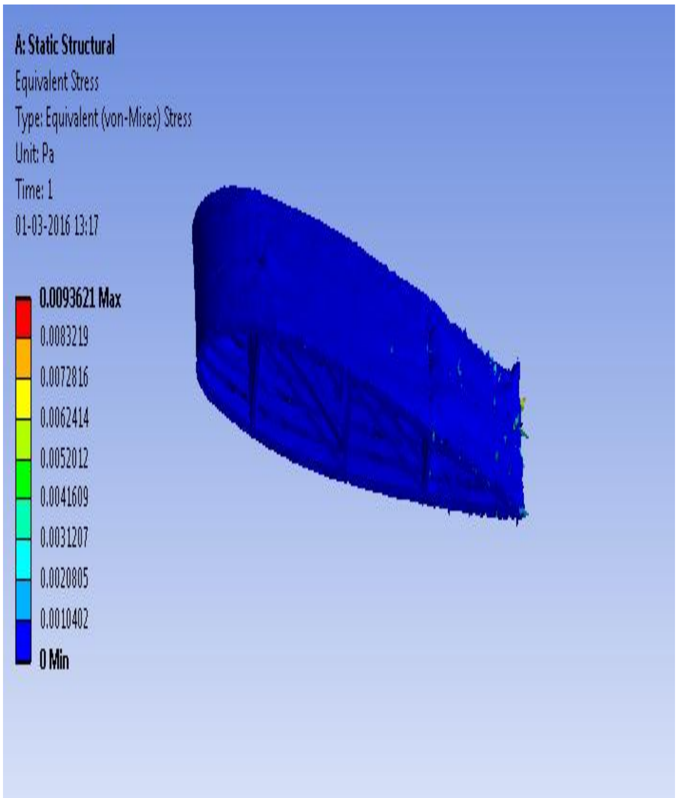

Fig. 24. Stress to the 7.25degree AOA for 6 Ribs Wing construction

TABLE V. COMPARISON BETWEEN 4 AND 7.25 DEGREE OF ANGLE OF ATTACK (6 RIBS)

S. No	Description		Case1 (At AOA 4)	Case2 (At Maximum AOA7.25)
1	Boundary condition		One end fixed and other end force acting upward direction	One end fixed and other end force acting upward direction.
2	Mesh type		Tetrahedrons	Tetrahedrons
3	Displacement	Maximum (mm)	1.275e-16	4.4673e-16
		Minimum (mm)	0	0
4	Stress	Maximum (N/mm^2)	0.0093621	0.0093621
		Minimum (N/mm^2)	0	0
5	Mass=6.659kg		Volume=6.6599e+6 mm^3	

The below table shows the comparison of stress, deformation and weight of the base model and optimized model. The variation of stress and deformation is induced in optimized model was compared with base model of the aircraft wing which is following below.

TABLE VI. COMPARISON BETWEEN BASE MODEL AND OPTIMIZED MODEL

Contents	Base Model	Optimized Model
Stress (N/mm^2)	5.327e^8	2.3414e^9
Deformation(mm)	0.5365e^3	2.1587e^3
Weight(kg)	8.76	2.962

IV. CONCLUSION

From the above results the reduction of weight is 55% decreased as compared to reference model and the deformation is reduced when compared to base model. So, the finalized and optimized rib section is the best profile to construct the wing and this rib section saving the design space of the aircraft wing.

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