FINITE ELEMENT ANALYSIS OF RIBS AND WING STRUCTURE OF BEECH AIRCRAFT

[1]Dr.V. SARAVANAN, [2]V.BABU, [3]B.S.NAVANEETH

[1]Assistant professor, [2]Assistant professor, [3]Assistant professor
[1]Aeronautical Engineering,
[1]Park College Of Engineering And Technology Coimbatore, India,
[2]Sanjay Ghodawat University Kolhapur, Maharashtra
[3]Park College Of Engineering And Technology Coimbatore, India.

Abstract : The objective of this paper is to perform the finite element analysis for wing structures of beech aircraft which is subjected to aerodynamic pressure loads. The requirements of the aircraft wings are High stiffness, High strength, High toughness and low weight. In this paper detailed design of aircraft wing structure with ribs placement is done and then stresses are estimated by using finite element methods with the help of PATRAN. Stress analysis of the whole wing section and root rib is carried out to compute the stresses at the wing and ribs due to applied pressure loads. It is shown that the designed wing could be used for high aerodynamic loads due to high stiffness of the wing

IndexTerms - **finite element analysis, aircraft structures, wing design, loads.**

I. INTRODUCTION

For aerodynamic reasons the wing contour in the chord direction must be maintained without appreciable distortion. Unless the wing skin is quite thick, spar wise stringers must be attached to the skin in order to increase the bending efficiency of the wing. Therefore to hold the stringer and wing surface to contour shape and also to limit the length of stringers to an efficient column compressive strength, internal support or brace units are referred to as wing ribs. The ribs also have another major purpose, namely, to act as a transfer or distribution unit. All the loads applied to the wing are reacted at the wing supporting points, thus these applied loads must be transferred into the wing cellular structure composed of skin, stringers, spars, etc., and then reacted at the wing support points. The applied loads may be only the distributed surface air loads which require relatively light internal ribs to provide this carry through or transfer requirement, to rather rugged or heavy ribs which must absorb and transmit large concentrated applied loads such as those from landing gear reactions, power plant reactions and fuselage reactions. In between these two extremes of applied load magnitudes are such loads as reactions at supporting points for ailerons, flaps, and leading edge high lift units and the many internal dead weight loads such as fuel and military armament and other installations. Thus ribs can vary from a very light structure which must receive and transfer loads involving thousands of pounds.

The skin construction which forms the shell of the fuselage likewise needs internal forming units to hold the fuselage cross-section to contour shape, to limit the column length of the stringers and to act as transfer agents of internal and externally applied loads. Since a fuselage must usually have clear internal space to house the payload such as passengers in a commercial transport, these internal fuselage units which are usually referred to as frames are of the open or ring type. Fuselage frames vary in size and strength from very light former type to rugged heavy types which must transfer large concentrated loads into the fuselage shell such as those from landing gear reactions, wing reactions, tail reactions, power plant reactions, etc. the dead weight of all the payload and fixed equipment inside the fuselage must be carried to frames by other structure such as the fuselage floor system and then transmitted to the fuselage shell structure. Since the dead weight must be multiplied by the design acceleration factors, these internal loads become quite large in magnitude.

Another important purpose or action of ribs and frames is to redistribute the shear at discontinuities and practical wings and fuselages contain many cut-outs and openings and thus discontinuities in the basic structural layout.

2.Modelling of wing and rib

The Beech craft Star ship is a twin-turboprop six- to eight-passenger pressurized business aircraft produced by Beech Aircraft Corporation.The Star ship is noteworthy for its carbon fibre composite airframe, canard design, lack of centrally located vertical tail, and pusher engine/propeller configuration. Carbon fibre composite was used to varying degrees on military aircraft, but at the time the Star ship was certified, no civilian aircraft certified by the US Federal Aviation Administration had ever used it so extensively. Beech chose carbon fibre composite for its durability and high strength-to-weight ratio. According to Beech, the Star ship weighs less than it would have if it were built from aluminium. Nonetheless, the empty weight of production aircraft exceeded the target by several thousand pounds.

Beech studied several configurations before settling on a canard configuration in early 1980. As configured, the Star ship is difficult to stall—the forward surface stalls before the main lifting surface, which allows the nose to drop and more-normal flight to resume.

A traditionally located vertical tail would have transmitted propeller noise into the airframe. In its place, directional stability and control is provided by rudders mounted in the winglets (Beech craft called them tip sails at the tips of the wings).

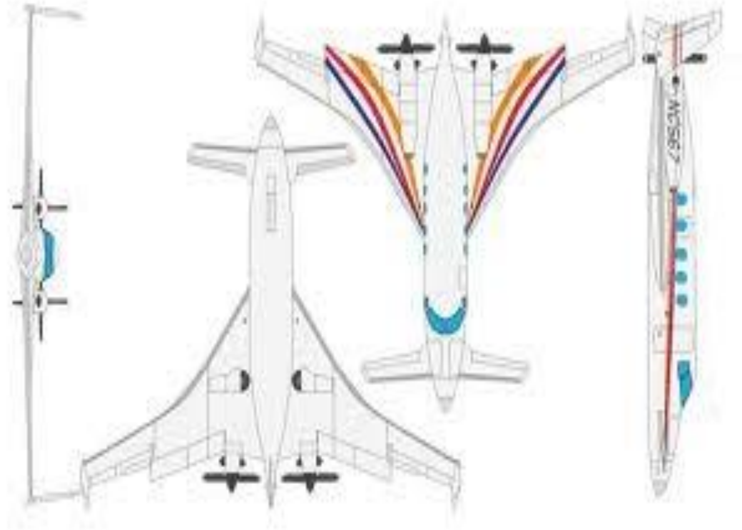

Figure 1: Plan View of Starship

Mounting the engines so that the propellers are facing rearward, pushing rather than pulling the aircraft, has the potential of a quieter ride since the propellers are further from the passengers and because vortices from the propeller tips do not strike the fuselage sides. However, the propellers are operating in a turbulent airflow in the pusher configuration (due to airflow past the wings moving aft in vortex sheets) and high-velocity exhaust gasses are discharged directly into the props, thus the resulting external propeller noise is more choppy and raucous than otherwise.

2.1 WING SPECIFICATIONS:

2.1.1 Wing Area and Loadings:

Wing Area : 280.88 sq. ft.

Wing Loading : 53.0 lbs. /sq. ft.

Power Loading (PT6A-67A: 1200 SHP) : 6.21 lbs. /shp.

2.1.2 Aerofoil Used:

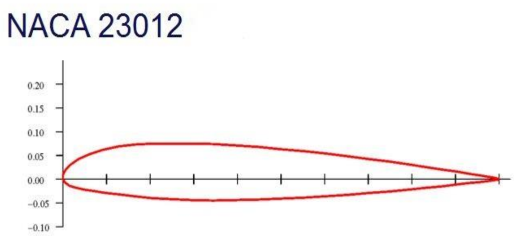

Fig 2: NACA 23012

The chord length of the ribs from root,

Rib 1 chord length =516mm.

Rib 2 chord length =423mm.

Rib 3 chord length =340mm.

Rib 4 chord length =256mm.

Rib 5 chord length =173mm.

Rib 6 chord length =162mm.

Rib 7 chord length =150mm.

Rib 8 chord length =137mm.

Rib 9 chord length =125mm.

Rib 10 chord length =114mm.

2.1.3 2D Profile of the Wing:

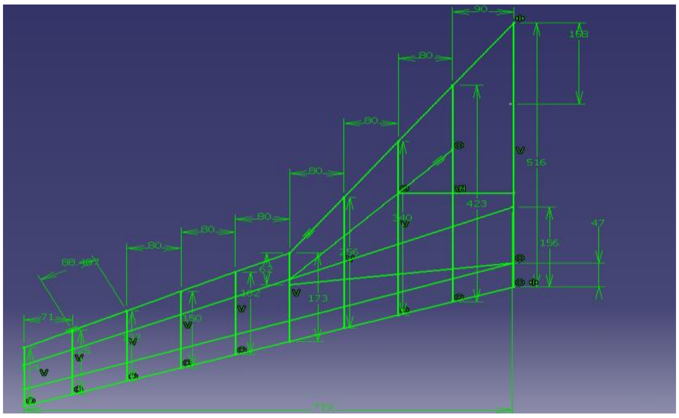

Fig 3: 2D-Sketch

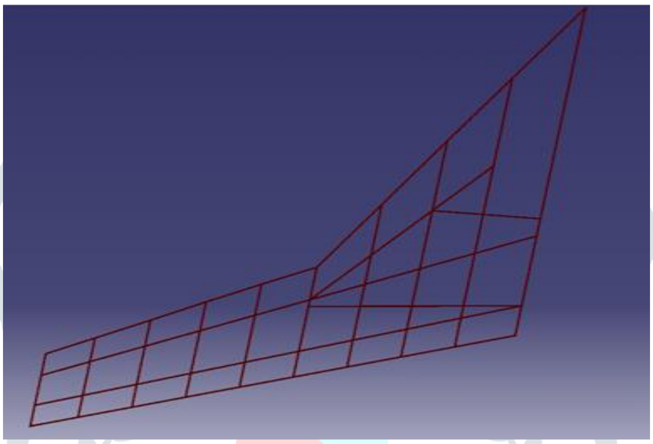

Fig 2: 2D-Profile

2.1.4 Wing Component Details:

Number of Spars = 2 Number of Ribs = 1 Number of Stringer = 14

Top Stringers - Z Section

Bottom Stringers - L Section.

2.2 DIMENSIONS OF WING COMPONENTS:

2.2.1 Spar Flange:

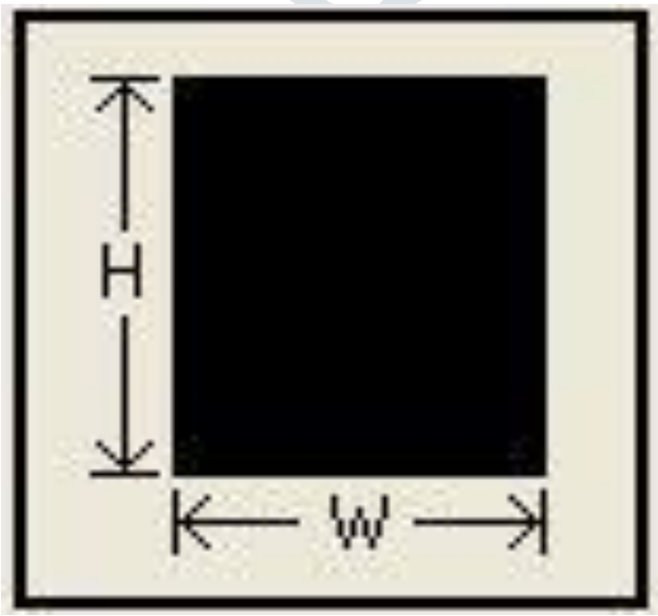

Fig 5: Cross Section of Spar Flange

Width (W) = 15mm.

Height (H) = 3mm.

2.2.2 Top Stringers:

In aerospace industries Z section are commonly used because of its very good rigidity and in top of the wing needs more bending resisting, because of pressure in the bottom of the wing.

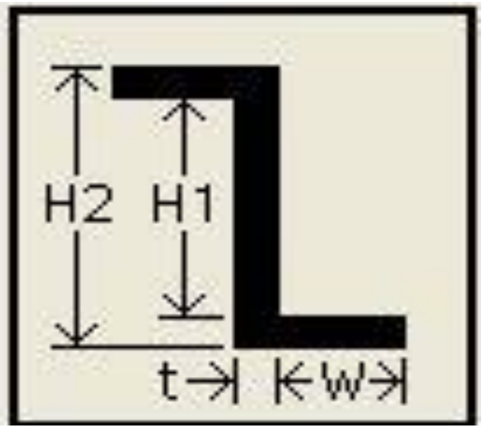

Fig 6: Cross Section of Top Stringers

Width (W) = 3mm. Height 1 (H1) =2mm. Height 2 (H2) = 4mm. Thickness (t) = 1mm.

2.2.3 Bottom Stringers:

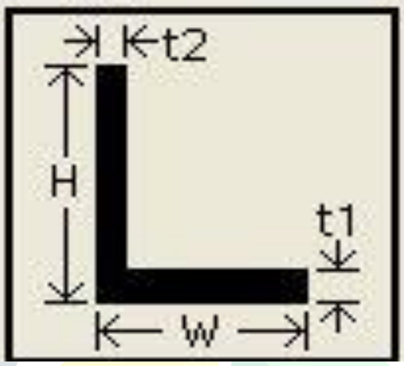

Fig 7: Cross Section of Bottom Stringers

Width (W) = 3mm. Height (H) =3mm. Thickness (t1) = 1mm. Thickness (t2)= 1mm.

2.3 3D MODEL OF THE WING:

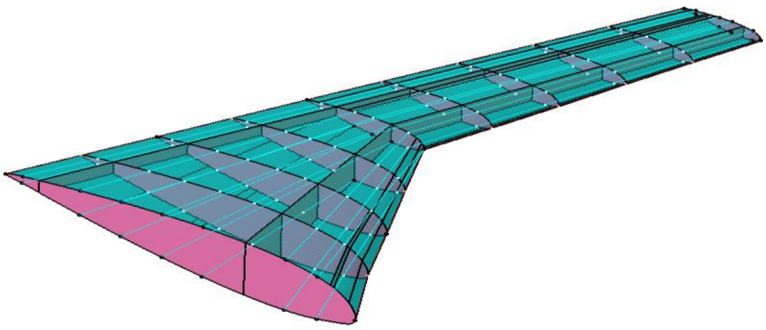

Fig 8: 3D Model of Wing

2.4 3-D MODEL OF RIB:

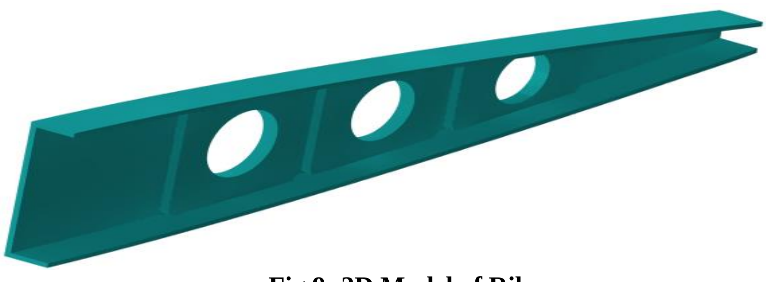

Fig 9: 3D Model of Rib

.4.1 DIMENSIONS OF RIB:

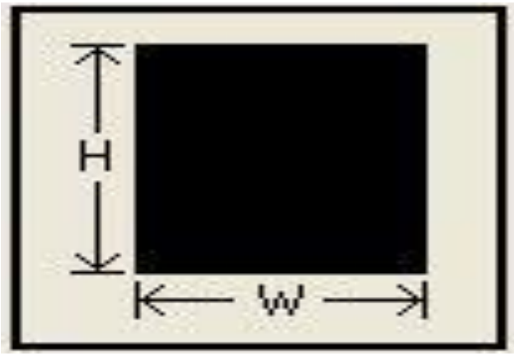

Fig 10: Cross Section of Rib Flange

Width (W) = 15mm. Height (H) = 2mm.

3.1 ANALYSIS DESCRIPTION AND ASSUMPTIONS

The FE model of wing box is made up of 1D and 2D mesh. Root rib meshed in wing box and also detailed as an individual component. Sub modelling approach has been used for analysing.

Wing and root rib has been modelled using the combination of CBAR, CBEAM, CQUAD and CTRIA elements. The CTRIA elements are used to represent the stiffness of the joint and the CQUAD elements are used to represent the surface and the CBAR, CBEAM are used to represent the stringers and rib flange.

The wing box FEM has 9216 DOF (degrees of freedom) and comprises the finite elements shown in the table below.
Number of Grids – 1536

Table 1: No. of Elements in Wing Finite Element Model

Element Type.	Numbers
CBAR	752
CBEAM	224
CQUAD4	1729
CTRIA3	33

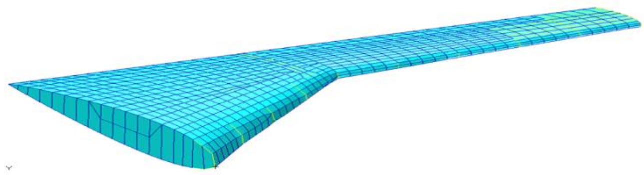

Fig 11: FE Model of the Wing.

3.1.1 RIBS:

Rib webs has been modelled using quad and tria elements and rib flanges has been meshed using bar elements. Rib webs has been represented with either one or two quad elements across its depth and bar elements has been used at top and bottom of the quad elements.

Fig 12: FE Model of the Ribs.

3.1.2 SPAR:

Like ribs spar webs has been represented using quad elements and flange has been represented using bar elements.. In front spar two quad elements has been used to represent the web and one quad element has been used to represent the web.

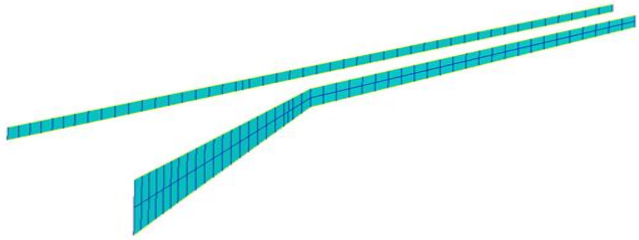

Fig 13: FE Model of the Spars.

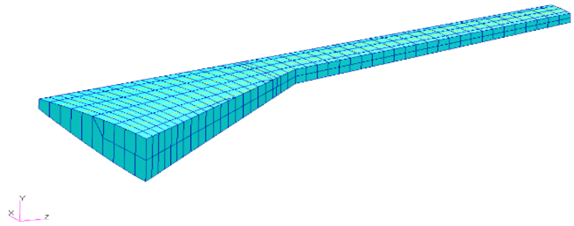

Fig 14: FE Model of the Wing Box.

3.2 MATERIALS:

Beech craft aircraft wing is made up of aluminum alloy. The properties aluminum alloy AL2024 T3411 has been considered. Since the alloy has good strength and good fatigue characteristics. The following are the properties of the aluminum alloy.

Table 2: Material Properties

Property	Value
Young's Modulus	70000 MPa
Poisson's Ratio	0.3
Density	2.89E-9 Kg/mm3

3.3 LOADS AND BOUNDARY CONDITIONS:

Entire root rib outer nodes have been arrested in all 3 translations as the beech craft wing is attached to fuselage through the box structure. 3 degrees of freedom in rotation has not been arrested since the rotations will be restricted by differential translations.

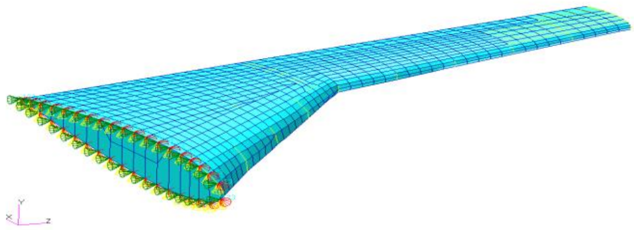

Fig 15: Boundary Conditions Applied in the Wing model.

3.4 Loading:

Cruising condition was assumed for analysis and no fuel pressure is used. Hence only pressure loads has been applied for analysis. Positive pressure value of 1 N/mm2 was applied at bottom surface and negative pressure of 0.5N/mm2 was applied on top skin.

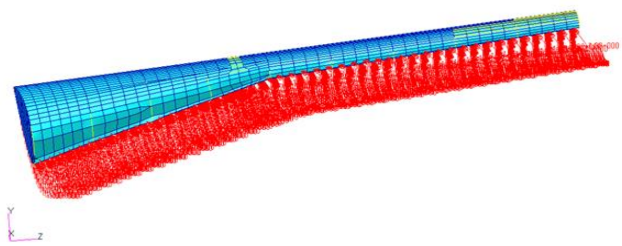

Fig 16: Pressure Applied on the Bottom Surface of the Wing.

1. RESULTS OF WING ANALYSIS:

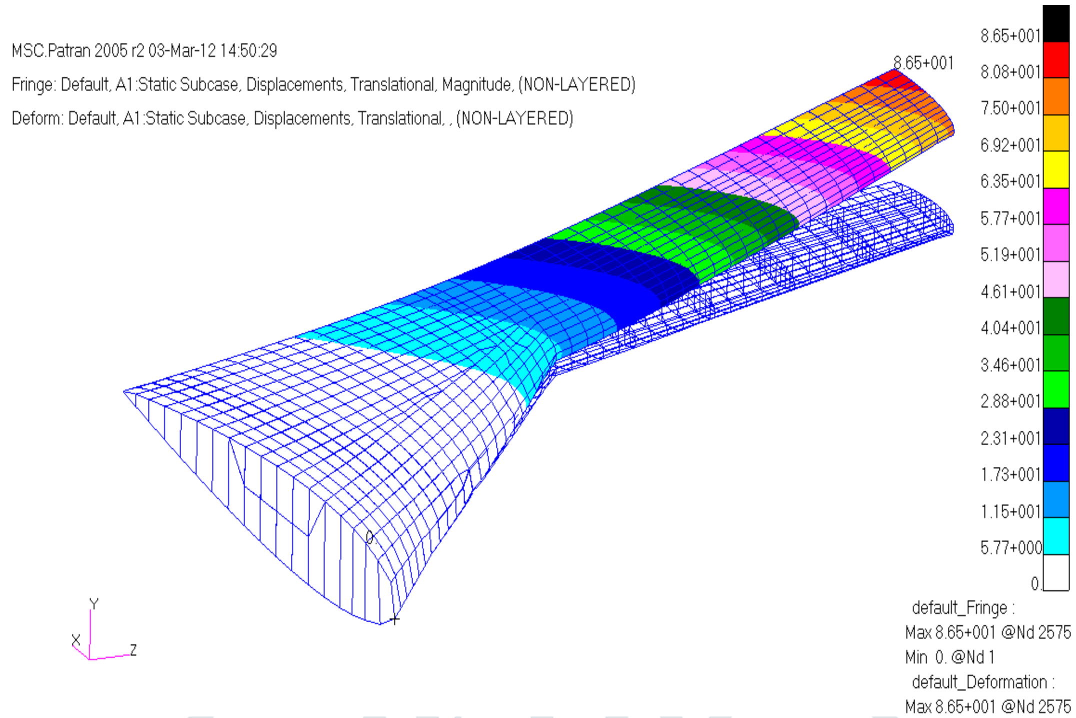

Fig 17: Displacement in the Wing.

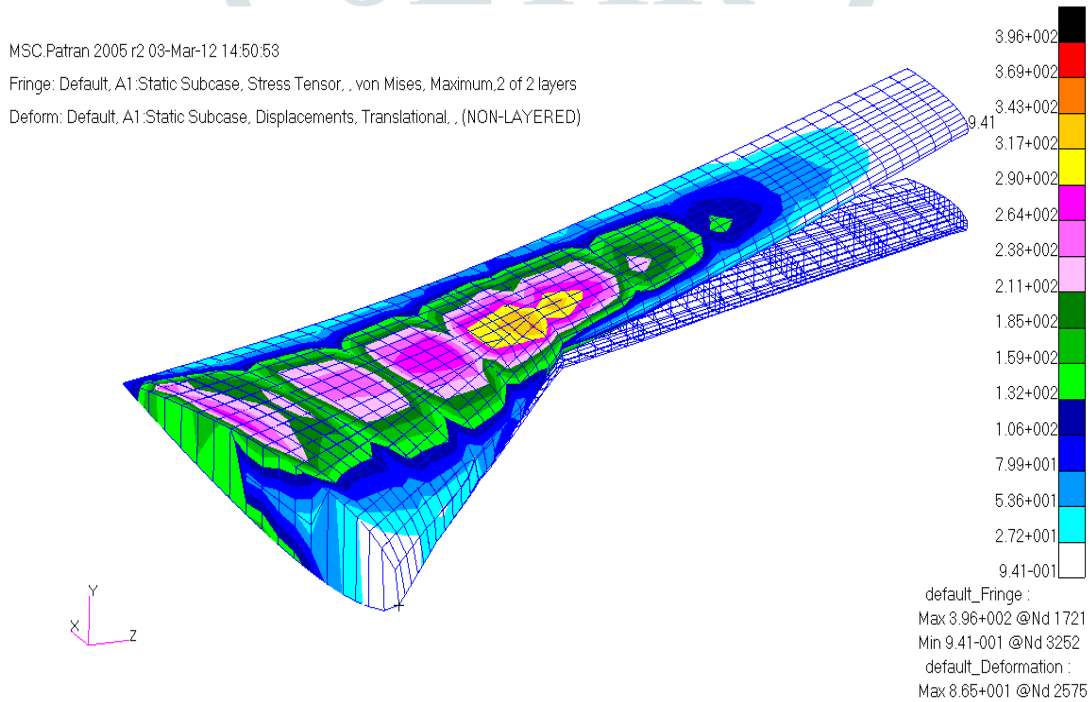

Fig 18: Stress in the Wing.

Maximum displacement =8.65mm

Maximum Stress =3.96x102 N/mm2

Minimum Stress =9.41x10-1 N/mm2

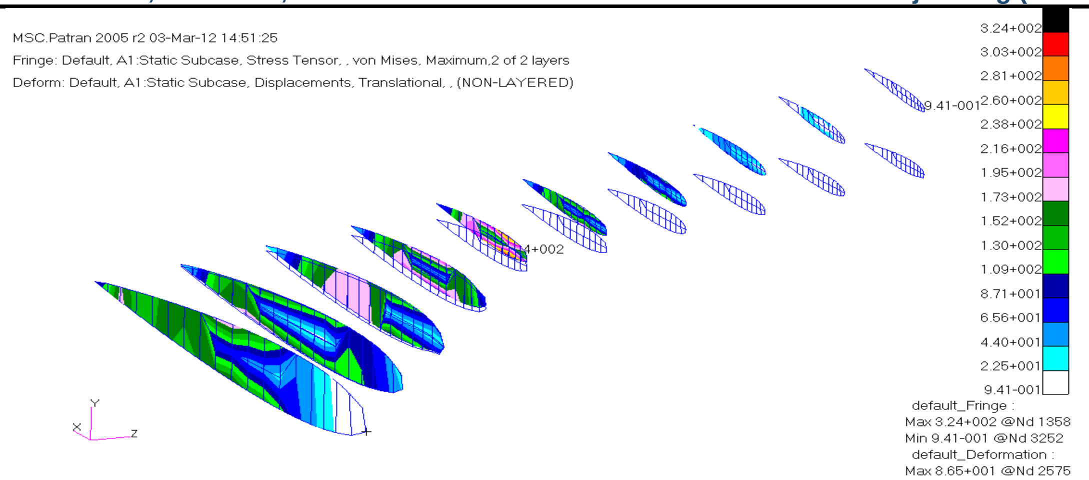

Fig 19: Stress and Displacement in the Ribs.

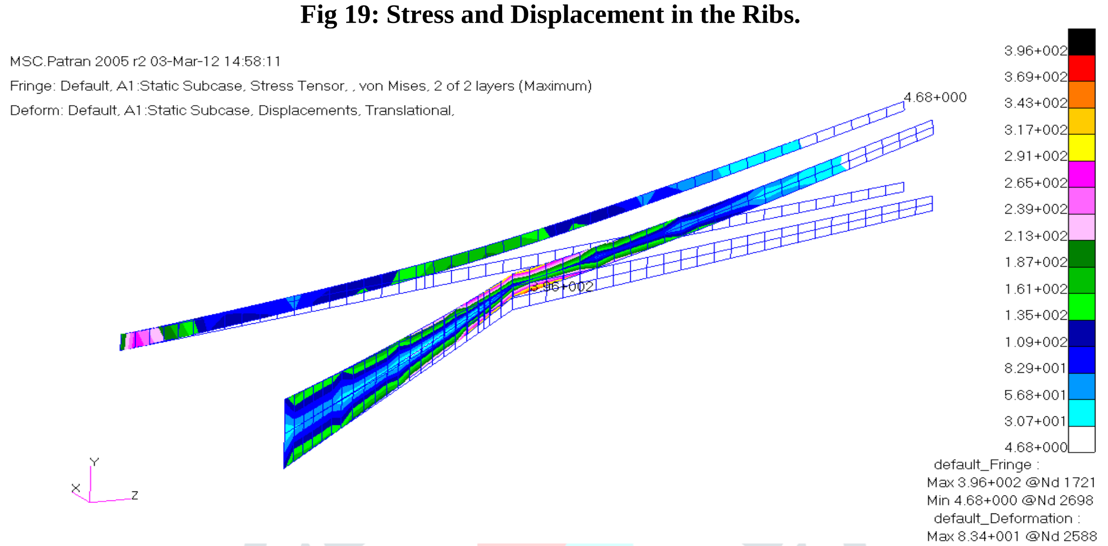

Fig 20: Stress and Displacement in the Spars.

4.1 DETAILED ANALYSIS OF ROOT RIB:

Root rib has been analyzed using sub modeling approach. CQUAD4 elements are used to mesh the surfaces. The load values has been taken from wing model and applied in root rib. The root rib FEM has 8406 DOF (degrees of freedom) and comprises the finite elements shown in the table below.

Number of Grids – 1401

Table 3: No. of Elements in Rib Finite Element model

Element Type	Numbers
CBAR	0
CBEAM	0
CQUAD4	1288
CTRIA3	0

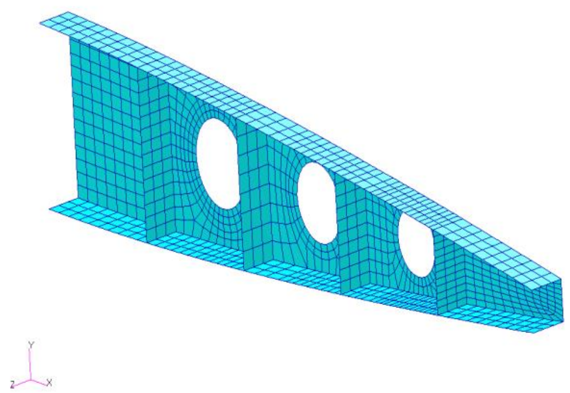

Fig 21: FE Model of Root Rib.

The leading edge and the trailing edge of the rib were arrested in 6 degrees of freedom which means both the sides are fixed.

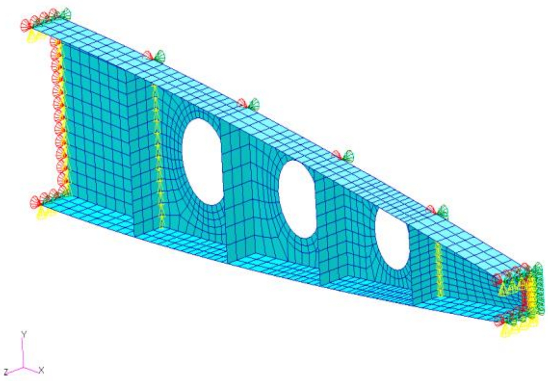

Fig 22: Boundary Conditions of Rib.

4.2 Pressure Loading:

Cruising condition was assumed for analysis and no fuel pressure is used. Hence only pressure loads has been applied for analysis. Positive pressure value of 1.5 N/mm2was applied at bottom surface and negative pressure of 1.5N/mm2 was applied on top surface.

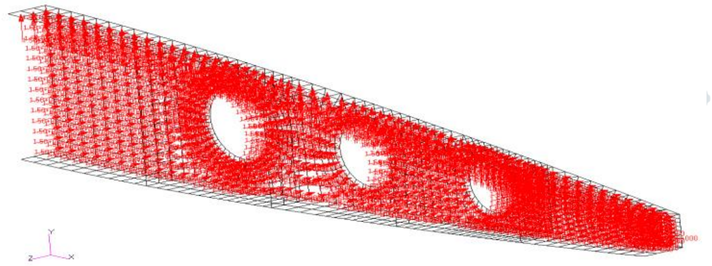

Fig 23: Pressure Applied On The Root Rib.

4.3 Results of Rib Analysis:

Displacement in the rib = 4.23x10-3 mm.

Maximum Stress = 2.27x102 N/mm2.

Minimum Stress = 1.43x10-1 N/mm2.

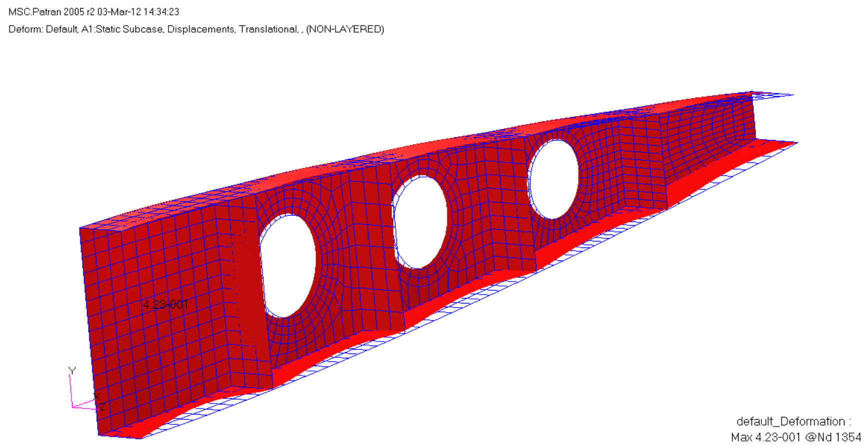

Fig 24: Displacement in the Rib.

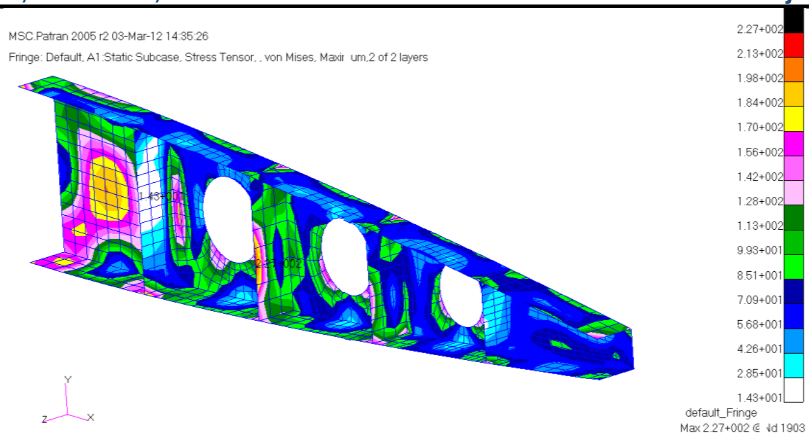

Fig 25: Stress in the Rib.

2. Conclusions

In this paper, the new design of wing section with ribs is modelled and analysis is carried out to compute stresses using PATRAN. From the above results we can conclude that at the above assumed loading conditions and constraints aircraft wing structure will not fail due to the aerodynamic pressure loads. The results obtained are optimum. The result has shown that the new designs can withstand high aerodynamic loads. The effect of other aeroelastic loads acting on the wing can substantially change the results, so the current project can be extended by applying different boundary conditions in the future.

Acknowledgements

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References

[1] Michael C. Y. Niu, “Airframe structural design”, Conmilit press Ltd.

[2] Megson, T.H.G.,“Aircraft structures for engineering students”, Elsevier Ltd, 2007.

[3] E. Kesseler and W.J. Vankan, “Multidisciplinary design analysis and multi-objective optimization applied to aircraft wing", National Aerospace Laboratory document, Netherland, 2006.

[4] Pritish Chitte, P. K. Jadhav, S. S. Bansode, "Statistic and DynamicAnalysis of Typical Wing Structure of Aircraft using Nastran," International Journal of Application or Innovation in Engineering & Management, vol. 2, no. 7, pp. 321-326, July 2013.

[5] Gukuloth Kavya and B.C. Raghukumar Reddy, " Design and Finite Element Analysis of Aircraft Wing Using Ribs and Spars," International Journal & Magazine of Engineering, Technology, Management and Research, vol. 2, no. 11, pp. 1443-1455, Nov. 2015.

[6] Sivarama Prasad Peruru,Suman Babu Abbisetti, "Design and finite element analysis of aircraft wing using ribs and spars," International Research Journal of Engineering and Technology, vol. 4, no. 6, pp. 2133-2139, Jun. 2017.

[7] Pavan G, Manjunath M V, " Static Analysis On Wing Spar Joint For An Aircraft Using Finite Element Method," International journal of engineering development and research, vol. 6, no. 3, pp. 144-152, 2018.

[8] T.S.Vinoth Kumar, A.Waseem Basha, M.Pavithra, V.Srilekha, “Static & dynamic analysis of a typical aircraft wing structure using MSC NASTRAN,” International journal of research in aeronautical and mechanical engineering, vol. 3, no. 8, pp. 1-12, Aug. 2015.

[9] Yuvaraj S R, Subramanyam P, " Design and Analysis of Wing of an Ultralight Aircraft," International Journal of Innovative Research in Science, Engineering and Technology, vol. 4, no. 8, pp. 7456-7468, Aug. 2015.

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