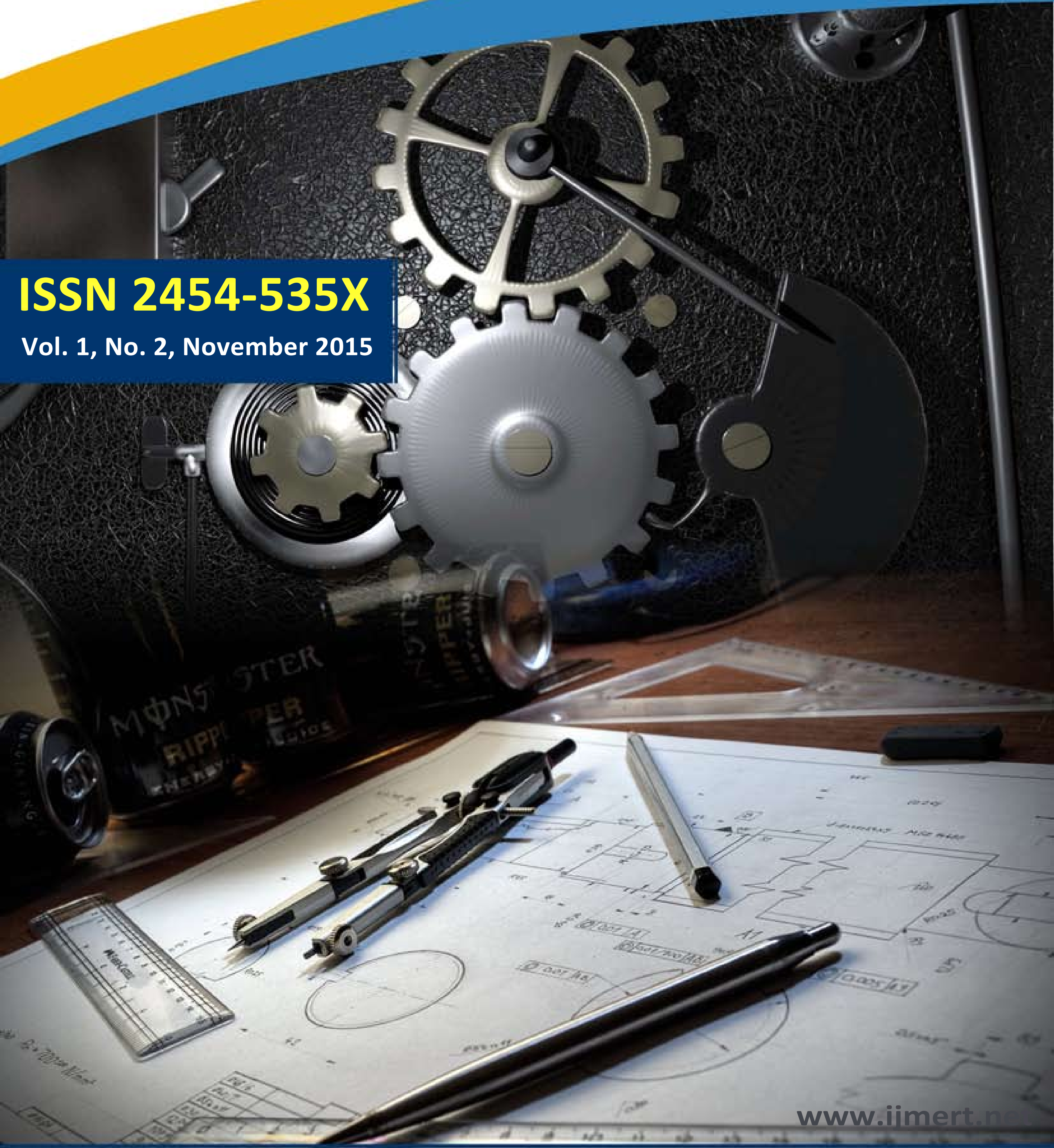
International Journal of
Mechanical Engineering Research and Technology



ISSN 2454-535X

Vol. 1, No. 2, November 2015

Email ID: info.ijmert@gmail.com or editor@ijmert.net

International Journal of Mechanical Engineering Research and Technology

ISSN 2454 – 535X www.ijmert.com
Vol. 1, No. 2, November 2015

Research Paper

WEIGHT AND STRENGTH OPTIMIZATION OF AIRPLANE FUSELAGE STRUCTURE FOR DIFFERENT MATERIALS

Y Prem Chand[1]* and K Krishna Veni[2]

*Corresponding Author: Y Prem Chand, ✉ premchand@gmail.com

The fuselage is an airplane's main body section that holds crew and passengers. The design of a fuselage must provide the necessary strength and rigidity to sustain the loads and environment that it will be subjected during the operational life of the airplane. In this present project, 3d model of fuselage is generated in created in NX-CAD based on previous papers. The 3d model of fuselage is converted to parasolid and then imported to ANSYS to perform finite element analysis. Structural static analysis is performed on finite element model of fuselage for aluminum material for static loads to determine deflections and stresses. In this project, dynamic characteristics of fuselage are evaluated by performing modal analysis to calculate natural analysis to see the structure behavior of fuselage. Harmonic analysis is performed at critical frequencies obtained from modal analysis for operating loads and deflections, stresses are tabulated. Static and dynamic analysis of fuselage is also performed for alternative material, i.e., carbon-epoxy material. From the analysis, results of both materials are tabulated. From these results, better material is selected based on weight and strength. 3D model of fuselage is generated by using NX-CAD software and analysis is carried out by using ANSYS software.

Keywords: Fuselage, Airplane, NX-CAD, Ansys, 3D model

INTRODUCTION

The fuselage of a modern aircraft is commonly referred to as semi- monocoque construction. A pure monocoque shell is unstiffened tube of thin skins, and as it is inefficient since unsupported thin sheets are unstable in shear and compression. In order to support the skin, we need to provide bulkheads, frames, stiffening members, stringers and longerons.

The stiffened shell semi-monocoque type of fuselage construction is similar to wing construction with distributed bending material. The fuselage as a beam contains longerons and stringers, frames and bulkhead and its

1 Student, Chebrolu Engineering College, Chebrolu, AP, India.
2 Associate Professor in Machine Design, Chebrolu Engineering College, Chebrolu, AP, India.

outer skin. The longerons carry the fuselage bending moment, by axial forces resulting from the bending moment. The skin carries the shear force from the applied torsional forces, external transverse and cabin pressure.

METHODOLOGY

The objective of this paper is to design 3d model of aero plane fuselage. The finite element analysis shall be done with aluminum and composite materials shall be carried out to check the structure strength and dynamic behavior. NX software was used for designing and analysis software (ANSYS) was used for finite element analysis.

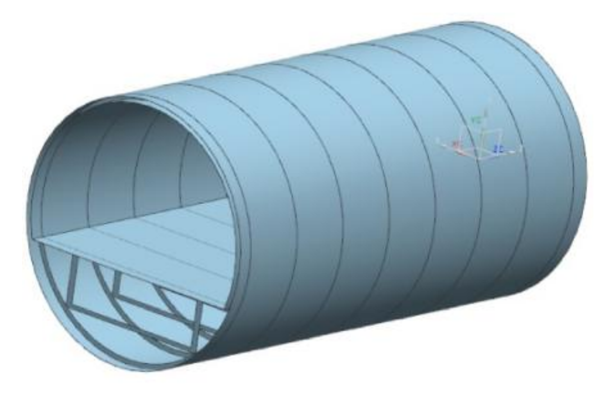
The Methodology Followed in the Project is as Follows

3d Model of Fuselage is Generated in NX-CAD. The 3d model of fuselage is converted to parasolid and then imported to ANSYS to perform finite element analysis. Structural static analysis is performed on finite element model of fuselage for aluminum material for static loads to determine deflections and stresses. Modal analysis is performed to calculate natural analysis to see the structure behavior of fuselage. Harmonic analysis is performed at critical frequencies obtained from modal analysis for operating loads and deflections, stresses are tabulated. Static and dynamic analysis of fuselage is also performed for alternative material i.e. carbon-epoxy material. From the analysis, results of both materials are tabulated. From these results, better material is selected based on weight and strength.

3d Modeling of Aero Plane Fuselage

UNIGRAPHICS NX software is used to generate the 3d model of fuselage. UNIGRAPHICS NX is the world's leading 3D product development solution.

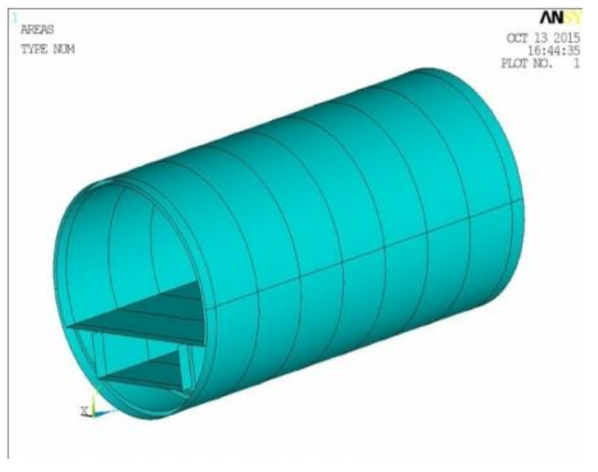
Figure 1: Shows Assembly of Aero Plane Fuselage



Finite Element Analysis of Fuselage for Aluminum Alloy

The fuselage model was meshed with shell63 element type. A total number of 14512 elements and 14254 nodes were created.

Figure 2: Shows the Geometric Model of the Fuselage



Static Analysis of Fuselage

The Objective of this analysis is to check the High stressed locations and deflections on the fuselage for the applied loads.

Figure 3: Shows the Finite Element Model of the Fuselage

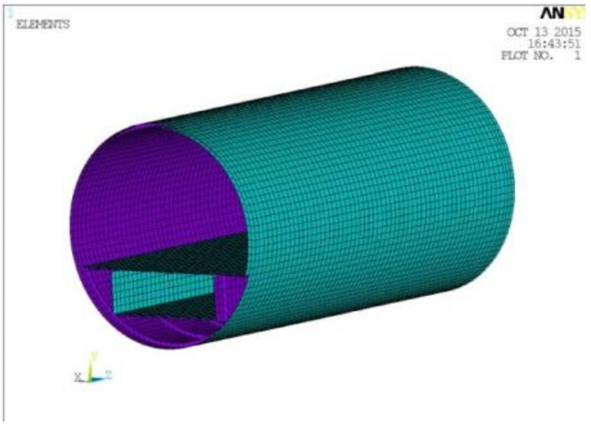


Figure 4: Shows the Boundary Conditions for Static Analysis

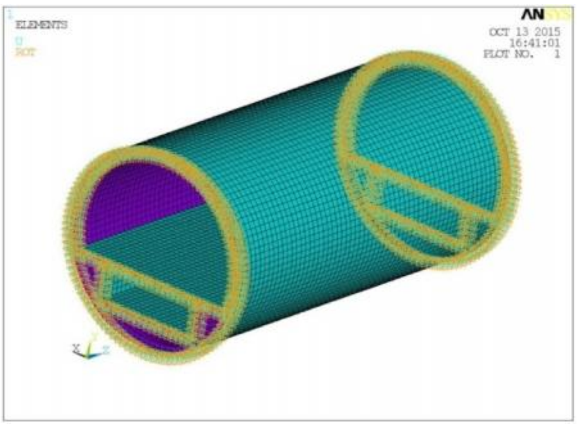
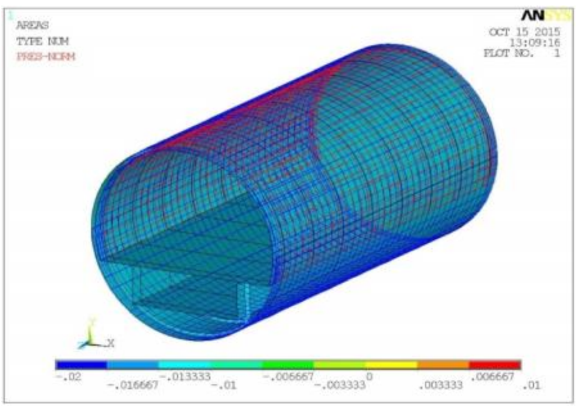


Figure 5: Shows the Applied Pressure Loads for Static Analysis



Boundary Conditions

- Internal pressure = 0.1 bar
- External pressure = 0.2 bar
- Fuselage both ends are arrested in all dof.

Results

The Maximum Von Misses stress of fuselage observed 17.52 MPa in static analysis.

From the analysis, the maximum Von Misses stress of 17.52 Mpa is observed on the fuselage. The maximum stress is observed

Figure 6: Shows Total Deflection of Fuselage for Static Analysis

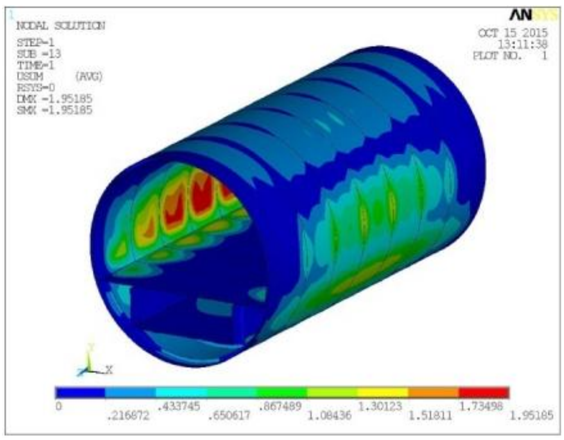
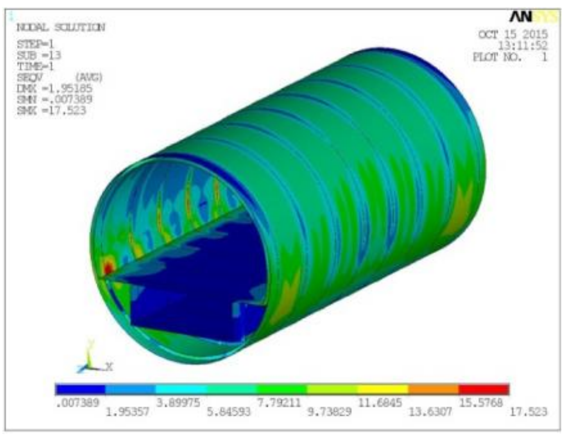


Figure 7: Shows Von Misses Stress of Fuselage for Static Analysis



on the flanges locations of the fuselage. The yield strength of the material is 414 Mpa.

Modal Analysis of Fuselage Structure

Modal analysis was carried out on fuselage to determine the first 10 natural frequencies and mode shapes of a structure. From the modal analysis, a total of 10 natural frequencies are observed. The total weight of the fuselage considered for the analysis is 3.33 tones.

Table 1: Shows the First 10 Natural Frequencies

Mode	Frequency (HZ)
1	14.494
2	14.992
3	15.612
4	16.18
5	16.603
6	16.856
7	16.943
8	17.468
9	18.752
10	19.984

Mode Shapes

To check the magnitude values of deflections and stresses at the above mentioned frequencies due to the operating loads, harmonic analysis is carried out on the fuselage.

Harmonic Analysis of Fuselage Graphs

Figure 8: Shows Mode Shape of Fuselage @14.49 Hz

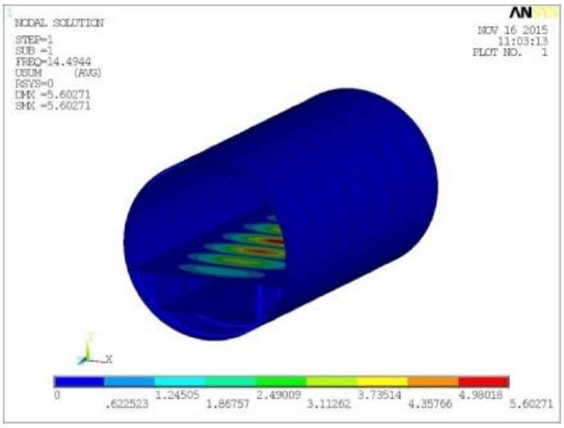


Figure 9: Shows Mode Shape of Fuselage @19.98 Hz

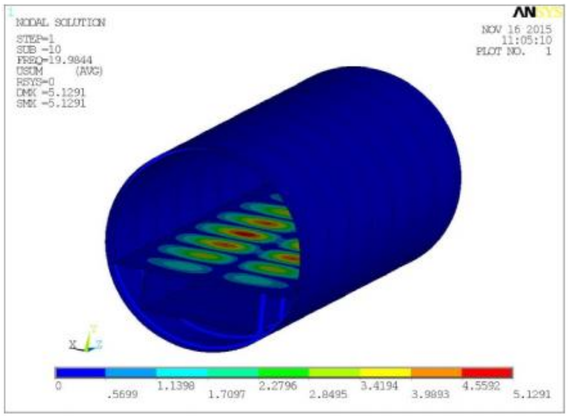
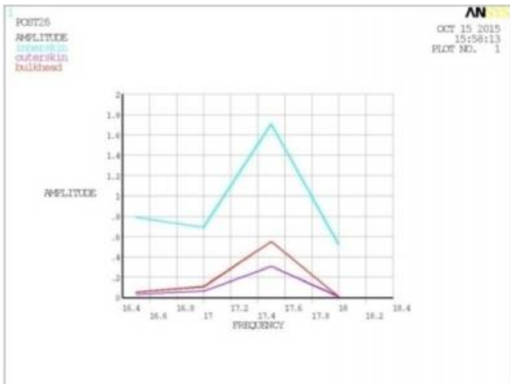


Figure 10: Shows the Harmonic Response at Different Locations on Fuselage Structure in Linear Scale



Stresses

From the above results it is observed that the stresses at the nearest natural frequencies 16.9 Hz and 17.5 Hz are 87.6 MPa and 389MPa respectively. According to the Von Misses Stress Theory, the Von Misses stress of fuselage at frequencies 16.9 Hz and 17.5 Hz are less than the yield strength of the material. Hence the design of fuselage is safe for the above operating loading conditions.

Figure 11: Shows the Von Misses Stress of Fuselage @ 16.9 Hz for Harmonic Loads

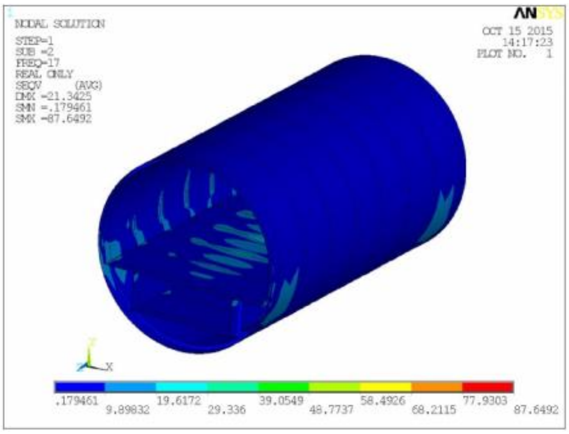
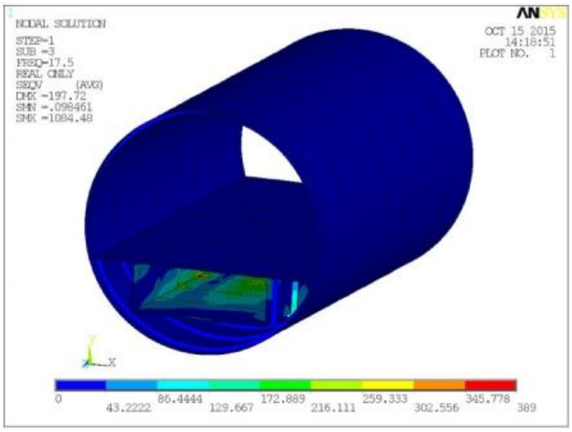


Figure 12: Shows the Von Misses Stress of Fuselage @17.5 Hz for Harmonic Loads



Static Analysis of Fuselage for Eglass/Epoxy Material

Results

From the above results it is observed that the principal stresses values 20.5 MPa, 7.18 MPa, and 0.009 MPa are less than the principal stresses values of the material 800MPa, 42 MPa, and 74 MPa respectively (i.e., 1st, 2nd and 3rd principal stresses). Hence according to the Maximum Stress Theory, the fuselage design is safe for the above operating loads.

Figure 13: Shows Total Deflection of Fuselage for Static Analysis

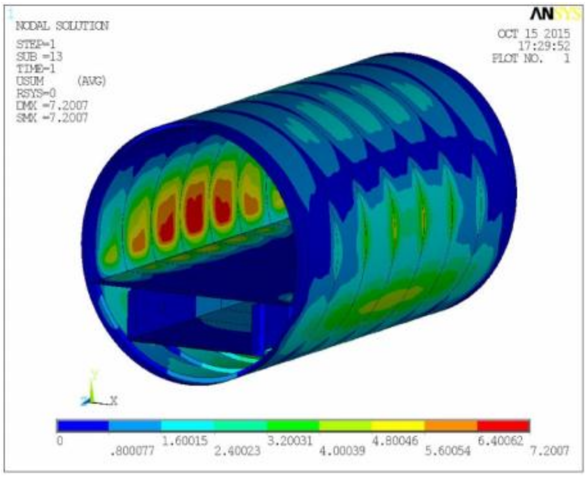


Figure 14: Shows 1st Principal Stress of Fuselage for Static Analysis

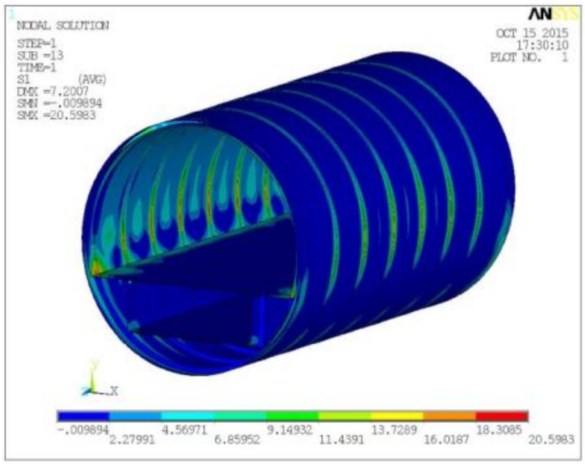


Figure 15: Shows 2nd Principal Stress of Fuselage for Static Analysis

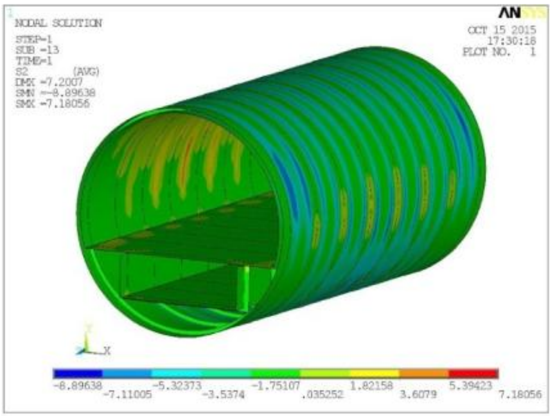


Figure 16: Shows 3rd Principal Stress of Fuselage for Static Analysis

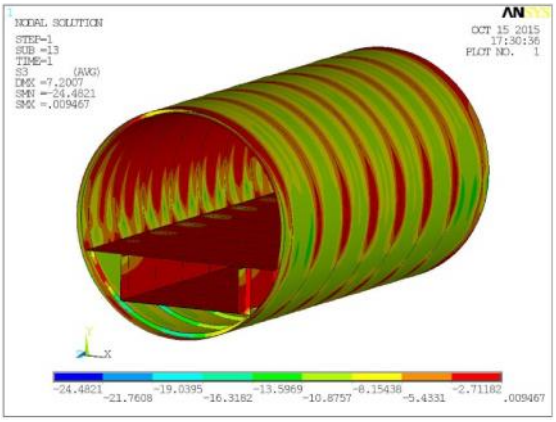
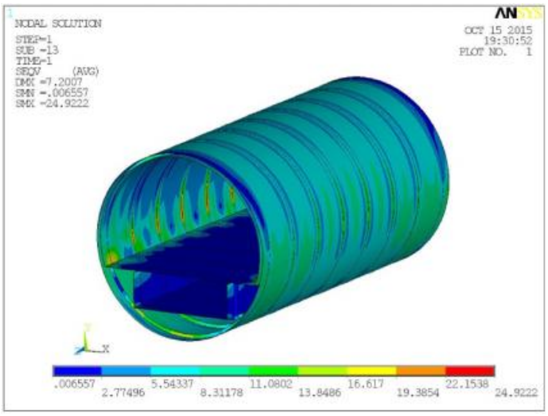


Figure 17: Shows Von Misses of Fuselage for Static Analysis



Modal Analysis of Fuselage Structure

Modal analysis was carried out on fuselage to determine the first 10 natural frequencies and mode shapes of a structure. From the modal analysis, a total of 10 natural frequencies are observed. The total weight of the fuselage considered for the analysis is 2.37 tones.

Table 2: Shows the First 10 Natural Frequencies

Mode	Frequency (HZ)
1	10.5641
2	10.6113
3	10.7248
4	10.9958
5	11.4756
6	11.5789
7	12.0828
8	12.3479
9	12.5429
10	13.3595

Mode Shapes

Figure 18: Shows Mode Shape of Fuselage @10.56 Hz

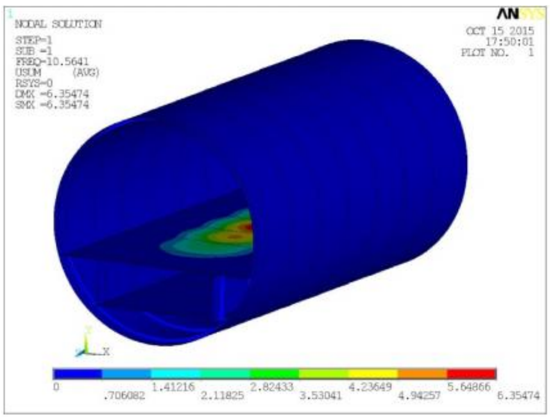
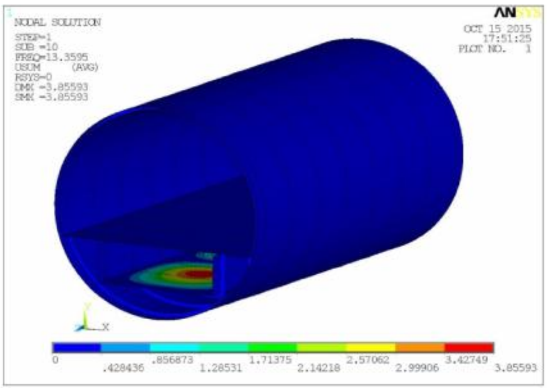


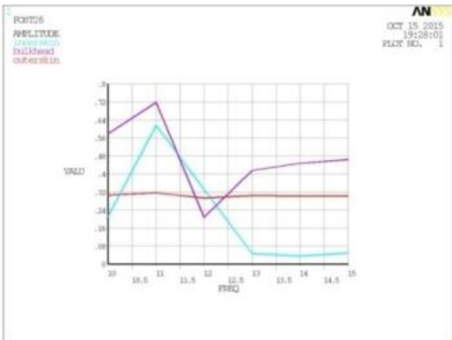
Figure 19: Shows Mode Shape of Fuselage @13.35 Hz



Harmonic Analysis of Fuselage

Graphs

Figure 20: Shows the Harmonic Response at Different Locations on Fuselage Structure in Linear Scale



Stresses

Figure 21: Shows the 1st Principal Stress of Fuselage @11.5 Hz for Harmonic Loads

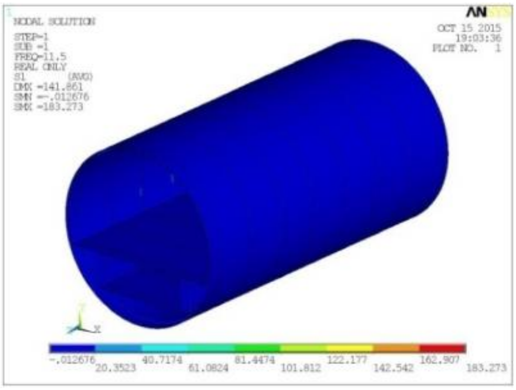


Figure 22: Shows the 2nd Principal Stress of Fuselage @11.5 Hz for Harmonic Loads

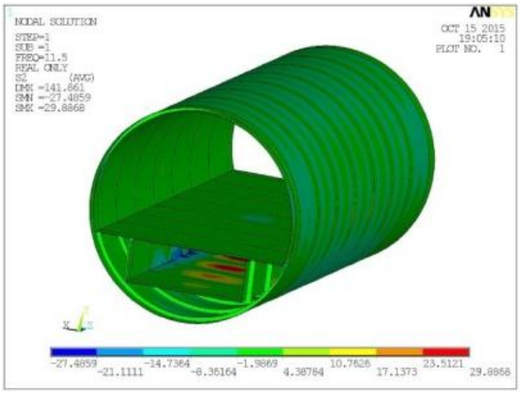


Figure 23: Shows the 3rd Principal Stress of Fuselage @11.5 Hz for Harmonic Loads

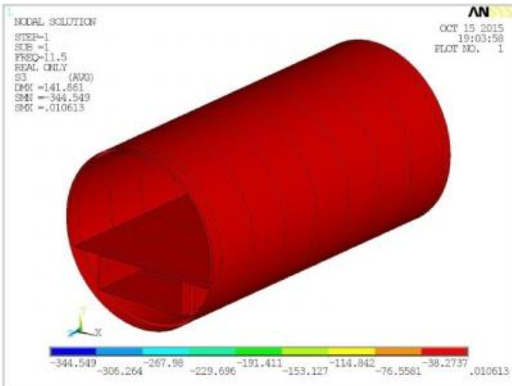
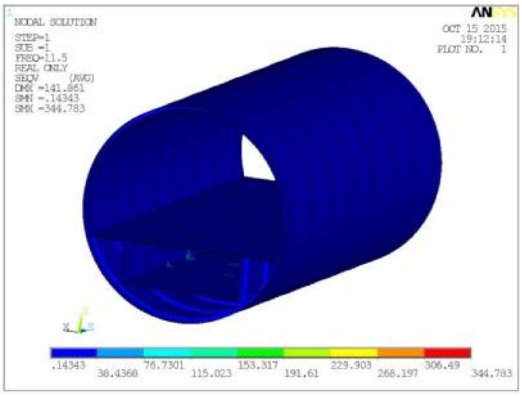


Figure 24: Shows the Von Misses Stress of Fuselage @11.5 Hz for Harmonic Loads



From the above results it is observed that the principal stresses of 11.5 Hz frequency values 182.3 MPa, 29 MPa and 0.0106 MPa are less than the principal stresses values of the material are 800 MPa, 42 MPa, and 70 MPa respectively (i.e., 1st, 2nd and 3rd principal stresses).

According to the Von Misses Stress Theory, the Von Misses stress of fuselage at frequency of 11.5 Hz is having less stresses than the yield strength of the material. Hence the design of fuselage is safe for the above operating loading conditions.

RESULTS

In the present project, the fuselage was studied for structural behavior and optimized for different materials (aluminum and Eglass/ epoxy).

Fuselage was studied for three analyses in structural analysis. They are:

1. Static analysis
2. Modal analysis
3. Dynamic analysis

Case 1: Structural Analysis of Fuselage for Aluminum Material

From Static Analysis

From the analysis, the maximum Von Misses stress of 17.52 Mpa is observed on the fuselage. The maximum stress is observed on the flanges locations of the fuselage. The yield strength of the material is 414 Mpa.

From Modal Analysis

- The total weight of the fuselage observed for the analysis is 3.33 tones.

From Harmonic Analysis

From the above results it is observed that the stresses at the nearest natural frequencies 16.9 Hz and 17.5 Hz are 87.6 MPa and 389 MPa respectively. According to the Von Misses Stress Theory, the Von Misses stress of fuselage at frequencies 16.9 Hz and 17.5 Hz are less than the yield strength of the material. Hence the design of fuselage is safe for the above operating loading conditions.

Case 2: Structural Analysis of Fuselage for Eglass/Epoxy Material

From Static Analysis

From the above results it is observed that the principal stresses values 20.5 MPa, 7.18 MPa, and 0.009 MPa are less than the principal stresses values of the material 800 MPa, 42 MPa, and 74 MPa respectively (i.e., 1st, 2nd and 3rd principal stresses). Hence according to the Maximum Stress Theory, the fuselage design is safe for the above operating loads.

From Modal Analysis

- The total weight of the fuselage observed for the analysis is 2.37 tones.

From Harmonic Analysis

From the above results it is observed that the principal stresses of 11.5 Hz frequency values 182.3 MPa, 29 MPa and 0.0106 MPa are less than the principal stresses values of the material are 800 MPa, 42 MPa, and 70 MPa respectively (i.e., 1st, 2nd and 3rd principal stresses).

According to the Von Misses Stress Theory, the Von Misses stress of fuselage at frequency of 11.5 Hz is having less stresses than the yield strength of the material. Hence the design of fuselage is safe for the above operating loading conditions.

Table 3: Comparison of Aluminum Alloy and E Glass/Epoxy Materials

S. No.	Material	Maximum Deflection	Von Misses	FOS	Weight
1	Aluminum alloy	1.95	17.52	414/17.52=23.63	32.63
2	E glass/ Epoxy	7.2	24.92	800/24.92=32.10	23.22

CONCLUSION

In the present project, fuselage was studied for structural behavior and optimized for different materials (aluminum and E glass/ epoxy materials).

In this project, the three-dimension model of fuselage was modeled in NX-CAD and imported into ANSYS software to analyze strength and dynamic characteristics of fuselage has been developed. The static strength and the dynamic characteristics about fuselage were analyzed with ANSYS software for different materials (aluminum alloy and E glass/epoxy materials).

From the above analysis it is concluded that the fuselage has stresses and deflections within the design limits for aluminum and E glass/epoxy materials). From the results we can conclude that the fuselage of E glass/ epoxy material has less weight and better factor of safety.

FUTURE SCOPE

The fuselage is an airplane's main body section that holds crew and passengers. Fuselage was studied for structural behavior and optimized for different materials (aluminum and Eglass/epoxy materials). To check the structure behavior of fuselage static, modal and harmonic analysis was done. Project can be extended by studying structural behavior of fuselage by considering carbon epoxy material.

REFERENCES

1. Fayssal Hadjez and Brahim Necib (2015), "Stress Analysis of an Aircraft Fuselage with and Without Portholes Using CAD/ CAE Process".
2. Gary L Giles (1998),"Design-Oriented Analysis of Aircraft Fuselage Structures".
3. Ing Wilhelm Rust and Dipl-Ing M Kracht (2015), "Recent Experiences in Load Analysis of Aircraft Fuselage Panels".
4. Karthick B, Balaji S and Maniiarasan P (2013), "Structural Analysis of Fuselage with Lattice Structure".
5. Karthik N and Anil Kumar C (2013), "Analysis of the Fuselage Structure for Multi Site Damage", *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 2, No. 7, pp. 3330-3335.
6. Marampalli Shilpa, Venkateswar Reddy M and Siva Kumar A, "Design & Analysis of Fuselage Structure Using Solid Works & ANSYS".
7. Michel van Tooren and Lars Krakers, "Multi-Disciplinary Design of Aircraft Fuselage Structures".
8. Nadakatti M M and Vinayakumar B Melmari, "A Review on Stress Analysis of the Fuselage Structure and Study of the Effect of Overload on Fatigue Crack Growth".
9. Sérgio Frascino Müller de Almeida (2009), "Design and Analysis of a

Composite Fuselage by Marco Aurelio Rossi".

10. Shivaraj Ranganatha S R, Ramamurthy V S and Girish K E (2014), "Buckling and Linear Static Analysis of Fuselage Structure Subjected to Air Load Distribution", *International Journal of Advance Research in Science and Engineering*, Vol. 3, No. 9, pp. 375-381.

11. Vasantha Kumar H and Karumbaiah B G (2015), "Optimization of Aircraft Fuselage Bulkhead Structure Using Msc/Patran and Nastran Software", *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 4, No. 6, pp. 4596-4601.

International Journal of Mechanical Engineering Research and Technology
#301, Balaji Heights Apts, Balaji Hills, Uppal, Hyderabad, India.
Phone: +91-09441351700 (or) +91-09059645577
Email: info.ijmert@gmail.com (or) editor@ijmert.net
Website: www.ijmert.net

02

9 772454 535001