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Optimization of Passenger Aircraft Fuselage using Buckling Analysis

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Abstract: The Fuselage is one of the main part of the aircraft design where passengers and cargo will be placed in two levels hear the main obstacles is has to bear maximum load and it should be light in weight ; The aim of this project work is to suggest best shape and best composite material using finite element analysis.
Initially data collection will be done to understand construction methodology and selection of materials; 3D models and assembly of circular and oval shape fuselages will be prepared using solid works. It will be converted into IGES format to conduct analysis in Ansys.
Structural and buckle analysis will be conducted on circular and oval shape fuselages by varying materials to validate and compare Values; Fatigue analysis will be conducted on same to evaluate life, factor of safety and fatigue stress.
Best shape and material will be suggested by considering above analysis results.

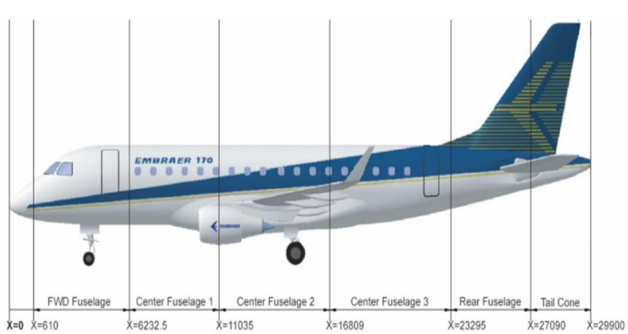
I. INTRODUCTION

Aircraft fuselages are subject to a wide envelope of mechanical loads. Flight and ground loads result in shear, bending and torsion while the internal pressurization leads to an internal stress system that can be described, in a highly simplified way, with the vessel equations. At the same time the fuselage is there to protect the passengers against a hostile environment that can be characterized by noise levels, temperatures and radiation levels.
A simplified fuselage is taken as design study object. The basic element is a stiffened cylinder, including a floor like division of the cross section, subjected to mechanical loads, external noise fields and a low external temperature

1) Provision of volume for payload (passengers & cargo).
2) Provide overall structural integrity.
3) Possible mounting of landing gear, power plant and antennas

A Design and Engineering Engine (DEE) 1 has been built and used as computational framework. The Multi-Model Generator in this DEE is a Knowledge Based Engineering application that is able to generate (input for) mechanical, acoustical and thermal models for subsequent analysis with a commercial finite element solver. The analyses are used to build response surfaces with a DOE approach. A gradient based (SQP) or a genetic algorithm subsequently explores the design space looking for minimum weight solutions. The most complex and uncertain part of the computational effort is the acoustical analysis. Therefore it was decided to build and test two metal cylinders, one stiffened and one unstiffened, for their response on a wide range of frequencies. The cylinders have been subjected to external noise and the transmission loss has been measured using a scanning microphone on the inside of the cylinder. The measurements have been used to verify and calibrate the calculations.

A. Functions Of Fuselage

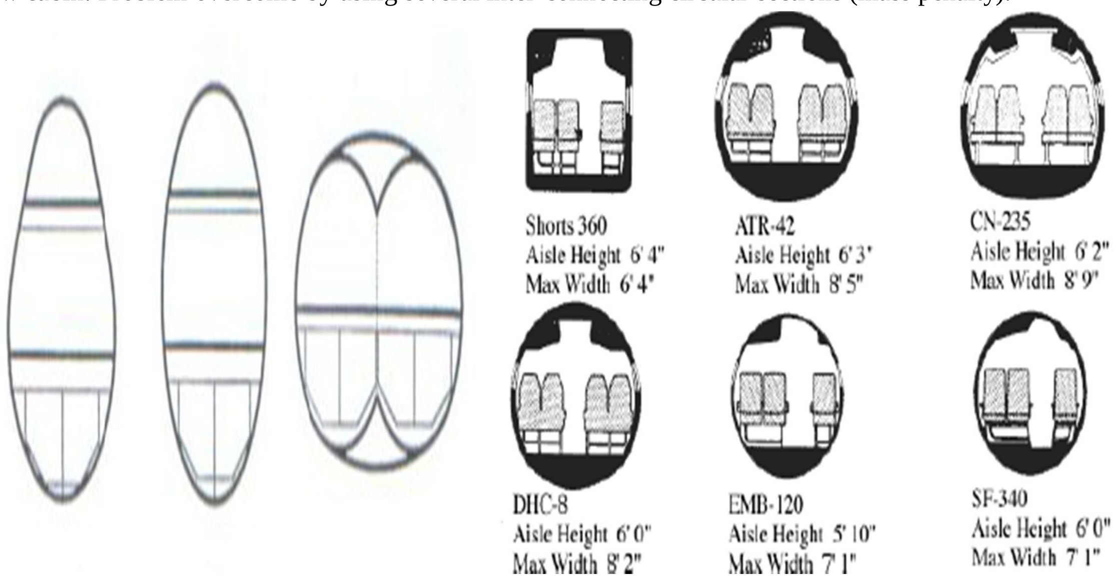


Fuselage sections

Most of the fuselage volume is occupied by the payload, except for

1) Single & two-seat light a/c.
2) Trainer & light strike a/c.
3) Combat a/c with weapons carried on outer fuselage & wing.
4) High performance combat a/c.

Shape mainly dictated by structural requirements for pressurization. Circular best structurally but may give too much unusable space above & below cabin. Problem overcome by using several inter-connecting circular sections (mass penalty).



Cabin Width & Cross-Section

II. LITERATURE SURVEY

A. Dr. M. Satheesha and Mr. Arun M P has worked on "Buckling Analysis of Fuselage Frame Using CAD/CAM Software ISSN: 2454-4248" by applying composite materials for fuselage hear they have used graphite epoxy (CFRP) as replacing material to the aluminum. In that report they have concentrated on buckle and vibrations. They have provided conclusion as: The modal analysis and buckling analysis of an aircraft fuselage have been done. The mode shapes, deflection and frequency values have been obtained and discussed. The fuselage has been analyzed using different material properties and all the results obtained are satisfactory. The fuselage structure can be redesigned in much better way using the obtained post-processing results. Structural stability results so obtained through the ANSYS, proves the model to be acceptable.

B. Mr. Manish Kumar from Hindustan University, has worked on "optimization of fuselage for better pressurization and drag reduction" in that report he has discussed abut shape optimization of fuselage to reduce the stress intensity to improve aerodynamic efficiency he have given the conclusion as : Design concept which integrates two shapes viz. a sphere and a cylinder. The resultant shape similar to an ellipse not only proved to provide better fuselage pressurization but also guaranteed a streamlined flow over its surface. The resultant effect is a drag minimizing fuselage which caters to better pressurization and minimal drag giving an aerodynamic efficiency of 65 at 5 degree angle of attack. Hoop Stress analysis shows the capacity to carry more load for elliptical shape. Reduction in minimum and maximum stress developing on the surface decreases by a significant amount of 88% and 10% respectively. Smooth aerodynamic shape results in less interference with the flow resulting in lesser drag and higher aerodynamic efficiency. Future work is to be done to find the effect of this shape on more factors like having a wide range of velocities and angle of attacks.

1) Cabin Length Estimation: Total length in any given unit of accommodation for single deck layout approximately

$[(P/p + g)\, s + t + 0.8\, w]$ m, where:

P = total number of passengers in unit
p = number of seats across cabin width
g = number of galleys across length
s = seat pitch (m)
t = number of toilets across length
w = number of cross aisles

2) Material Properties and Boundary Conditions

Aluminum	Al 7075
Density	2.81 g/cc
Hardness, Brinell	150
Tensile Strength, Ultimate	572 MPa
Tensile Strength, Yield	71.7 GPa
Modulus of Elasticity	71.7 GPa
Poisson Ratio	0.33
Fatigue Strength	159 MPa
Thermal Conductivity	130 W/m-K

3) E-Glass Epoxys-Glass Epoxy

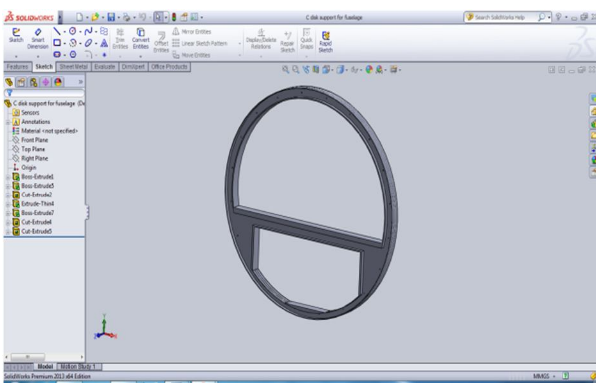
Elastic Modulus	934GPa
Poisson's Ration	0.23
Mass Density	2.48 g/cc
Yield Strength	4585MPa
Thermal Conductivity	1.35 W/m-K

Elastic Modulus	85 Gpa
Poisson's Ration	0.2
Mass Density	2.6 g/cc
Yield Strength	500Mpa
Thermal Conductivity	1.35 W/m-K

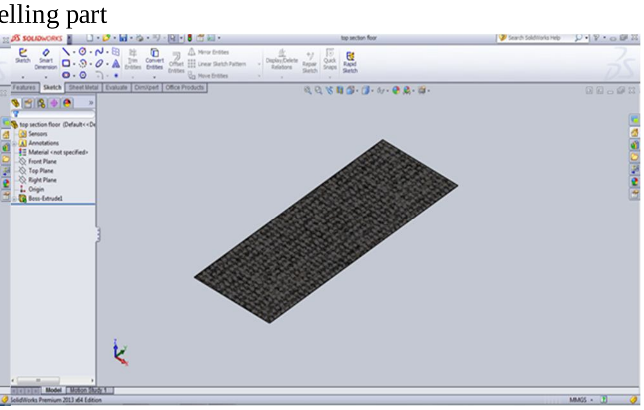
4) *Fiber Reinforced Polymers:* Fiber-reinforced polymers or FRPs include wood (comprising cellulose fibers in a lignin and hemicelluloses matrix), carbon-fiber reinforced plastic or CFRP, and glass-reinforced plastic or GRP. If classified by matrix then there are thermoplastic composites, short fiber thermoplastics, long fiber thermoplastics or long fiber-reinforced thermoplastics. There are numerous thermoses composites, but advanced systems usually incorporate aramid fiber and carbon fiber in an epoxy resin matrix.

From the wide family of composites, fiber reinforced composites have taken much attention due to their better mechanical properties

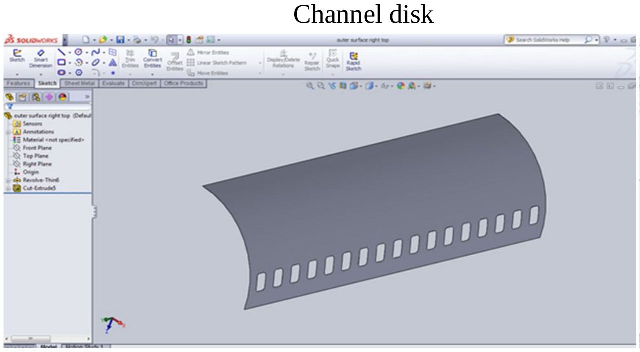
Modelling part



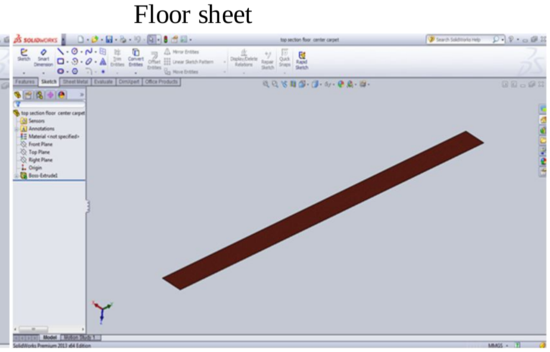
Channel disk



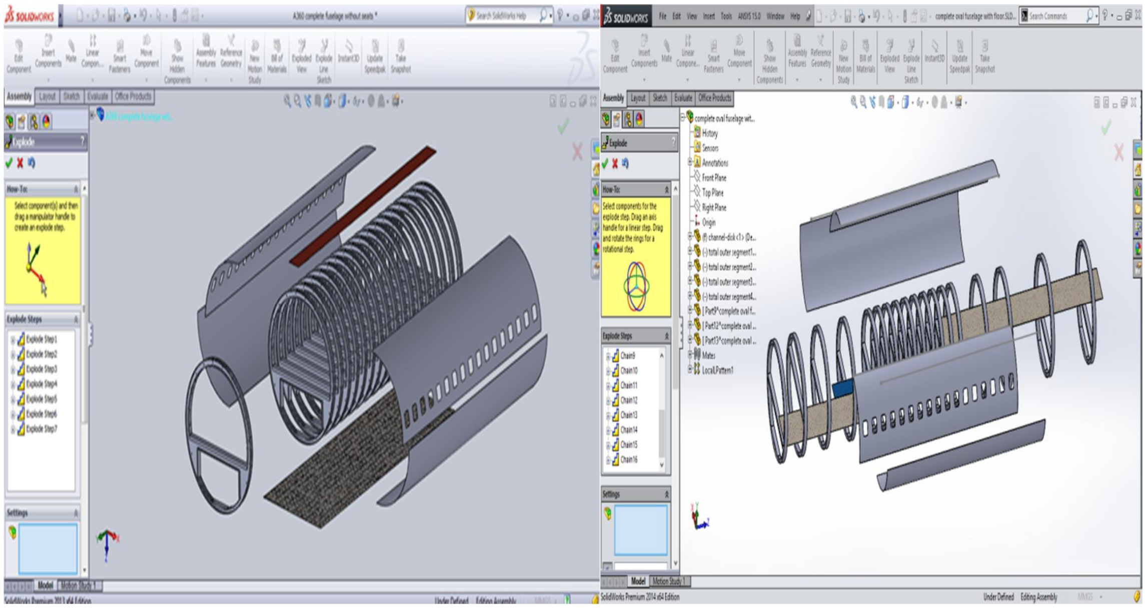
Floor sheet



Outer segment of the body



Floor center sheet



Exploded view

5) *Results of Circular Section*

Circular	ALU	E-GLASS	S-GLASS
Stress	669.35	671	444.26
Strain	.00359	.0089	.0066
Deformation	.907	2.547	1.686
Buckle 1	41	14.6	14.6
Buckle 2	45	16	16
Buckle 3	47.8	17	17

	ALU	E-GLASS	S-GLASS
Safety factor	1.86	1.523	1.59
Frequency and deformation 1	0/1.4	0/1.42	0/.89
Frequency and deformation 2	0/2	0/2.09	0/1.22
Frequency and deformation 3	7.27e-4/2.3	7.27e-4/2.3	0/1.343
Frequency and deformation 4			1.18e-3/1.131

6) *Results of Oval Section*

oval	ALU	E-GLASS	S-GLASS
Stress	670	671.9	549.78
Strain	.0033	.0095	.0077
Deformation	1.917	5.424	4.43
Buckle 1	29.4	10.48	12.8
Buckle 2	34	12	14.8
Buckle 3	36	13	15.9

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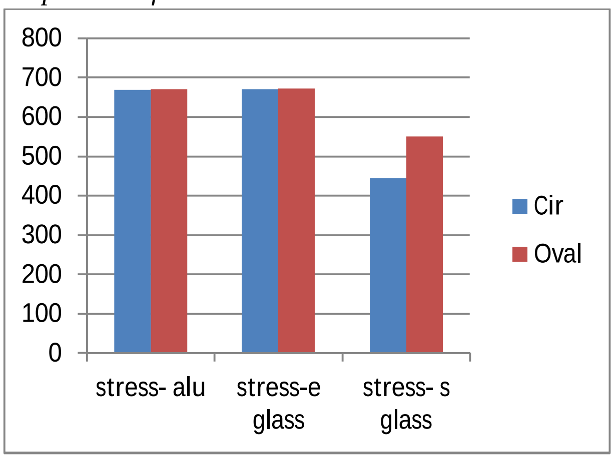
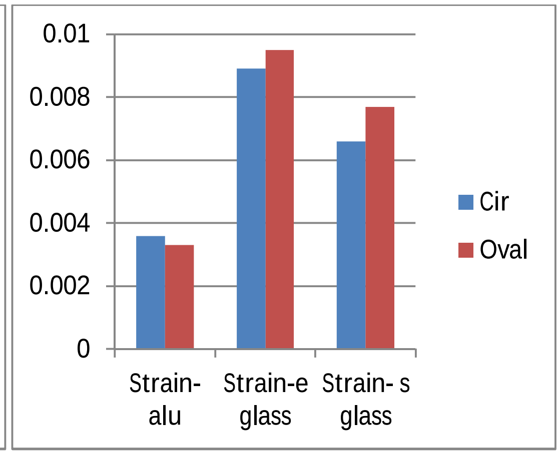
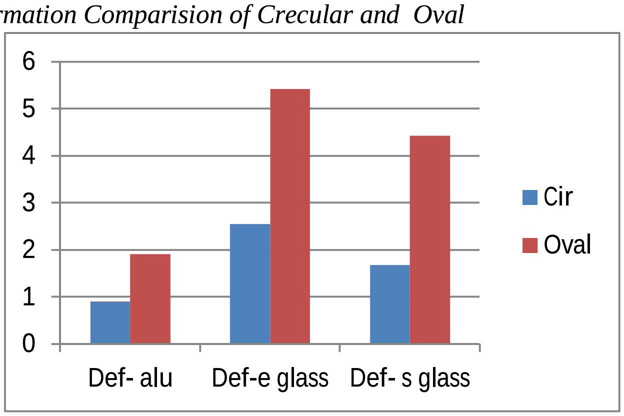
	ALU	E-GLASS	S-GLASS
Safety factor	3	2.46	3.38
Frequency and deformation 1	0/1.77	0/1.77	0/1.1
Frequency and deformation 2	0/2.1	0/2.1	0.855
Frequency and deformation 3	2.26e-4/1.58	2.26e-4/1.58	4.13e-4/.99

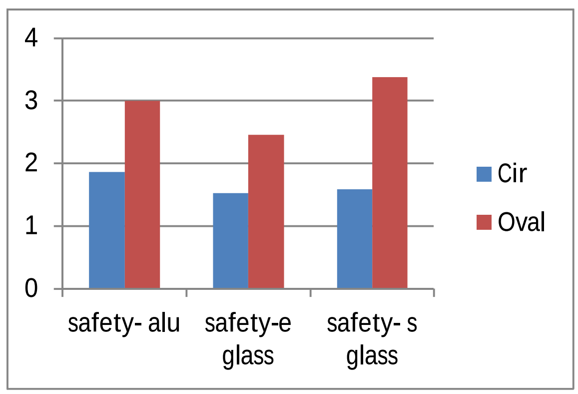
7) Stress Comparision of Circular and Oval



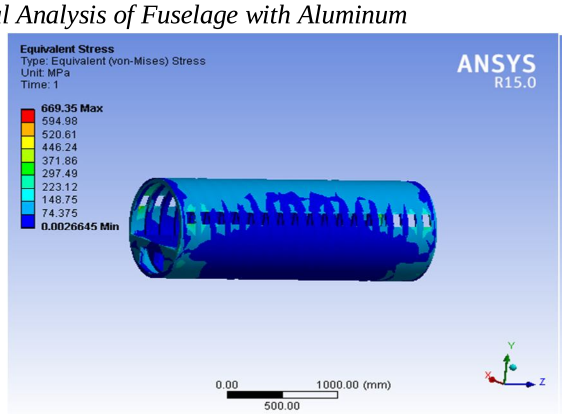


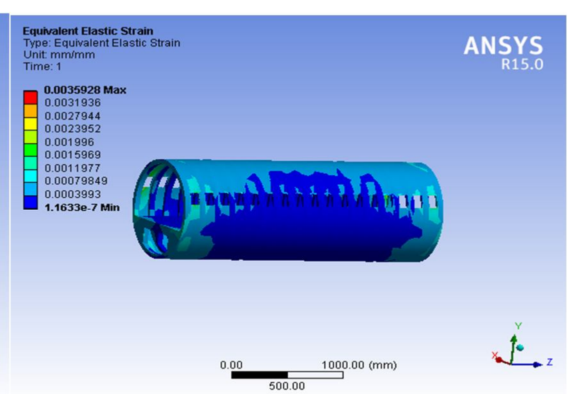
8) Deformation Comparision of Crecular and Oval



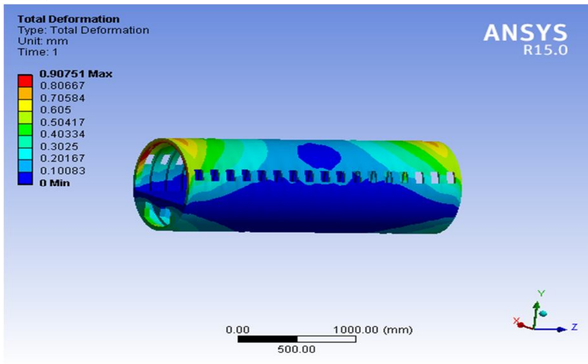


9) Structural Analysis of Fuselage with Aluminum

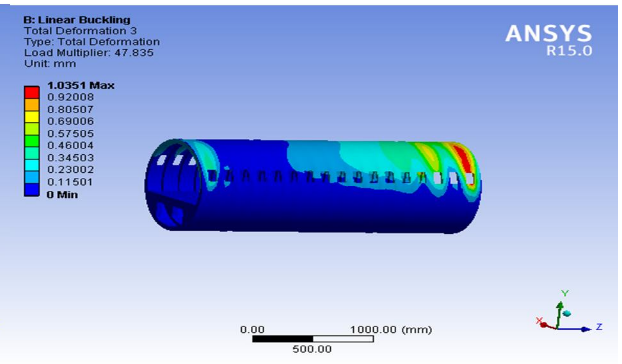




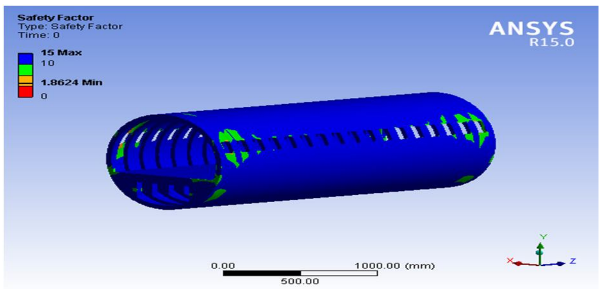
Von-misses stress (669.35 MPa)Strain (.00359)



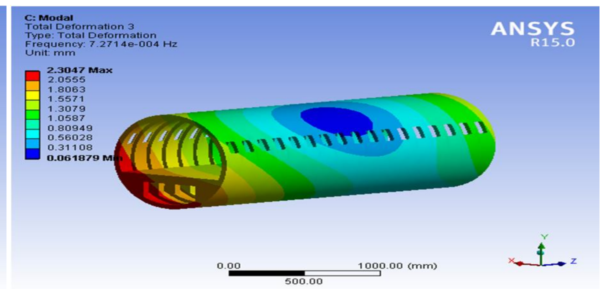
Total Deformation



Buckle value at mode 3

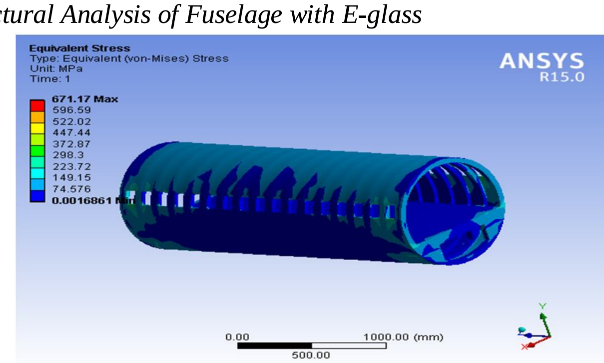


Safety factors on object

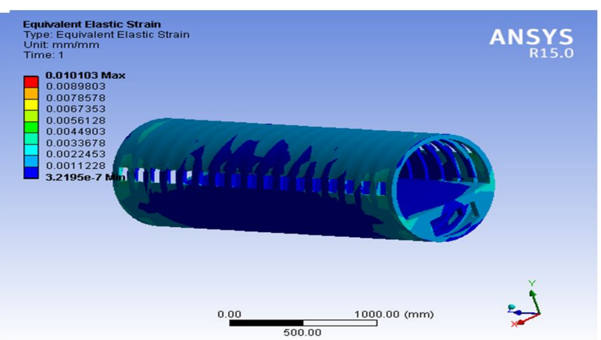


Natural frequency 7.2714Hz

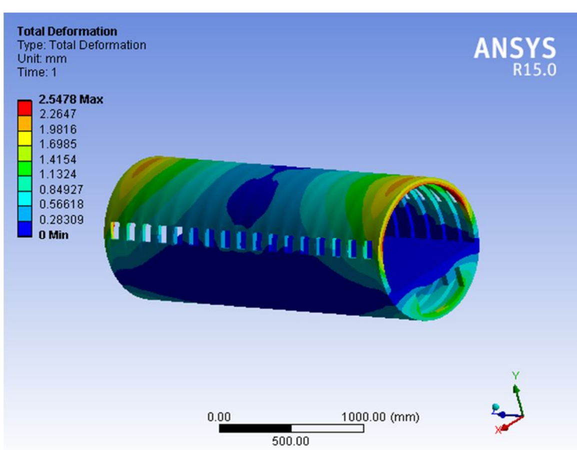
10) Structural Analysis of Fuselage with E-glass



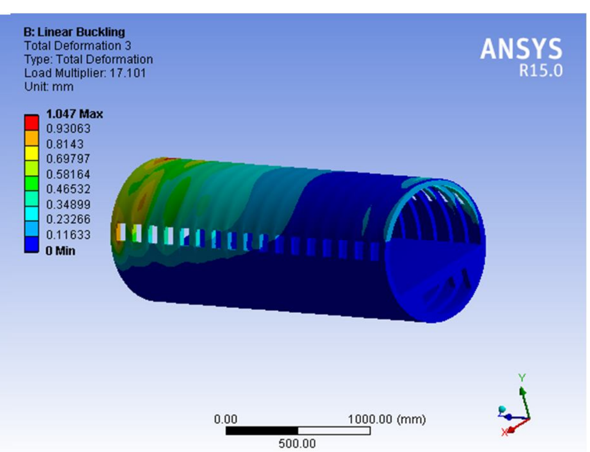
Von-misses stress (671 MPa)



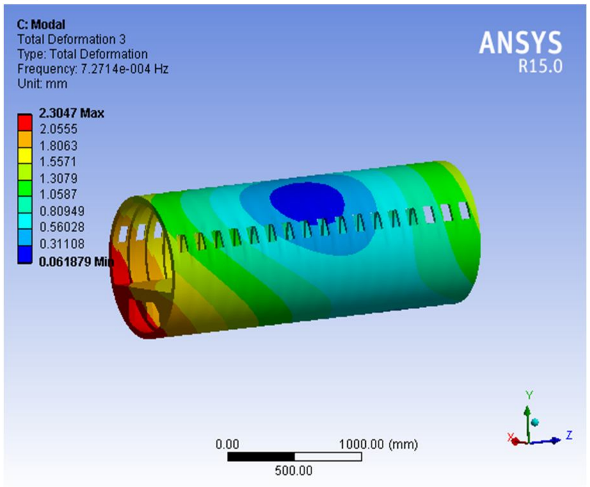
Strain (.0089)



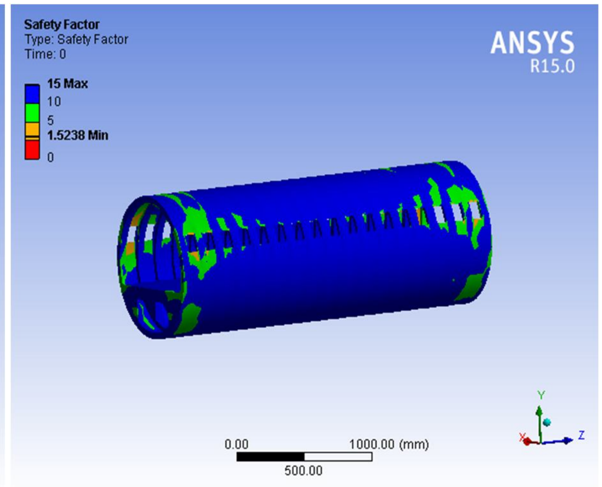
Total Deformation



Buckle value at mode 3

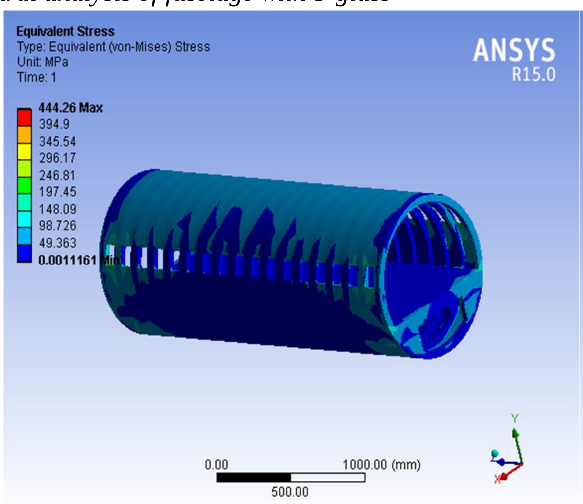


Total Deformation

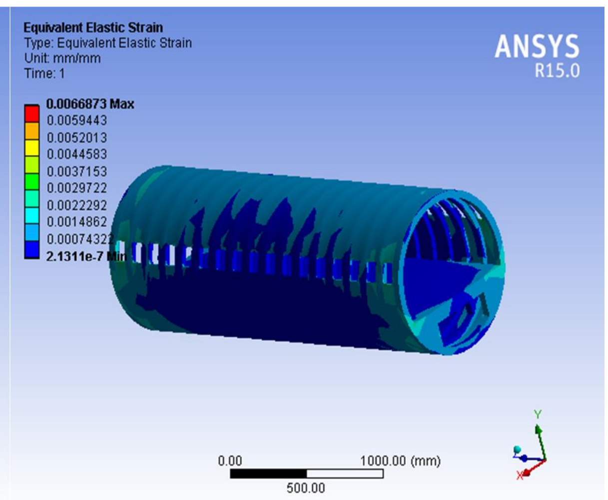


Safety factors

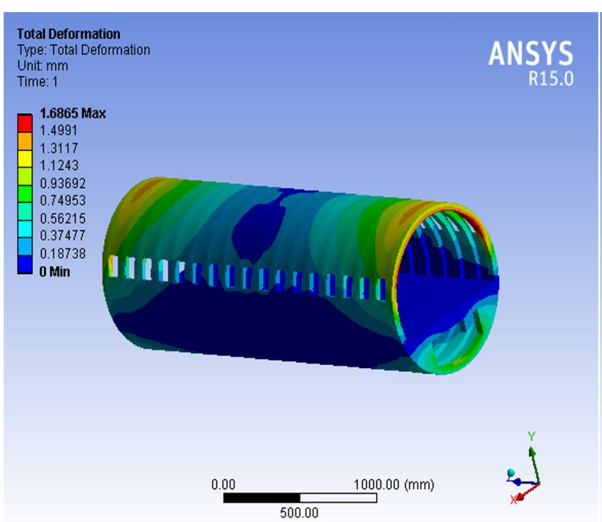
11) Structural analysis of fuselage with S-glass



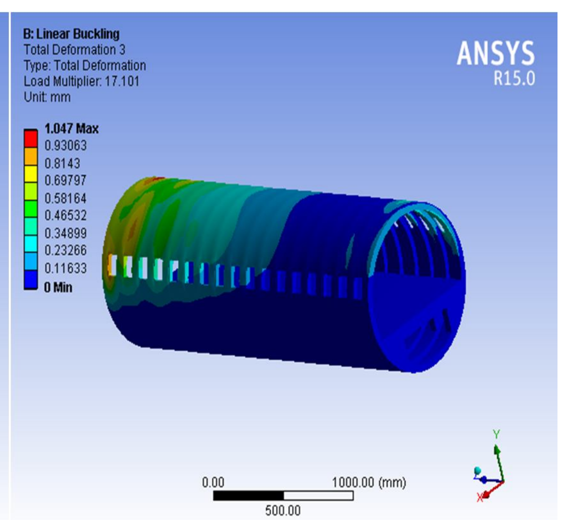
Von-misses stress (444.26 MPa)



Strain (.0066)



Total Deformation1.686mm



Buckle value at mode 3

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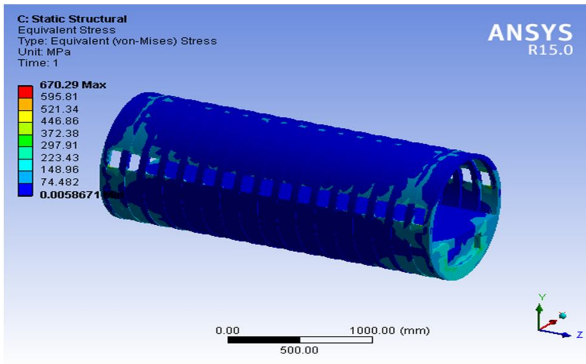
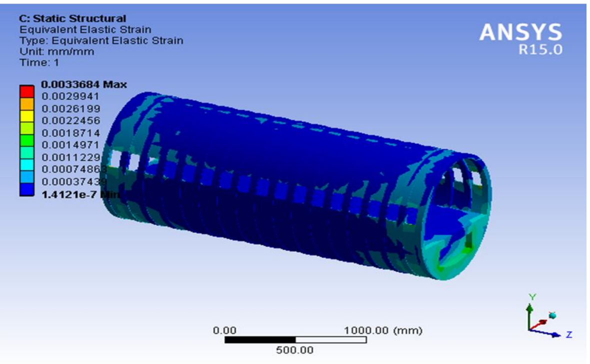
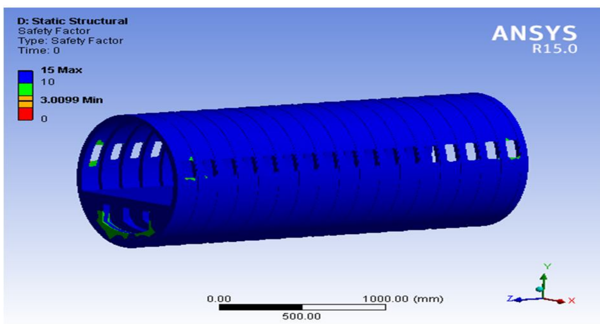
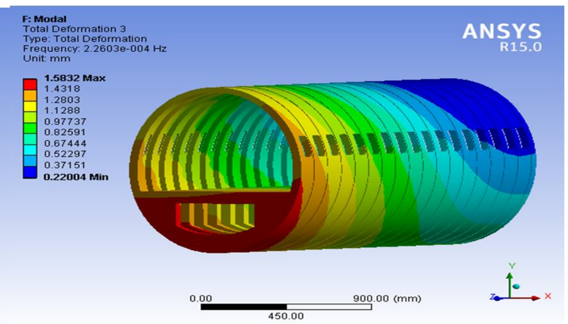
12) Structural Analysis of Fuselage with Aluminium Geometry Shape- Oval





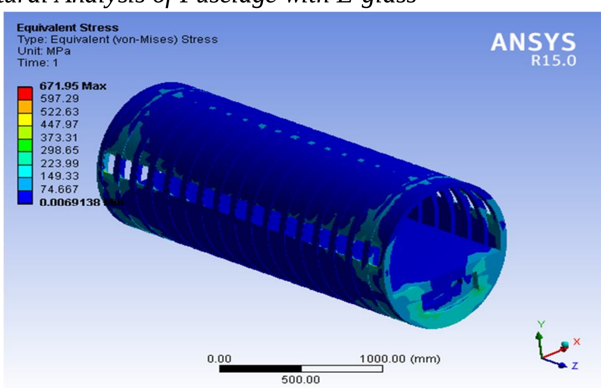
Von-misses stress (670MPa) Strain (.0033)

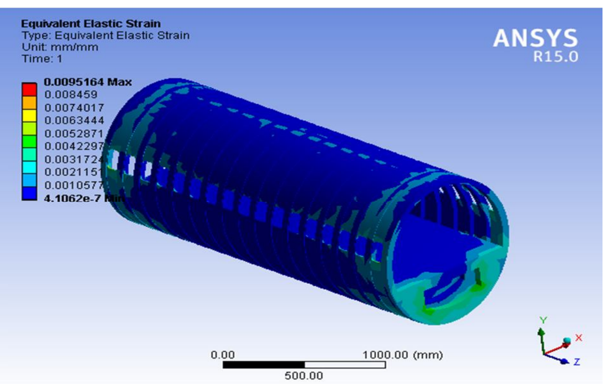




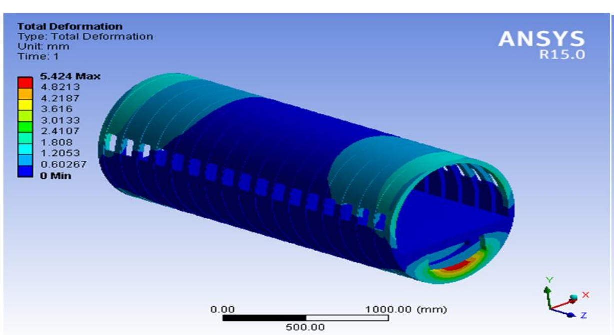
Safety factors for oval geometry Natural frequency for oval geometry

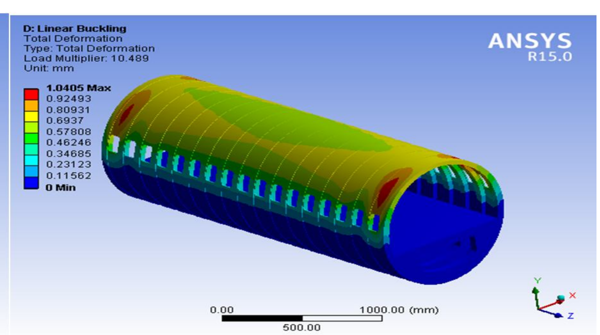
13) Structural Analysis of Fuselage with E-glass





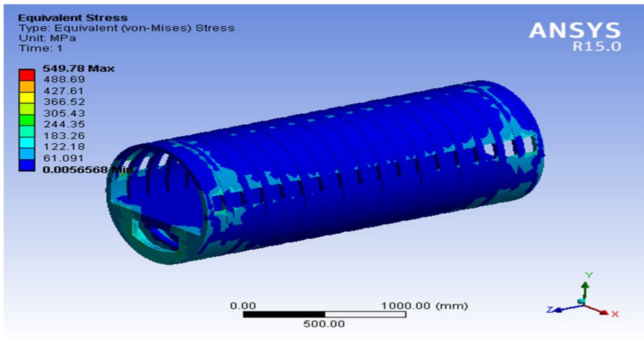
Von-misses stress (671.9MPa) Strain (.0095)

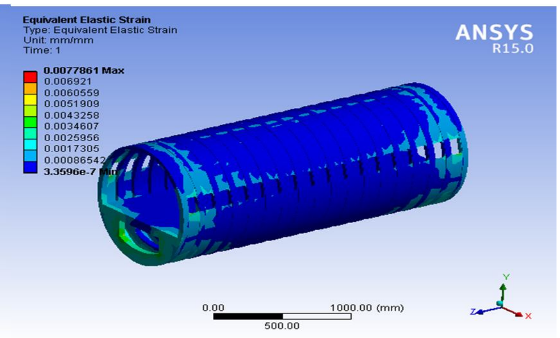




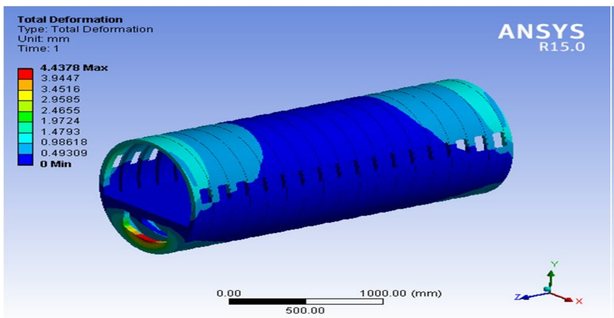
Total Deformation (5.424)Buckle value at mode 1

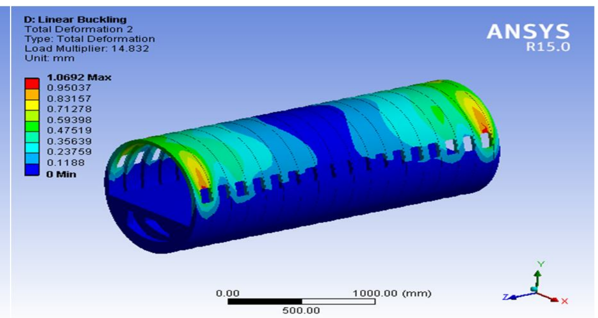
14) Structural Analysis of Fuselage with S-glass





Von-misses stress (549.78) Strain (.0077)





Total Deformation (4.43)Buckle value at mode 2

III. CONCLUSION

This thesis work is to provide optimum solution for fuselage manufacturing by reducing weight efforts and by improving structural strength; hear in this theses composite materials and the shape of fuselage has been studied.

In the previous papers they have studied vibrations in composite materials and proved that carbon epoxy's can be used for fuselage manufacturing and various shapes have been studied. Hear in this work previous research (base paper) analysis also conducted to verify current work error percentage as per the obtained results the error % between previous and current analysis about .3% only.

In our theses structural, fatigue, buckle and vibrational behavior has been studied with changes in shape and material to suggest optimum shape and material for fuselage. As per the obtained results both shapes has nearest value variations only; but while considering safety factor value better to use oval instead of pure circular shape to ensure maximum/ optimum quality, and s-Glass epoxy will be the best option for fuselage than compare to Aluminum-7075 and E-Glass epoxy

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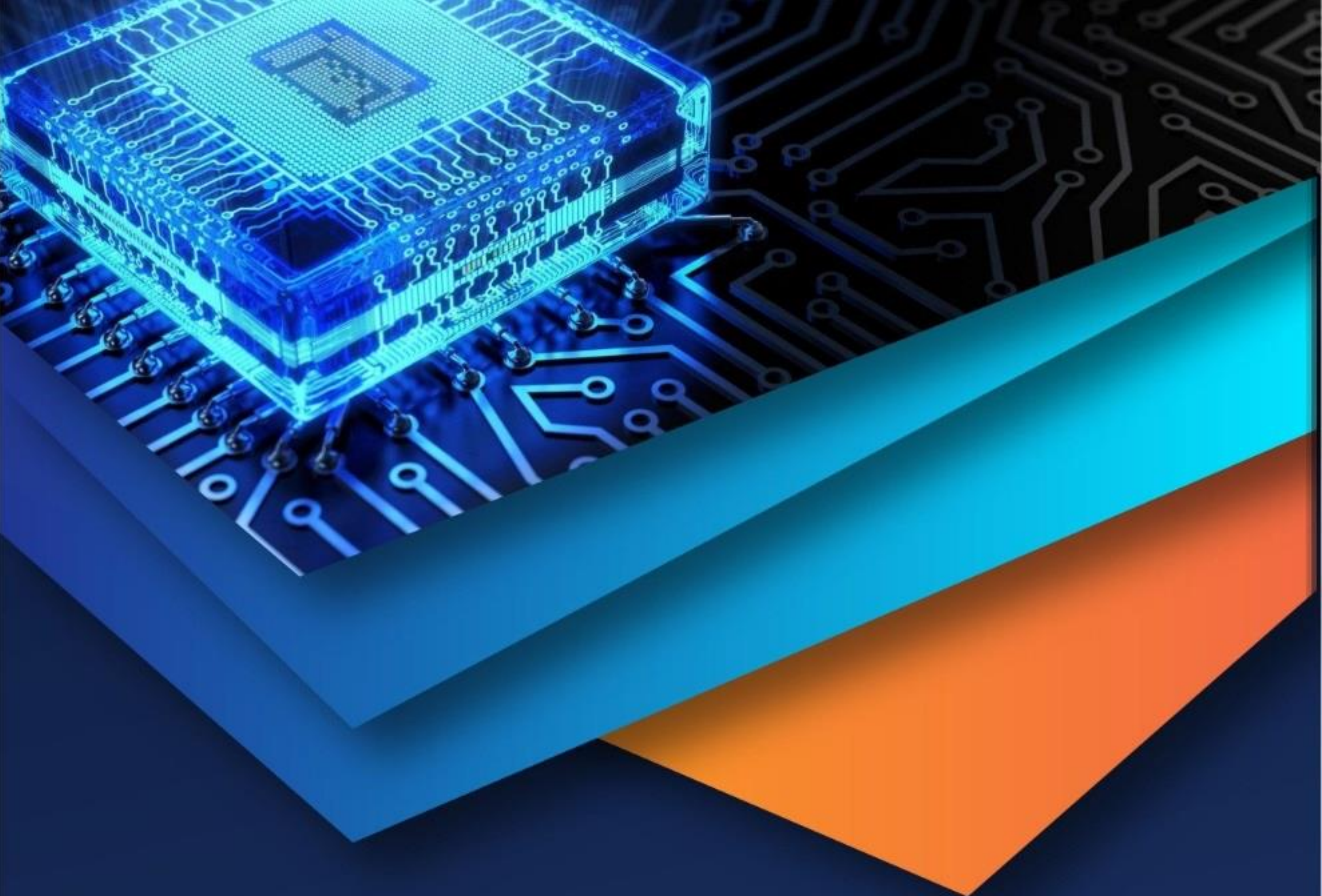

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