Design and Study of Different Parameters of A Submarine Radome By Using ANSYS

Ch. John Marie Britto[1], S. Vijaya Kumar[2]
[1]PG Student in CAD/CAM, Department of Mechanical Engineering, KSRM College of Engineering, Kadapa.
[2]Assistant Professor, Department of Mechanical Engineering, KSRM College of Engineering, Kadapa.

Abstract: Radomes are the electromagnetic windows that shield the microwave sub-systems from the environmental effects. The major requirement of a Radome is its transparent nature to microwaves and for most of the cases mechanical properties are also equally important. A Radome has to withstand high water pressures for underwater applications. Composite materials due to their high strength to weight ratio, high stiffness and better corrosion resistance are potential source for underwater applications. The concept of 'tailoring' the material properties to suit the Radome is attained by selecting proper reinforcement, resin matrix and their compositions. The mechanical properties of composite material are evaluated by testing specimens as per ASTM standards and the modulus properties are calculated using classical theories of composite materials which are utilized in designing of Radome. The designing of the radome is done by SolidWorks design software. ANSYS a Finite Element software package is used to analyze the problem. The Static structural Analysis is carried using the calculated theoretical pressure that is applied on the Radome. The Radome is also carried out modal analysis to check for the different frequencies of the Radome. Here, three different types of materials are used for comparing the various parameters such as deformation, stress and strain and frequencies.

Keywords: Radome, FRP's, Water pressure, Hoop stress.

I. INTRODUCTION

Radome (short form for Radar Dome) is an electromagnetic window, which acts as a protective shell for high precision and sensible electronic components, such as antennas, to keep their structure, temperature resistance, aerodynamic and electromagnetic performances. In other words, a Radome is a covering over the antenna protecting it from hard environments and conditions, such as strong wind, rain or snow, hailstone, high or low temperature etc., without its electrical characteristics. It is a component that surrounds electrical, structural and material sciences.

Basically, these are defined on the basis of the platform on which they are mounted such as airborne, ship bourne, ship bourne and ground based. Airbourne Radomes have to withstand severe aerodynamic loads, temperature gradients, rain corrosion, precipitation impact and high altitudes. Ground-based Radomes have to meet different situations like dust, wind, high temperatures, and shocks, while ship borne Radomes have to withstand salt corrosion and fungus growth. In submarine Radomes, high water pressures of about 70 bars have to be withstood.

Hence, the environmental requirement plays an important role in the design of Radomes for various applications. Under ideal conditions, a Radome is a mechanical structure which is electrically invisible. This property mainly depends on matching its composition and materials composition to a particular application and the radio frequency range at which it is needs to work.

The Function of the Radome are as follows:

1. The Radome protects the installation from the deteriorating effects of environment and extends the durability of antenna and other equipment.
2. The overall performance of the antenna will be increased with the use of Radome.
3. A Radome helps to have overall economy and weight reduction.
4. A Radome permits the submarine borne antenna to function with good efficiency under high head of the water over the submarine.

II. LITERATURE REVIEW

Lachiram and G Shantaram [1] studied about the development of exposed hardware for underwater applications and arrived at the mechanical structures and their shape to be taken for underwater applications. Their work identified the fabrication processes of Radome as matched die moulding.

G.Gopal et al [2] studied about the usage of Finite Element Analysis for development of C-Sandwich Radome for under water applications and it also discussed the material selection for the Radomes. They used E-Glass Epoxy Resin as Radome material and the composite lay-up was laid as 0^o and 90^o which was giving the optimum strength of the fibres.

M.Madhusudhana Rao et al [3] studied about the failure of underwater shells subjected to high external pressure due to buckling and observed that the specific stiffness of the reinforcing fibre plays an important role and suggested high strength carbon epoxy shells with ultra-high modulus fibres in the thickness portion.

N.S Kumar et al [4] studied on the different forms of metals, alloys, ceramics, polymers and composites for fabricating different components or systems used in naval applications. They discussed about the use of polymers in the form paints, seals, washer, sonar encapsulant, hose, adhesives for various applications such as underwater weapons, submarine fire control systems.

III. INTRODUCTION TO COMPOSITES

Composite material is the combination of two or more materials with different properties and characteristics of the parent material. The composite material mainly contains two components namely reinforcement (fibre) and the matrix (resin). The fibre may be in form of continuous strand and roving, chopped strands, yarns, whiskers, mats etc., And the resin in viscous form withstand the fibres together and imparts strength to the fibre. Composites have many characteristics that are different from conventional engineering materials. They provide the material of choice for designers in variety of reasons including low weight, high stiffness, high strength, electrical conductivity (or non-conductivity), low thermal expansion, low or high rate of heat transfer and corrosion resistance. That means 'Tailoring design' of materials is possible.

In the beginning, balsa and plywood were used as material for Radomes. But due to their moisture absorption tendency they were not used later. Metals cannot be used as Radome materials because they are conductors of electricity which will absorb the transmitted electromagnetic waves by the antenna and they lack corrosive resistance. So Fibre Reinforced Plastics (FRP's) such as Glass, Carbon, Aramid etc., came into picture. Glass fibres are graded into many types depending on their properties. And carbon fibres are the known strongest fibres which have many advantages. Composite materials made from E-Glass fibres and epoxy resins have become very prominent as a Radome material due to its excellent transparency to microwaves and having good mechanical properties.

IV. AIM OF THE PROJECT

To develop a layered Sandwich FRP Radome which protects the electronic equipment from high water pressure and transparent to electromagnetic waves with the help of SolidWorks for designing & ANSYS Software for analysis. Also two types of materials FRP's epoxy (E-glass and Carbon) and their combination is used for studying the different parameters of the Radome.

V. DESIGNING OF RADOME

SolidWorks is a modern Computer Aided Design (CAD) program developed by Dassaults Systems, France. The Radome is modeled in SolidWorks with the standard dimensions that are considered from literature. The Radome is designed according to the dimensions that are considered in this particular case only. These may vary on the basis of the antenna size, its features, its application and installations present. Considering all these, the dimensions are to be specified.

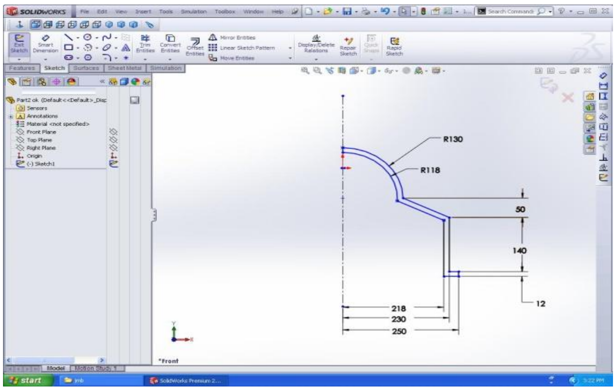


Fig 1. 2D drawing of the Radome

The half portion of Radome is drawn in any view and it is made to revolve about the axis.

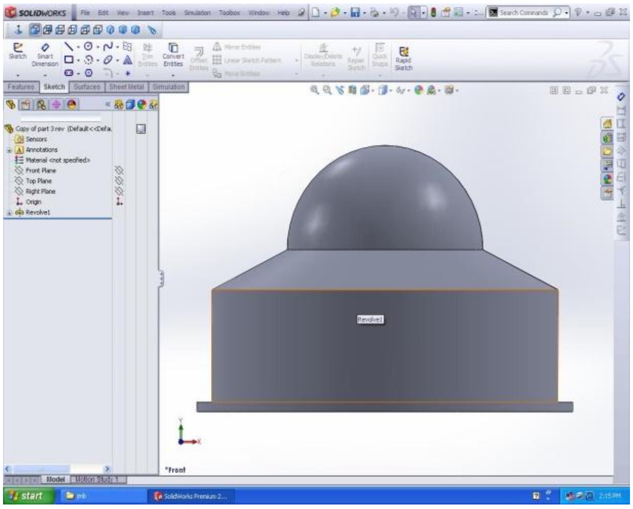


Fig 2. Revolved 3D model of the Radome

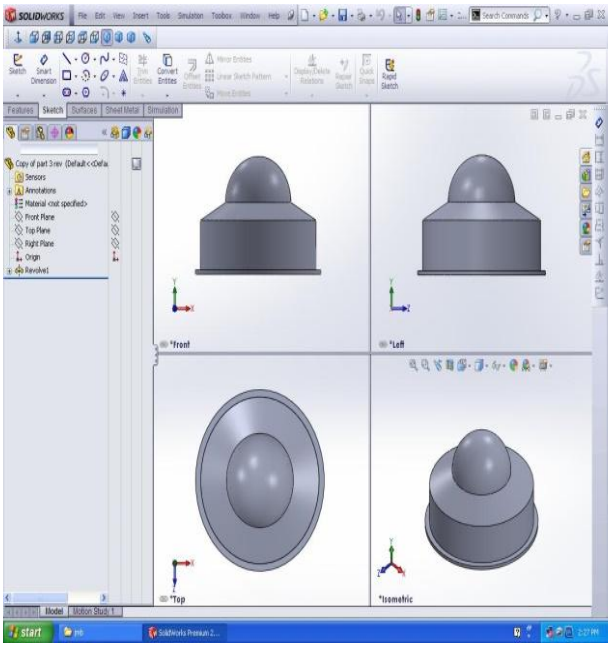


Fig 3. Different views of the Radome

VI. CALCULATIONS

LOAD CASES: The Radome is to be designed on the various loads it bears while operating. The various load cases considered are:

Case (i):Water head pressure acting on Radome (due to under water)

Water head Pressure acting on Radome (P) = ρgh

where ρ = Density of sea water = 1027 kg/m^3

g = Acceleration due to gravity = 9.8 m/s^2

h = Water head (depth at which object is immersed)

= 450 m (design)

Therefore, Pressure P = 45.337 bar

Case (ii): Pressure acting on Radome platform traveling under water at speed of 25 knots (i.e., at 12.866 m/s)

Water Pressure acting on Radome (P) = $C_d\ \rho\ V^2/2$

where C_d = Co-efficient of Drag = 0.5

ρ = Density of Sea water = 1027 Kg/m^3

V = 12.861 m/sec

Therefore, Pressure P = 0.42 bar

Case (iii): Pressure acting due to wind speed at 240 kmph (when object exposed to wind)

Wind Pressure acting on Radome (P) = $C_d\ \rho\ V^2/2$

where C_d = Co-efficient of Drag = 0.5

ρ = Density of Air at sea level = 1.225 Kg/m^3

V = 66.66 m/sec

Therefore, Pressure P = 0.0136 bar

From the above three load cases; water head pressure acting on Radome (due to under water) is more and predominant. Hence Radome is designed to withstand static water head pressure of 45.337 bar.

VII. ANALYSIS

Before doing the analysis on the Radome, it is designed in SolidWorks as a surface model and it is imported into the Ansys. And Static structural and Modal Analysis are done. The Following assumptions are made before analyzing the model.

1. Water pressure acting on the periphery of the Radome.
2. Material properties taken for Fibre/ Epoxy resin with fibre orientation of 0^o and 90^o
3. Mounting flange of Radome of assumed rigid body.

7.1 STATIC STRUCTURAL ANALYSIS:

The Radome is undergone to structural analysis by acting a pressure of 45.337 bar.

Material – E Glass Epoxy:

The orthotropic material properties of E-glass epoxy are considered for analysis.

Imported model:

Next, as these composites are orthotropic in nature, the complete model is built layer by layer by giving different orientations and thickness for each layer. This is done by giving thickness of 0.75mm to each layer with an orientation of 0^o and 90^o alternatively. And finally this completes the model.

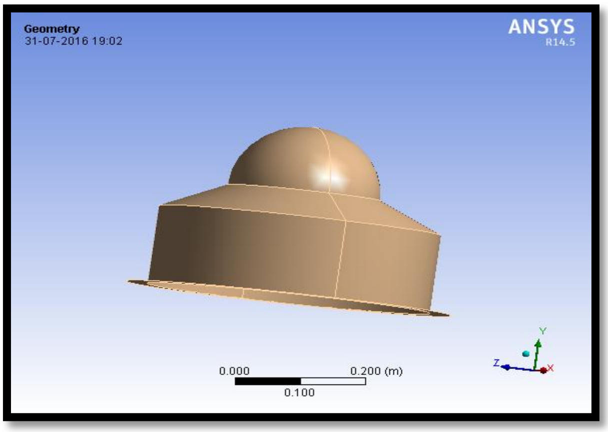


Fig 4. Imported model from SolidWorks

Meshed model:

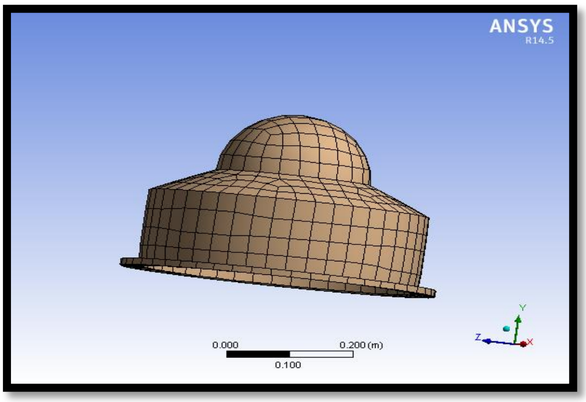


Fig 5. Meshed model

Fixed supported model:

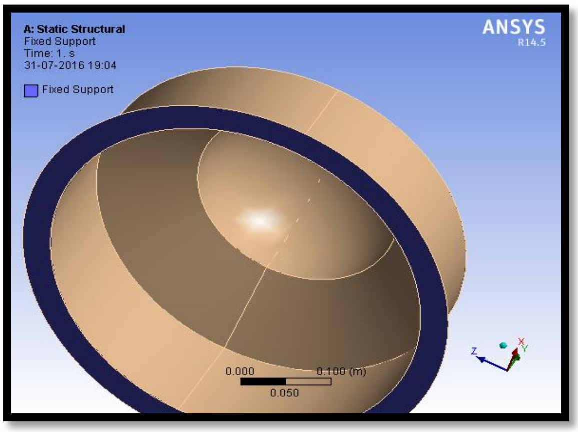


Fig 6. Fixing the Bottom part of the Radome

Pressure:

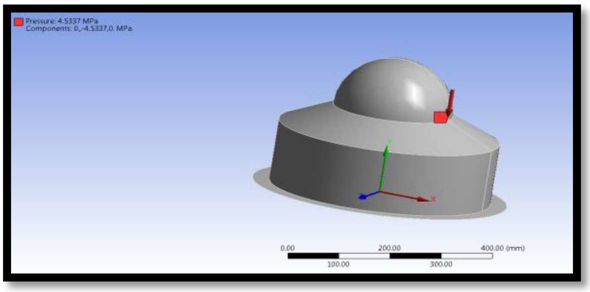


Fig 7. Applying pressure on the Radome

RESULTS FROM STRUCTURAL ANALYSIS:

The following results are be obtained from the analysis.

Deformation:

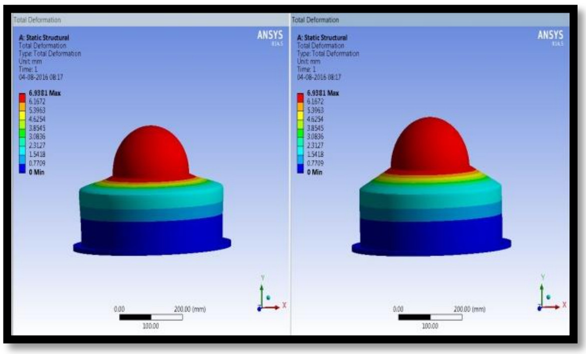


Fig 8. Deformation results for E-glass epoxy

Stress:

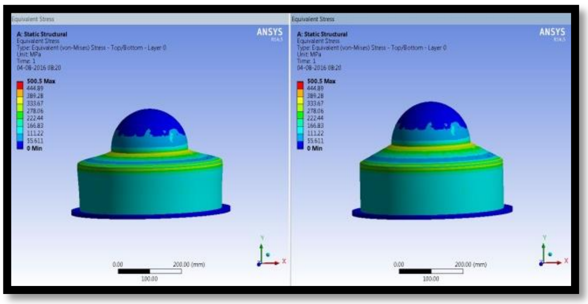


Fig 9. Stress results for E-glass epoxy

Strain:

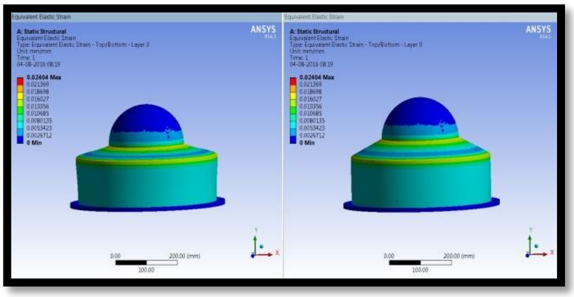


Fig 10. Strain results for E-glass epoxy

7.2 MODAL ANALYSIS:

This analysis is done to find the natural frequencies of Radome. And this is done without the application of any force or pressure on the Radome.

RESULTS FROM MODAL ANALYSIS:

Mode 1:

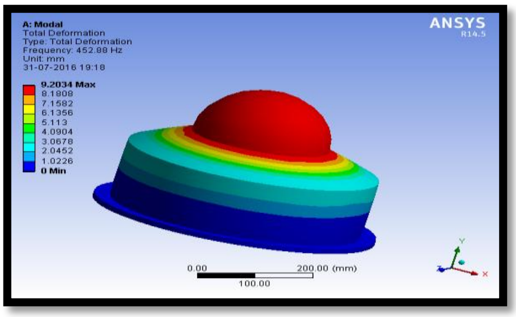


Fig 11. Frequency at Mode 1

Mode 2:

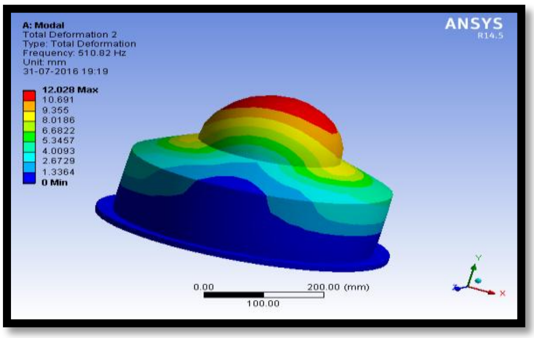


Fig 12. Frequency at Mode 2

Mode 3:

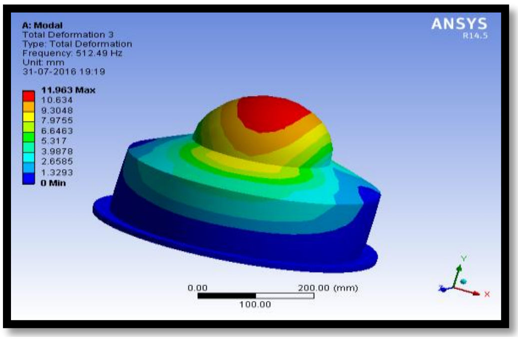


Fig 13. Frequency at Mode 3

Mode 4:

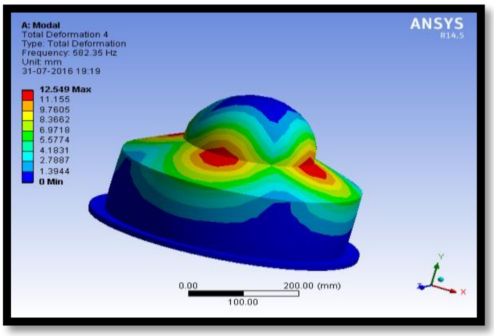


Fig 14. Frequency at Mode 4

Mode 5:

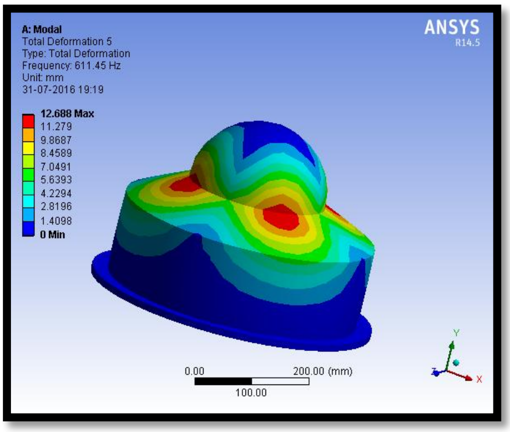


Fig 15. Frequency at Mode 5

In the same manner, the material properties of Carbon epoxy, and the combination of both E-glass and Carbon epoxy are considered and both Static Structural and Modal analysis are done. And the obtained results are tabled below.

VIII. RESULTS AND DISCUSSIONS

Result Table from Static Structural Analysis:

	Deformation (mm)	Stress (MPa)	Strain
Glass epoxy	6.9381	500.5	0.02404
Carbon epoxy	1.7272	580.79	0.0064736
Combination of E-glass and Carbon epoxy	2.3822	885.49	0.0064658

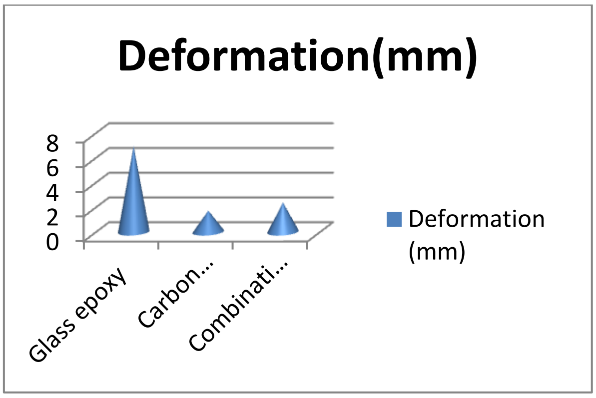
Result Table from Modal Analysis:

		E-glass epoxy	Carbon epoxy	Combination of E-glass and Carbon epoxy
Mode 1	Frequency (Hz)	452.88	1075.8	989.09
	Deformation(mm)	9.2034	16.537	15.328
Mode 2	Frequency (Hz)	510.82	1081.5	994.1
	Deformation(mm)	12.028	16.44	16.717
Mode 3	Frequency (Hz)	512.49	1438.5	999.76
	Deformation(mm)	11.963	26.465	17.895
Mode 4	Frequency (Hz)	582.35	1506.1	1005.4
	Deformation(mm)	12.549	27.09	15.401
Mode 5	Frequency (Hz)	611.45	1892.9	1007.7
	Deformation(mm)	12.688	15.857	15.394

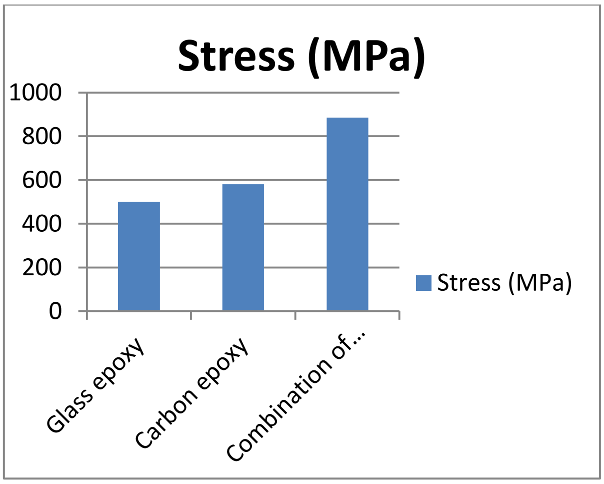
From the above Modal analysis result table, it is observed that the frequencies are increasing from Mode 1 to Mode 5 for every material. And the Deformations vary at each Mode, at those frequencies.

The different values that are obtained above from the analysis are plotted in graphs as shown.

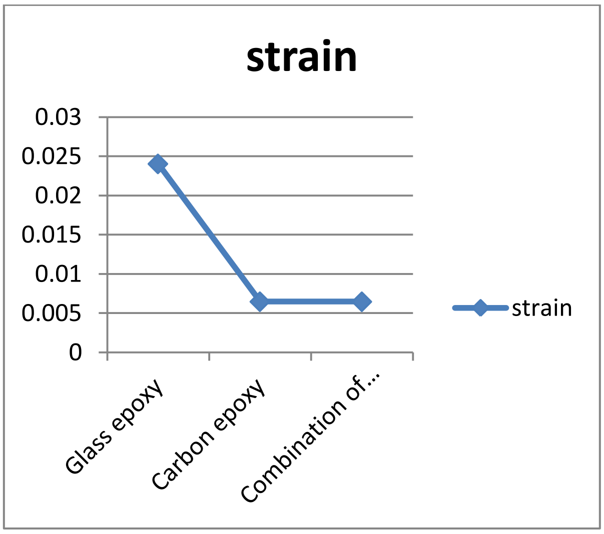
Graphs:



Graph 1. Comparisons between Composite materials with respect to Deformation



Graph 2. Comparisons between Composite materials with respect to Stress



Graph 3. Comparisons between Composite materials with respect to Strain

Comparisions:

Based upon the Static structural Analysis and the graphical representation of various materials the following comparisons are done:

1. For E-glass epoxy, the deformation is greater than the remaining two materials, and the stress observed is less than that of other materials. Also, the strain occurred is greater than Carbon Epoxy and their Combination.

2. The deformation occurred in Carbon Epoxy is very less and stress is medium when compared to the other materials. And the strain in the material is less than E-glass epoxy.

3. For combination of E-glass and Carbon epoxy, the deformation is medium and the stress is higher when compared to the E-glass and Carbon. The Strain is almost equal to the Carbon Epoxy.

4. The maximum deformation is occurred in E-glass epoxy (6.93mm) when compared to the Carbon epoxy and Combination of both. This deflection is occurred at the topmost portion (point) of the Radome.

5. The maximum stress is observed for combination of E-glass and Carbon epoxy. And whereas the maximum strain is occurred for E-glass epoxy.

IX. CONCLUSIONS

From the above Analysis of the Submarine Radome, the following conclusions can be made:

1. From the Structural Analysis, the stress values that are obtained considered to be in close agreement with the theoretical ones. Because in the analysis, the each and every orthotropic nature of the FRP is considered and whereas in theoretical it depends on specific parameters only according to the theory of classical mechanics. This is due to the reason that a vast amount of study is to be done on these composites.

2. From the comparison of materials, it is found that the E-glass is undergoing to least amount of stress when compared to the others at the same pressure. At present stage, it is better and appropriate to use it as Radome material and also because of its special property of transparency and dielectric nature. Here, by this further study it gives an ample scope of using Hybrid composites for more effective performance of the Radome electrically and mechanically.

3. The frequencies that are obtained for all materials are safe. Because the frequencies that are obtained are more than four times of the natural frequency of Submarine which is about 5-33 cycles/sec., (since the safety factor of Submarine is greater than four).

X. FUTURE SCOPE OF THE PROJECT

At present, Radomes are manufactured by using E-glass epoxy material. From this thesis, it is observed that the mechanical properties of the Radome can be increased by using Carbon epoxy and even by the combination of both.

This further leads to the scope of fabrication of newer composites by varying the fibre material in the process, also their weight fractions which further leads to the improvement of physical, mechanical and electrical properties which leads to new research.

A thorough literature search reveals that there are no systematic studies on mechanical properties of thermosetting composites. Based on this thesis, the data is useful for material technologists, mechanical engineers and defense engineering, to make use of this database for the generation of new materials for specific application.

REFERENCES

[1] Lachiram and G.Shantaram "Development exposed hardware for Underwater applications" Proceedings on Seminar Underwater Systems and Engineering (USE-2003), NSTL, Visakhapatnam, 2003.
[2] G.Gopal & Lachiram, "FEA and development of C-Sandwich Radome for underwater applications", International Conference on Recent Advances in Computer Aided Engineering, Hyderabad, 2006.
[3] M.Madhusudhana Rao & K.K.K Sanyasi Rao "Composite Materials for Underwater Applications" Proceedings on seminar Naval Materials Present and Future Trends, 2000.
[4] N.S.Kumar, G.P.Agrawal & C.G.S.Sarma "Compatible Properties of Materials for Naval applications" Proceedings on seminar Naval Materials Present and Future Trends, 2000.
[5] Cady WM, Karelitz MB, Louis A Turner, "Radar Scanners and Radomes", 1948.
[6] Bryan Harris "Engineering Composite Materials" The Institute of Materials, London, 2nd edition, 1999.
[7] Autar K.Kaw "Mechanics of Composite Materials", 2nd Edition, Publisher CRC Taylor & Francis, 2010.
[8] Dr. Gates PJ & Lynn NM "Ships, Submarines & the Sea" Vol.2, Brassey's (UK), 1990
[9] Bryan Harris, "Engineering Composite Materials" 2nd edition, 1999.
[10] Sun CT "Strength Analysis of Unidirectional Composite Laminates" Comprehensive Composites Materials, Vol 1, Elsevier, 2000.
[11] Stephen P Timoshenko, James M Gere "Theory of Elastic Stability" 2nd edition, McGraw Hill Book Company, 1963