FEA AND DEVELOPMENT OF C-SANDWICH RADOME FOR UNDERWATER APPLICATIONS

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Abstract

C-Sandwich Radome is made of composite material, which is used to protect the antennas from hostile environmental conditions. The development of radomes for underwater application demands high strength structure, resistant to underwater severities and effective joint sealing to withstand high hydrostatic pressure. The shape, strength and construction of radomes have to satisfy electrical, structural and environmental requirements. Composite materials made from E-Glass as fibers, epoxy as resins and syntactic foam as core have become very popular as C-Sandwich radome materials due to its outstanding transparency to microwaves and good mechanical properties. The composite Radomes for underwater application are to be mounted on antenna housing unit to cover antenna systems. Composite Radomes with different type of configuration was developed. The preliminary design was carried out using classical method. FEA (Finite Element Analysis) was performed to investigate the structural requirement and select the best-suited configuration of the radome. The difficulties in manufacturing of radomes have been overcome by adopting different fabrication techniques and systematic process planning. The developed radomes were subjected to established pressure testing to investigate the structural requirement and select the best-suited configuration. This paper mainly deals the FEA, manufacturing aspects and pressure testing of C-Sandwich radome for underwater applications.

Keywords: *C-Sandwich, Radome, Finite Element Analysis (FEA), Pressure Testing*

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1. INTRODUCTION

Radome *(RAdar DOME)* is a protective dome which guards the Antennas of an Electronic Communication System from the outside environment. The Radome should be able to withstand various external loads and conditions and is to be transparent to the Electro Magnetic Waves. The transparency requirement is the main reason why metals are not suitable for making Radomes. The radome material should cause less electrical characteristics distortion with minimum bore sight error, lower absorption and transmission losses. Composites of glass fibers and epoxy are being used for Radome Manufacture.

Development of radomes for underwater systems is a challenging task. It requires proper care and execution right from material selection to design, analysis, and manufacturing process, testing and proving [1]. In an underwater application, the Radomes are subjected to high hydrostatic pressure and saline corrosive environment. While the strength of the Radome is directly proportional to the thickness of the radome, its electrical transparency is inversely proportional. Hence, for an underwater Radome, thickness and shape optimization together with the selection of construction is an important task to meet its functional requirement. Proper seal preparation also holds the key for providing leak proof joints at the interfaces.

The subsequent sections cover the development of Radomes for antenna systems with the finite element analysis and design validation by pressure testing.

2. CONSTRUCTION DETAILS

The construction of radome is influenced by the type of antenna which is required to be protected from environmental hazards. The developed radome needs to cover antenna arrays operating in microwave broad band frequency range. In theory, high frequency antenna arrays demands less thick radomes. A solid-wall construction would result in thick wall thickness to withstand the design pressure which would degrade the performance of the antennas. Hence it is inevitable to reduce the radome thickness. However, a thin wall radome will fail in a high pressure environment. So, a thicker Radome with a 'C' Sandwich construction (Two cores of porous material having di-electric constant almost equivalent to that of air and three dense skins [2,3] as shown in Figure 1 is designed.

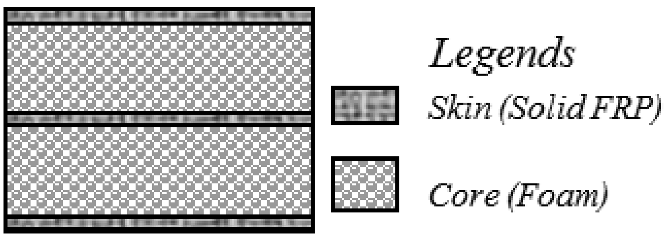

Fig 1'C' Sandwich Construction

The skin material used is made of E-Glass / Epoxy laminate and the core material is syntactic foam / epoxy.

A hemispherical geometry withstands the external pressure better than a flat surface. In order to further strengthen the structure, the geometry of Radome is optimized by selecting a semi-cylindrical structure. The curvature of the Radome is decided considering the viewing angle of the antenna array. The sectional view of the Radome is shown in Figure 2.

Fig 2 Cross Section of ‘C’ Sandwich Radome

3. FEA OF RADOMES

The FEA (Finite Element Analysis) of radomes was carried out using Ansys software. C-sandwich radome modeled using sandwich shell element. $0^o/90^o$ plain weave cloth has been approximated as combination of unidirectional laminas with fiber orientation at $0^o/90^o$[4] to carry out the finite element analysis. The uniform pressure is applied on top face of the element and fixed boundary conditions applied at mounting surface. Mechanical properties evaluated conducting tests on standard test specimens of composite material are used in analyzing the problem and results extracted after post processing. Analysis of flat and Semi-cylinder radomes were conducted to compare the effect of geometry on structural strength. The finite element models of the Radomes are shown in Figure 3(a, b).

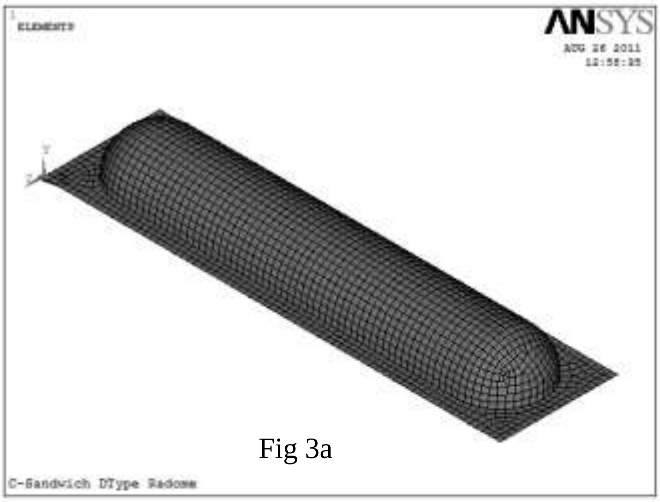

Fig 3a

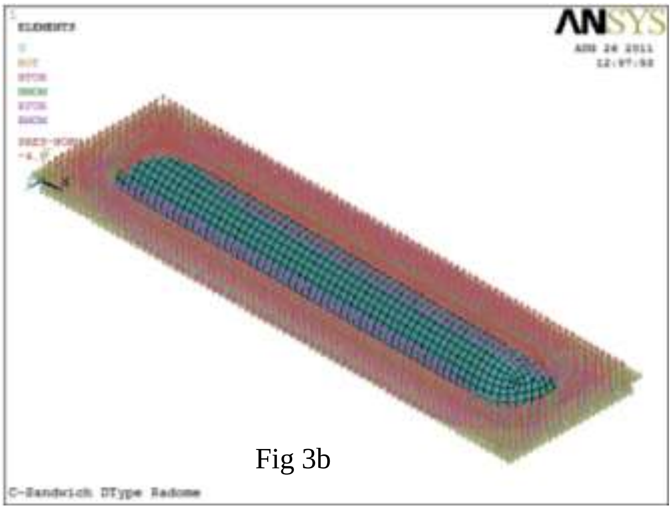

Fig 3b

Fig 3 (a, b) Finite Element models of Radome

4. MANUFACTURING OF RADOMES

The ‘C’ Sandwich radome was fabricated using E-glass as skin and syntactic foam as core material. Based on size and shape of radome, it was determined to fabricate by matched-die moulding method. The fabrication technique involves laying E- Glass cloth with resin over a male mandrel and applying pressure using a female mandrel. Three sets of mandrels are required for manufacture of this particular radome. The syntactic foam cores are hand laid and machined to shape. Machining was avoided on skins and flanges due to the chances of crack propagation and delaminating of layers. A titanium metal flange was provided to the radome, as the bottom surface requires machined and ground finish to achieve effective sealing. Titanium was machined giving continuous feeds using sharp tools. Due to chemical reactivity of titanium material, low cutting speed, high feed rate and large amount of cutting fluid used. The flatness required for radome FRP surface and on titanium flange has been achieved by adopting proper tooling and fixtures.

The metal ring may be embedded with radome using epoxy resin. But the epoxy bond being brittle in nature is likely to crack over a period of time. In order to achieve more positive joint between metal and nonmetal, the mechanical joint was intended. The metal flange was fastened to the radome by providing ‘O’ ring between the joint. In addition rubber sealant was applied between the joint, to provide leak proof sealing.

Clear polyurethane coat was applied over the radomes to avoid water absorption.

5. PRESSURE TESTING

The developed Radomes were subjected to pressure testing to check the structural integrity. The radome is mounted on a dummy plate along with the gaskets. Prior to the pressure test, a leak test of joints is conducted. The external pressure test is then conducted by keeping the assembly in a pressure testing chamber as shown in Figure 4. The assembly is subjected to a pressure testing cycle to determine the structural strength of the Radome and the effectiveness of joints. The external hydrostatic pressure tests carried by increasing the pressure at the rate of 4 bar/min in four equal stages, holding 3 minutes at each stage. After reaching the test pressure, unit under test is held for one hour duration. Destructive test is carried out by increasing pressure up to 1.5 times the test pressure and observed for one minute. Then external pressure was decreased to 1 atmosphere following the same sequence.

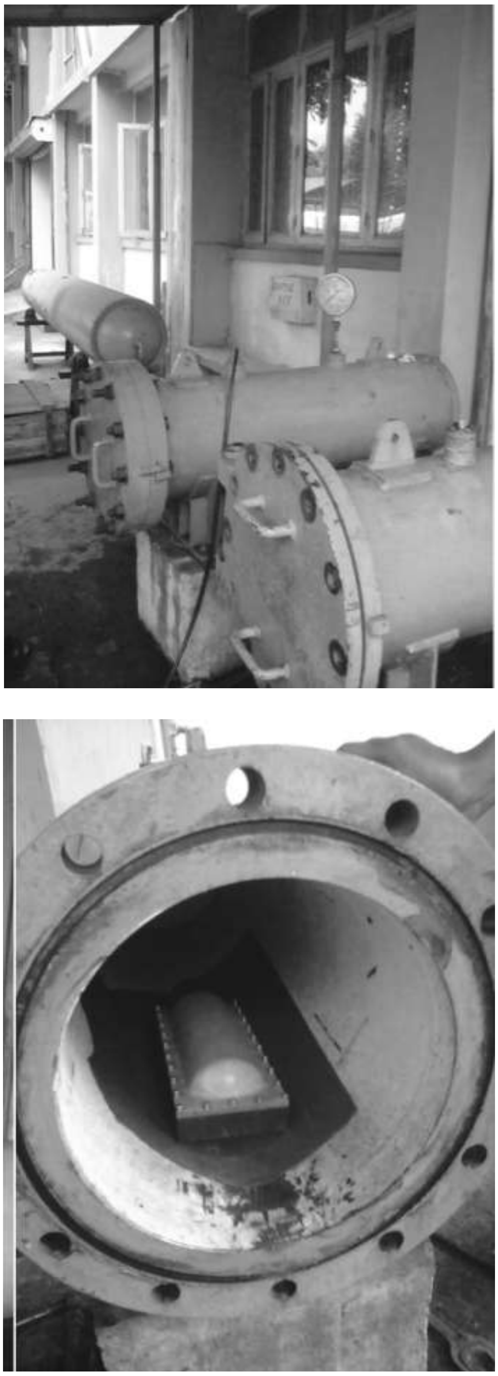

Fig 4 Pressure Testing Chamber

6. RESULTS AND DISCUSSIONS

The FE Analysis results of the C-Sandwich Radome are given in Figures 5 – 8.

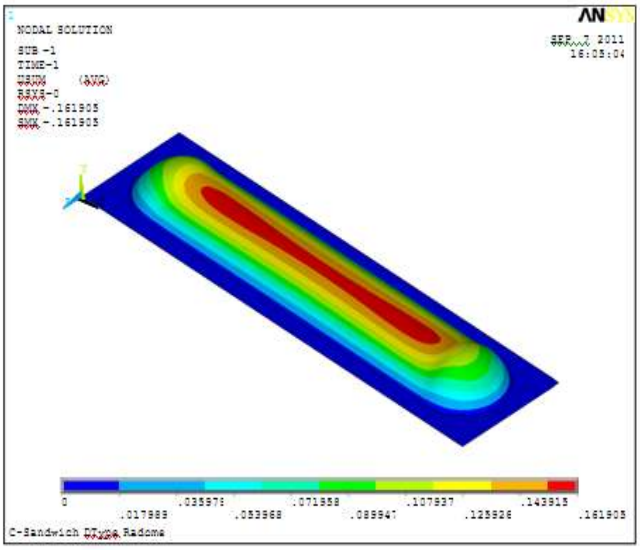

Fig 5 Displacement Contours (0.161 mm): Hemispherical D type Configuration Radome

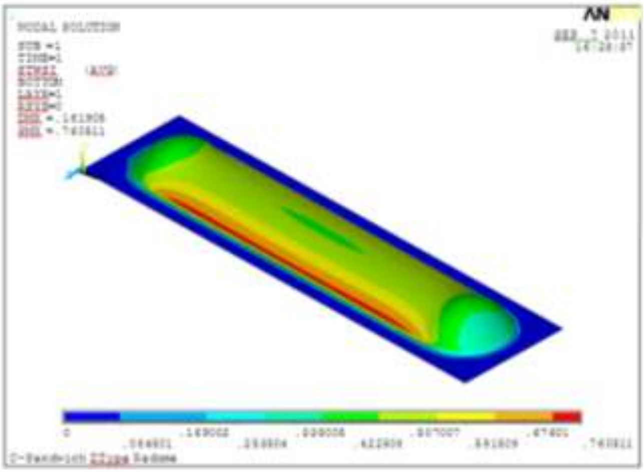

Fig 6 Tsai-Wu Strength Index (0.7605): Hemispherical D type Configuration radome

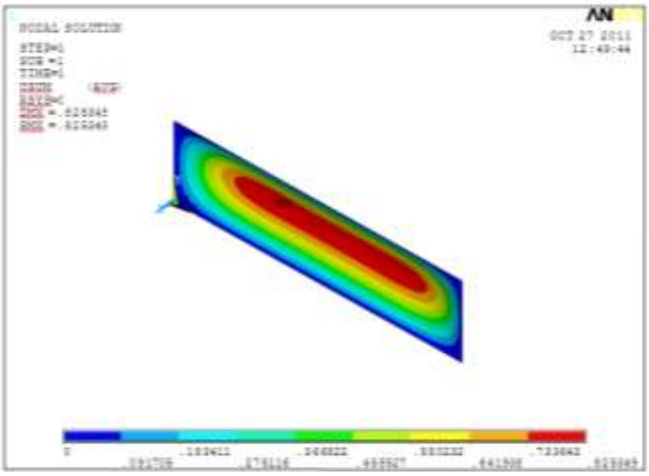

Fig 7 Displacement Contours (0.83 mm): Flat type Configuration Radome

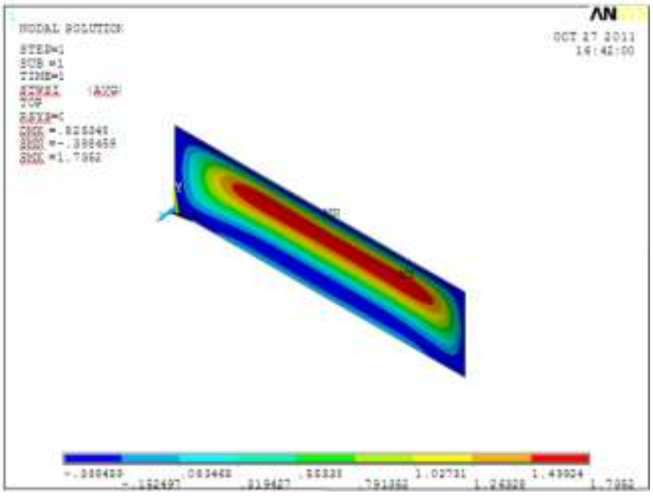

Fig 8 Tai-Wu Strength Index (1.73): Flat Configuration radome

The deformation of the flat radome as per FE Analysis result is 0.83mm. The maximum deformation in the case of flat configuration should be below 0.5 mm. If the deformation exceeds 0.5mm, the radome will come in direct contact with the antenna elements and cause its damage. Tsai-Wu Strength Index is an indicative of factor of Safety (1/Tsai-Wu Index) of composite materials. The inferred factor of safety of semi-cylindrical radome is 1.4 where as that of flat configuration is 0.57. The FE Analysis suggests that the semi-cylindrical configuration is well within safe limits. However, since the FE Analysis is an approximation and the strength of composites depends also on the manufacturing process, validation of the structural strength is to be carried out by pressure test. The semi-cylindrical 'C' sandwich radome withstood the pressure test successfully.

7. CONCLUSION

C-Sandwich construction of radome cross section is preferable from electrical point of view. To improve the structural strength, geometrical optimization plays an important role. A semi-cylindrical geometry is able to withstand the high hydrostatic pressure test successfully. Utmost care has to be taken in manufacturing of radomes to meet the stringent requirement of underwater application.

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