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Design, Development and Analysis of Doppler Weather Radom by using a bamboo composite sheet

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***Abstract* - The project goal was to Design, Development and Analysis of Doppler Weather Radom by using a bamboo composite sheet. Radar plays a significant role in managing air and sea transportation, monitoring a certain areas, surveying, remote sensing, predicting weather, and defense. To protect the Radar against environmental factors, a radome is required. The design of a Radome is in football shape by using longitudinal units of pieces/gore. The broad (13m dia.) flattened and circular because it often used to prevent ice and freezing rain from accumulating directly onto the metal surface of antennas. In the case of a spinning radar dish antenna, the radome also protects the antenna from debris and rotational irregularities due to wind. Its shape is easily identified by its hard-shell, which has strong properties against being damaged. A simple method of predicting the performance of a Radome is the use of Doppler Theory. In this method the Radome is divided into a number of longitudinal sections (orange peel) along the curve length and joint together with overlap joint. In comparison with fiberglass, PTFE-coated fabric, etc. materials with bamboo fiber sheet is very less cost, light weight and strong and stiff. So there will be huge difference in overall cost and performance. the radome made by bamboo sheet(BMB) is not only natural and bio-degradable, it manifests in many other advantages, including the frugality of the innovation. Both in meeting the design criteria and the structural analysis, it has been observed that the BMB based material fares very well and strongly recommended.**

***Key words*- Radome, Bamboo, Composite fiber, Doppler, Design, Analysis etc.**

I. INTRODUCTION

A radome (which is a portmanteau of **radar and dome**) is a structural, weatherproof enclosure that protects a microwave (e.g. radar) antenna. The radome is constructed of material that minimally attenuates the electromagnetic signal transmitted or received by the antenna. In other words, the radome is transparent to radar or radio waves. Radomes protect the antenna surfaces from weather and conceal antenna electronic equipment from public view. They also protect nearby personnel from being accidentally struck by quickly rotating antennas. Radomes can be constructed in several shapes (spherical, geodesic, planar, etc.) depending upon the particular application using various construction materials (fiberglass, PTFE-coated fabric, etc.).

Doppler Effect

The **Doppler Effect** (or **Doppler shift**) is the change in frequency of a wave for an observer moving relative to its source. It is named after the Austrian physicist Christian Doppler, who proposed it in 1842 in Prague. It is commonly heard when a vehicle sounding a siren or horn approaches, passes, and recedes from an observer. Compared to the emitted frequency, the received frequency is higher during the approach, identical at the instant of passing by, and lower during the recession.
In classical physics, where the speeds of source and the receiver relative to the medium are lower than the velocity of waves in the medium, the relationship between observed frequency f and emitted frequency f_0 is given by

$$f = \left(\frac{c + v_r}{c + v_s} \right) f_0$$

Where,
c is the velocity of waves in the medium;
v_r is the velocity of the receiver relative to the medium; positive if the receiver is moving towards the source (and negative in the other direction);
v_s is the velocity of the source relative to the medium; positive if the source is moving away from the receiver (and negative in the other direction).
The frequency is decreased if either is moving away from the other.
The above formula assumes that the source is either directly approaching or receding from the observer.

Radome Sizing

Radomes that have a spherical shape with a truncation or height usually between 80% and 90% of the radome's diameter. Radome diameter and truncation are primarily driven by antenna size and type. Although the exact radome size is determined by the

specific antenna, some basic assumptions can be made to aid in obtaining a rough radome size. For preliminary design estimates, the following assumptions may be used.
Antenna specific assumptions for radome diameter selection considerations:

- Prime Focus antenna - equal to 1.5 times the reflector diameter
- Offset Feed antenna - equal to 2.3 times the reflector diameter

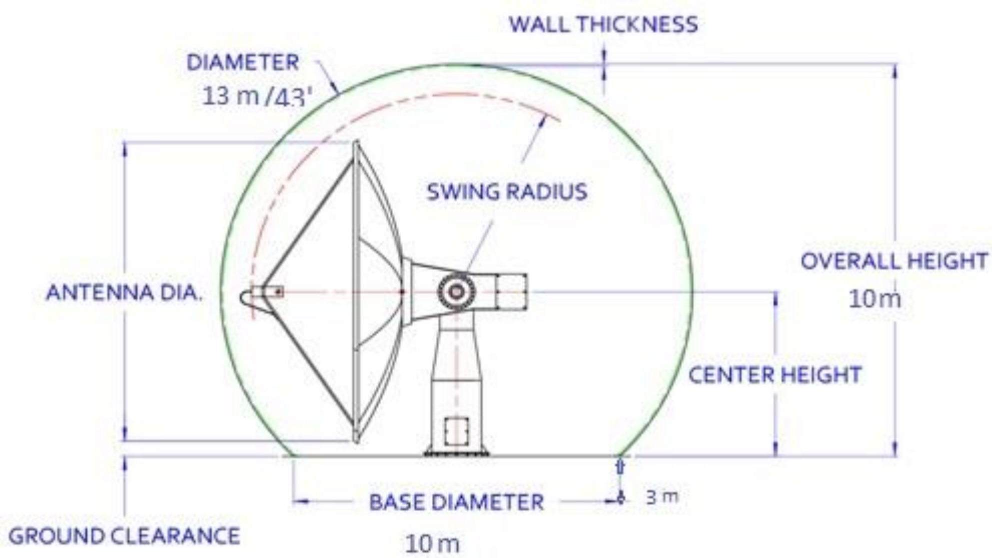

Figure 1: Radome sketch

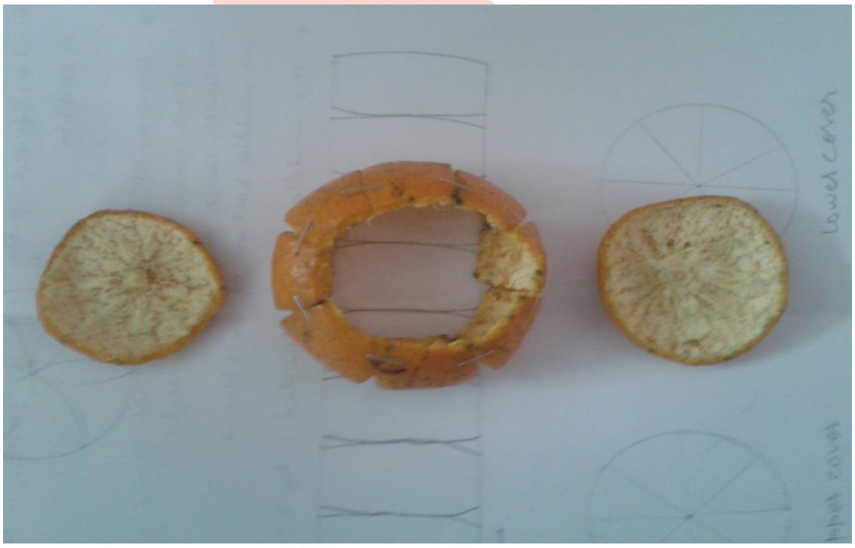

Figure 2: Top view of orange peel

Flat Pattern Development of Radome

Generative Shape Design is carried out and flat pattern is developed using CATIA V5 and SOLIDWORKS.
Sphere shape is selected for aerostat model. The diameter of spherical envelope is 13 m (6.5m Radius).The sphere is divided into 16 gores in longitudinal way as shown in Figure.

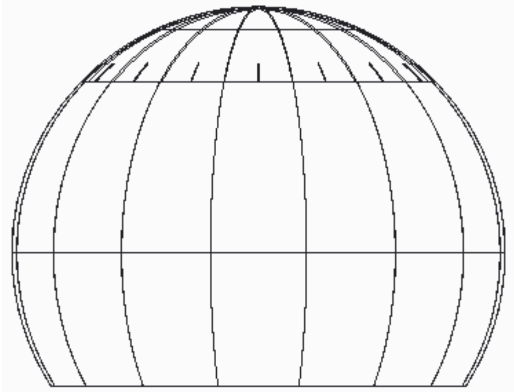

Figure 3: Longitudinal Sphere dome geometry

Criteria for flat pattern development

1) Maximum available width of fabric is 2.55 m, which is constrained for any panel.
2) To develop the flat pattern we have assumed a cut of 0.5 m diameter at nose.

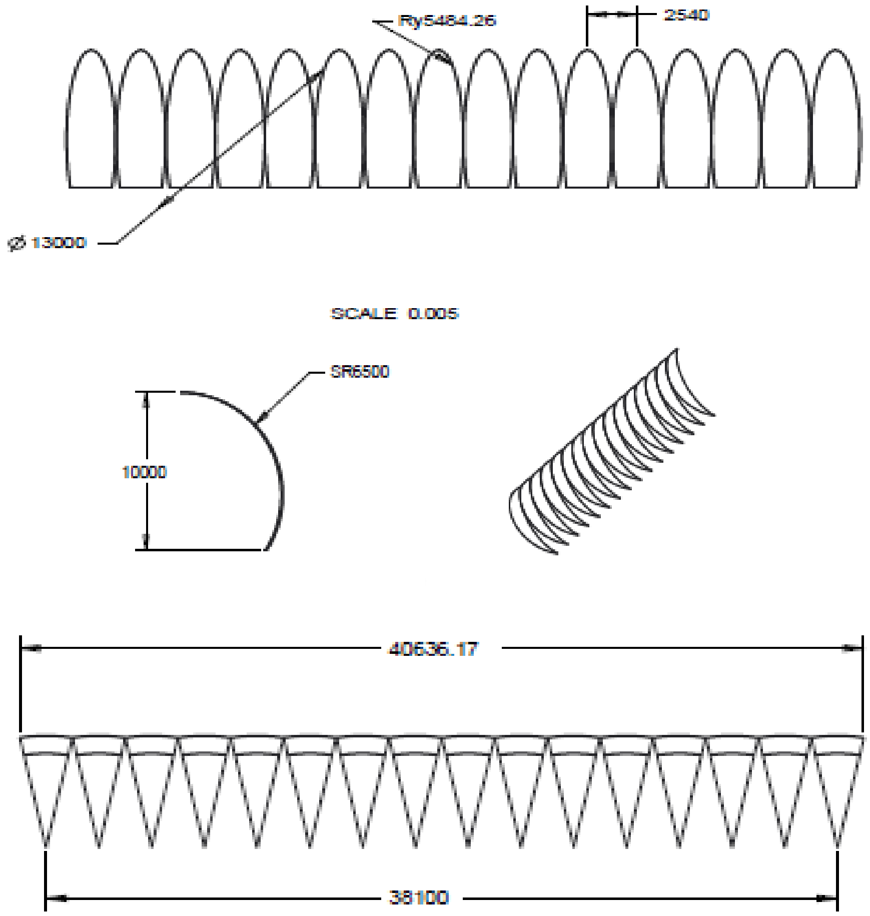

Figure 4: Flat pattern development of BMB radome

Calculation:

$Surface\ area\ of\ sphere\ A = 4\pi r^2$ ……………………… A= 530.92 m^2

$Volume\ of\ shphere\ V = \frac{4\pi r^3}{3}$ ……………………….V= 1150.34 m^3

Circumference of sphere C= π d ………………………C= 40.84 m

Length of each Gore L = ……………………….L=8+2 m

Bamboo and bamboo fiber reinforced composites

The diversity of bamboo is itself reflected by its number of species, there are roughly 1000 species of bamboo found word wide. Bamboo grows very fast rather it is better to say extremely fast growing grass. Since, ancient time's bamboo has been utilized in many Asian countries as well as South America for centuries.

Bamboo can be considered an ecological viable substitute for commonly used wood in many ways. Bamboo attains maturity in 3 years as compared to wood which takes almost more than 20 years. After maturity tensile strength of bamboo is comparable to mild steel. The growth rate of bamboo is unbelievable, the known fastest bamboo grows vertically two inches per hour and in some moso bamboo species the height of 60 feet is achieved only in 3 months, thus the cutting down this substitute wood would not affect the ecological balance at all. Trade for bamboo and bamboo products is growing very rapidly, the reason for market value of bamboo is shortage of wood production in many countries and bamboo is best option to substitute wood in terms of growth factor.

Table 1: Mechanical properties of bamboo fiber based reinforced composites.

S.No	Bamboo Fiber Based Biocomposites	Tensile Strength (Mpa)	Young's Modulus (Gpa)	Flexural Strength (Mpa)	Flexural Modulus (Mpa)
1	BF (30%) + PP	25.80 ± 60.37	1.357 ± 0.9	45.49 ± 0.88	2077 ± 4
2	BF (30%) + MA-g-PP	37.37 ± 0.47	1.37 ± 0.6	56.73 ± 0.49	2929 ± 5
3	BF + MA-PP	35.1 ± 2.42	4.69 ± 0.55	–	–
4	BF+EP	86.57	–	119.69	11901.11

5	BF+EP+NaOH	135	–	149	9500
6	BF+PE	126.2	2.48	128.5	3700
7	BF(30%)+HDPE	25.47	2.674	27.86	2911.7

BF = bamboo fiber; BS = bamboo strips; PP = polypropylene; MA-g-PP = maleic anhydride grafted polypropylene; EP = epoxy; PE = polyester; HDPE = high density polyethylene; IUP = Isophthalate unsaturated polyester resin.
The SEM studies revealed better dispersion of fiber into PVC matrix due to increased amount of coupling agents used. The enhancement in mechanical properties was also indication of strong bonding between matrix and bamboo fiber. The tensile strength and chemical resistance of bamboo fibers treated with alkali and coated with polystyrene and polyurethanes systems was carried out. The combination of different matrixes leads to increase in tensile properties and similar trend was observed in chemical resistance of bamboo composites.

Comparison of Bamboo Fiber Reinforced Composites with Conventional Composites

Bamboo fibers are well known for strong, stiff, inferior microfibrillar angle with the fiber axis and thicker cell wall and are considered as ‘‘nature’s glass fiber’’. The production of large quantity of synthetic fiber reinforced composite, e.g. glass/carbon fiber reinforced polymer composites, conventional composites and petroleum based plastics have posed serious threat to ecosystem.
Recently technology involved to process hybridization and reinforcement of bamboo fibers with glass, jute, oil palm, coir and other fibers compounding or mixing with matrices and fabricated advance composites with high mechanical and thermal properties. Researchers stated that bamboo fibers can replace up to 25 wt.% of glass fibers without lowering mechanical properties of glass fiber based composites. The thermal properties of hybrid composites were enhanced due to the presence of bamboo and glass fibers, and it attribute to hybridization effect and fiber/matrix interface bonding. Researchers studied the effect of alkali treatment of bamboo fiber on tensile properties and chemical resistance of individual and mixed bamboo–glass fiber reinforced composites. They revealed that mixing of fibers directly affect the tensile properties of composites. However, hybrid composites possessed better properties than bamboo fiber composites, which they ascribed due to the low amorphous cellulose components from bamboo fibers due to the strong acids and base treatment. In another previous work they reported fabrication of bamboo-glass composites, and studied flexural and compressive properties of bamboo-glass composites.

Table 2: Comparative Properties of Bamboo Fiber Based Reinforced Composites.

Comparative properties									
s.no			**Tensile strength (MPa)**	**Tensile modulus (GPa)**	**E (%)**	**Flexural strength (MPa)**	**Flexural modulus (GPa)**	**Density (kg/m3)**	**Specific heat (J/kg K)**
1	Fiber	BF	500–575	27–40	1.9–3.2	100–150	10–13	1200–1500	1000–1250
		GF	124–150	7–10	2.5–4.8	110–150	5–9	2350–2500	796–810
2	Composites	BF–EP Vf =65%	87–165	3–15	1.7–2.2	107–140	10–12	1160–1250	–
		GF–EP Vf = 65%	180–220	5–10	2.7–3.5	195–250	7–12	1960–2020	–

E = elongation at break; BF = bamboo fiber; GF = glass fiber; EP = epoxy; Vf = volume fraction (the ratio of fiber to matrix ratio V/v).

II. DESIGN

Design is the creation of a plan or convention for the construction of an object or a system (as in architectural blue prints, engineering drawings, business processes, circuit diagrams and sewing patterns). Design has different connotations in different fields (see design disciplines below). In some cases the direct construction of an object (as in pottery, engineering, management, cowboy coding and graphic design) is also considered to be design.
CATIA and SOLIDWORKS is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Creo Elements/Pro and NX (Unigraphics) and solid works.

Meshing Approach and Mesh

There are often some misunderstandings regarding structured/unstructured mesh, meshing algorithm and solver. A mesh may look like a structured mesh but may/may not have been created using a structured algorithm based tool. For e.g. GAMBIT is an unstructured meshing tool.
Therefore, even if it creates a mesh that looks like a structured (single or multi-block) mesh through pain-staking efforts in geometry decomposition, the algorithm employed was still an unstructured one. On top of it, most of the popular CFD tools like, ANSYS FLUENT, ANSYS CFX, Star CCM+, Open FOAM, etc. are unstructured solvers which can only work on an unstructured mesh even if we provide it with a structured looking mesh created using structured/unstructured algorithm based meshing tools. ANSYS ICEM CFD can generate both structured and unstructured meshes using structured or unstructured algorithms which can be given as inputs to structure as well as unstructured solvers, respectively.

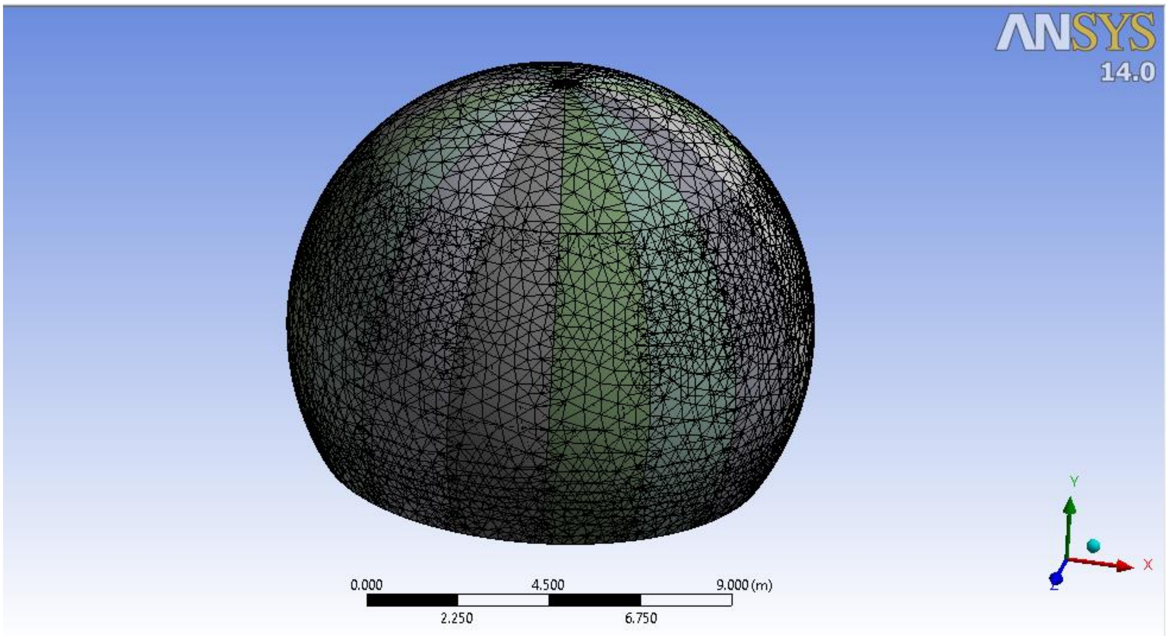

Figure 5: Mesh sketch of Radome

Table 3: Meshing Details

Object Name	*Mesh*
Defaults	
Physics Preference/ State	Mechanical/ Solved
Sizing	
Element Size	0.50 m
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	4.e-002 m
Inflation	
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Patch Conforming Options	
Triangle Surface Meshed	Program Controlled
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Defeaturing Tolerance	Default
Statistics	
Nodes	16224
Elements	1884

Result Comparison

Table 4: Compression between Bamboo & Composite fiber (CFR)

RESULT	BAMBOO	CFR	UNIT
Von Mises Stress	$2.7192e^{6}$ (Max) $1.0899e^{5}$ (Min)	$1.3658e^{7}$ (Max) $5.2606e^{5}$ (Min)	Pa
Total Deformation	$1.4037e^{-3}$ (Max) 0 (min)	$1.5377e^{-3}$ (Max) 0 (Min)	m
Directional Deformation	0 (max) $-1.3858e^{-3}$ (Min)	0 (Max) $-6.66381e^{-3}$ (Min)	m
Elastic Strain	$1.9511e^{4}$ (Max) $7.6845e^{-6}$ (Min)	$6.8552e^{-4}$ (Max) $2.8102e^{-5}$ (Min)	m/m
Strain Energy	1.0695 (Max) $1.3746e^{-3}$ (Min)	24.539 (Max) 3.154 (Min)	J
Alternating Stress	$2.7192e^{6}$ (Max) $1.0899e^{5}$ (Min)	$1.3658e^{7}$ (Max) $5.2606e^{5}$ (Min)	Pa
Biaxiality Indication	0.91173 (Max) -1 (Min)	0.91769 (Max) -1 (Min)	
Safety Factor	15 (Max) 11.437 (Min)	15 (Max) 9.3343 (Min)	

III. CONCLUSIONS

From the above analysis, graphs and comparison of analysis table it can be clearly seen that the radome made by bamboo sheet(BMB) is not only natural and bio-degradable, it manifests in many other advantages, including the frugality of the innovation.

The cost of BMB sheet is less than CFRP and the same time there is a large difference between the weight of BMB and CFRP. BMB is less weight than CFRP, PTFE-coated fabric, etc. it can sustained in maximum wind speed 243 m/s and the maximum pressure load for bamboo is 38500 pa.

Both in meeting the design criteria and the structural analysis, it has been observed that the BMB based material fares very well and strongly recommended.

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