Performance Study of various Aircraft Radome

Tusharkanti Panda Associate Professor,
Toofan Swain Asst. Professor,
Smaraka Majhi, Deepak Pradhan Student
Department of Mechanical Engineering
Einstein Academy of Technology and Management
Bhubaneswar, Khurdha
Odisha, India

***Abstract*-Radome is a manifestation made from radar and dome. It is a protection or inclusion in order to save radar antennas from environmental impacts such as dust, rain etc. For various aircraft the shape, size and material of the radome will be different. In this research various aircraft radomes are designed by using CATIA V5 and then analyzed by ANSYS 12 with varying pressure acting on it and material properties. From the analysis it can be concluded which material can withstand high pressure as per its shape and size.**

***Key words-cover or enclosure to protect the antenna, different aircraft size and shape will be different*.**

INTRODUCTION

A radome 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 radom*e* 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.). When found on fixed-wing aircraft with forward-looking radar (as are commonly used for object or weather detection), the nose cones often additionally serve as radomes. On rotary-wing and fixed-wing aircraft using microwave satellite for beyond-line-of-sight communication, radomes often appear as blisters on the fuselage. In addition to protection, radomes also streamline the antenna system, thus reducing drag. A radome is 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. The basic function of a radome is to form a protective cover between an antenna and the environment with minimal impact to the electrical performance of the antenna. This improves system availability since the antenna is not affected by winds, rain or ice. It also provides a stable environment for service personnel from harsh weather conditions. There are a wide variety of Radome types, and they can be placed on different parts of the aircraft, making its design different for each case. For example, most common large aircraft radomes typically form the nose or tail cone of the aircraft, or they can be flush mounted or sited on the leading or trailing edges of a wing, fuselage or tail fin. This project is about various aircraft Radome located in front of the aircraft which houses a radar system. The conception of such a unit is subjected to electrical requirements of the radar such as high transmission, low reflection, far-field radiation pattern, power transmittance, low absorption and small bore sight errors among others. The word Radome is a portmanteau of the words radar and dome. So a radome is a dome which covers the radar to protect the antenna assembly from environmental hazards. The cover of a radar sensor builds a very important part of the sensor and can have an important influence on sensitivity, radiated antenna pattern and immunity to vibrations. Radome design means minimizing microwave reflection at the surface of the cover. Poor radome layout can even cause unwanted sensitivity on the backside of the sensor. The cover material can act as a lens and focus or disperse the radar waves. This is why it should have a constant thickness within the area used for transmission. In an airborne application the aerodynamically designed radome is subject to in-flight damage from bird strikes, erosion, precipitation static, thunderstorm electric fields, lightning strikes, delamination, water ingression, and particle damage such as hail or debris on the tarmac. The scope of this project is to present a complete radome design using Catia V5, studying material options, analyzing and determining a wide range of mechanical loads, using ANSYS to finish with structural verifications, as bird impact numerical analysis and mechanical material testing.

TYPES / CLASSES / STYLES

Radomes for use on flight vehicles, surface vehicles and fixed ground installations are classified into various categories according to MIL-R-7705B. Categories are determined by the specific radome use and wall construction. Customer satisfaction is met by the following, Type's definitions

- Type I: low frequency radomes at or below 2 GHz.
- Type II: Directional guidance radomes having specified directional accuracy and requirements.

Bore sight error (BSE), bore sight error slope (BSES), antenna pattern distortion and antenna side lobe degradation.

- Type III: narrowband radomes with an operational bandwidth less than 10%.
- Type IV: multiple frequency band radomes used at two or more narrow frequency bands.
- Type V: broadband radomes generally providing an operational bandwidth between 0.100GHz and 0.667GHz.
- Type VI: very broadband radomes that provide and operational bandwidth greater than 0.667GHz.

Style definitions

Radome styles are defined according to the dielectric wall construction. There are 5 basic styles.

• Style A**:** Half wave walls solid (monolithic).

• Style B**:** Thin wall monolithic with a wall thickness equal to or less than 0.1 wavelengths at the highest operating frequency.

• Style C**:** A-Sandwich multi-layered wall. Consisting of three layers two high density skins and a low density core. The dielectric constant of the skins is greater than the dielectric constant of the core material. 0.25 wavelengths.

• Style D**:** Multi layered wall having 5 or more dielectric layers. Odd number of high density layers and an even number of low density core layers. As the number of layers is increased, the broadband frequency performance is improved.

• Style E**:** Other radome wall constructions not fitting into the above style definitions. Including the B-Sandwich consisting of two low density skins and a high density core. Dielectric constant of the skins is less than the dielectric constant of the core.

RADOME CHARACTERISTICS

It has been well-known for some time that the presence of a radome can affect gain, beam width, side lobe level, and the direction of the bore sight, or pointing direction of a radar antenna. The radome characteristics are classified in to,

- Electrical Characteristics
- Mechanical Characteristics

Electrical Characteristics

The electrical-performance characteristics are quantified in terms of transmission loss, beam deflection, pattern distortion and reflected power.

A. Transmission Loss

The transmission loss is a measure of energy loss due to reflection and absorption as a result of transmission of the signal through the radome. Faulty repair procedures can create regions of transmission loss not present in the original radome.

B. Beam Deflection

Beam deflection, also known as bore sight error, is the shift of the main-lobe electrical axis due to the presence of the radome.

C. Pattern Distortion

Pattern distortion due to the presence of an incorrectly repaired radome can cause changes in the main-lobe beam widths, null depths and the structure of the side lobes.

D. Reflected Power

Reflected power can cause degradation of the pattern and raise side lobe levels. It can also cause frequency pulling of a magnetron.

Mechanical Characteristics

The basic purpose of using a radome is to protect an antenna from its environment. It is required to withstand the various environmental effects like wind, hail, snow, ice, sand, lightning and in the case of high speed airborne applications, thermal erosion and aerodynamic effects. In fact, these environmental factors determine the mechanical design requirements of radome. In meeting these requirements there is no option but to compromise the desire for ideal electro magnet transparency of the radome, because the mechanical and electrical requirements are often in conflict. As leader man points out, when the mechanical specifications are severe (like in high-speed airborne radars), it is difficult to find a design that meets satisfactorily both mechanical and electrical requirements. Unless such circumstances, it may be necessary to relax the electrical specifications to some extent. The five important mechanical requirements of radome are as follows:

- Strength**:** To sustain the aerodynamic and handling loads
- Stiffness**:** To provide elastic stability.
- Temperature resistance**:** To tolerate extreme conditions in flight and on ground.
- Resistance to moisture absorption**:** To keep the material property constant.
- Abrasion and Erosion resistance**:** To reduce the effects of rain, hailstorm, dust, stone etc.

RADOME MATERIALS

Materials used in the construction of radomes include fiberglass, quartz, graphite and Kevlar. Resins include polyester, vinyl ester, cyanate ester and epoxies. Construction techniques include hand lamination, infusion and prepreg fibers. Laminate consistency is also a component in radome performance and as such some manufacturers only produce radomes using prepreg materials. Core materials such as honeycomb and foams (thermo formable cores) are used. For high tolerance specifications a clean room is required. No carbon can enter the laminate as this can significantly reduce system performance. The ideal radome material is one which is electrically very transparent to electromagnetic energy such that a minimum power is lost in transmission through the material, and structurally must retain its physical integrity throughout the entire flight trajectory in the presence of resulting aerodynamic loads, thermal stresses, environmental conditions, and to endure as long as required by the life of vehicle.

- Radome material must be dry and electrically isolating. Do not use coatings or paints containing metallic or carbon particles.
- Most used and recommended radome materials.

DESIGN OF RADOME USING CATIA

Modeling of radome is carried out by using Catia V5 and the finite element analysis of this radome design is carried out using Ansys. Using the design calculations, modeling is done by using CATIA V5 software. Now knowing the drawing of radome, model is created by using CATIA V5. This ensures that the drawing and model are exact or identical in nature. The model is created by using CATIA V5.

Tools requirements
Sketch

- Sketch tool
- Profile tool
- Constraint tool

Part

- Shaft
- Pattern
- Grove
- Revolve

The Procedure for designing the radome model in Catia V5 is,

1. Start the Catia V5 software.
2. Go to start in the catiaV5, and then select mechanical design and then select part design.
3. Select a plane in the Catia V5 and then go to sketch tool bar.
4. And then select the spline tool bar and draw the sketch as per the given design parameters.
5. After completing the sketch, go to exit work bench tool bar.
6. Then the sketch will be displayed in 3 dimensional model.
7. And then go to the shaft tool bar and select the required plane and select ok.
8. Now we will get a 3 dimensional solid model of the radome.
9. And then select the base and go to the shell tool bar and give the required thickness of the radome and select ok.
10. Thus, the modeling of the aircraft radome is performed successfully using Catia V5.

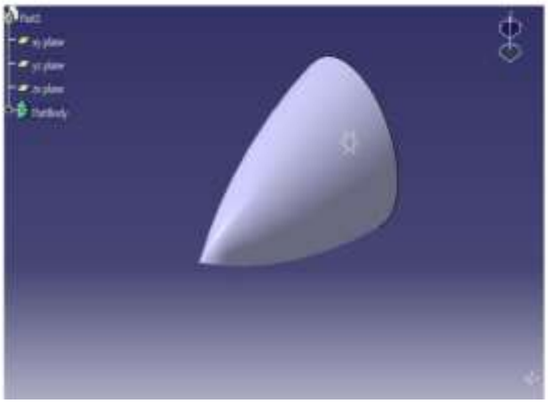

Fig.1. Catia model of high speed radome

Fig.1 explains about the design of the high speed radomes in Catia V5.

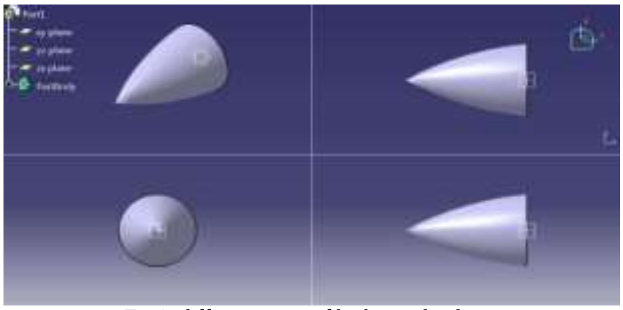

Fig.2. different views of high speed radome

Fig .2 explains about the different view of high speed aircraft radomes in Catia V5.

ANALYSIS OF DIFFERENT TYPES OF RADOME

Finite element analysis of radome is carried using ANSYS FE tool. The Finite Element method is a numerical technique for solving a range of physical problems. Geometrical model of radome is generated as per radome sketch. Suitable elements are selected and optimum size of mesh is generated. Material properties, evaluated from tests, are assigned. Boundary conditions, load cases are applied to complete the preprocessing stage. The post results obtained after FE analysis are compared with design requirements. Often being the first choice for detailed structural analysis, finite element analysis discreteness the distribution of a variable through a complex geometry by dividing the region into small elements of simple geometries. The elements are interconnected mathematically at the nodes, ensuring that the boundary of each element is compatible with its neighbor whilst satisfying the global boundary conditions. All physical problems are broken down into a series of matrix equations, where the governing equations of the system take a specific form for the type of problem to be solved. Finite element analysis, therefore, breaks down a complex problem into a series of coupled equations in matrix form, which are normally solved using general purpose solvers.

Pre processor

Model generation is done in this processor, which involves material definition, creation of a solid model and finally meshing. Here CATIA V5 is used as the preprocessor for creating the model of a radome which is later taken for the purpose of analysis.

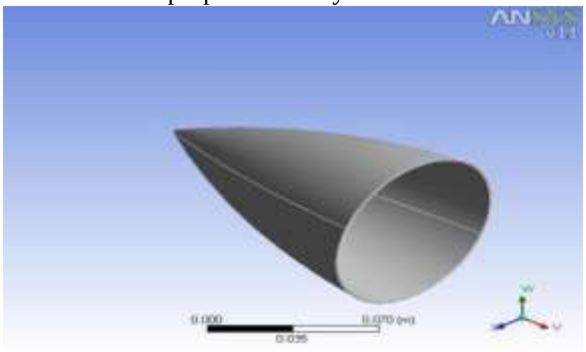

Fig .3 radome model in Ansys

Meshing

In the FEM analysis of different aircraft radome meshing is the initial step that is to be followed after the model is being imported for the purpose of analysis. Meshing is the process that divides the model into finite number of elements for the analysis. In general, a large number of elements provide a better approximation of the solution.

However, in some cases, an excessive number of elements may increase the round-off error. Therefore, it is important that the mesh is adequately fine or coarse in the appropriate regions. An analysis with an initial mesh is performed first and then reanalyzed by using twice as many elements.

The two solutions are compared. If the results are close to each other, the initial mesh configuration is considered to be adequate. If there are substantial differences between the two, the analysis should continue with a more-refined mesh and a subsequent comparison until convergence is established.

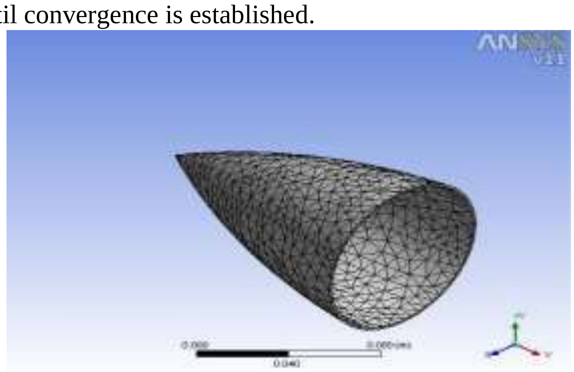

Fig.4 Meshed model of high speed fighter aircraft

RESULTS AND DISCUSSIONS

The model designed in CATIA V5 and analyzed using the Ansys v11.The analyzing is carried out in ceramic materials, E-glass fiber and carbon epoxy fiber.

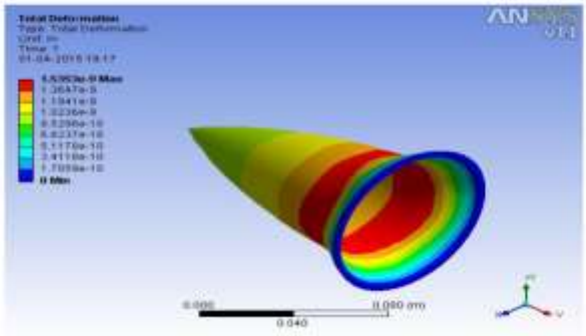

Fig.5 analyzed model of high speed aircraft radome

Fig .5 explains about the analyzed model of high speed aircraft with various pressure acting on it .

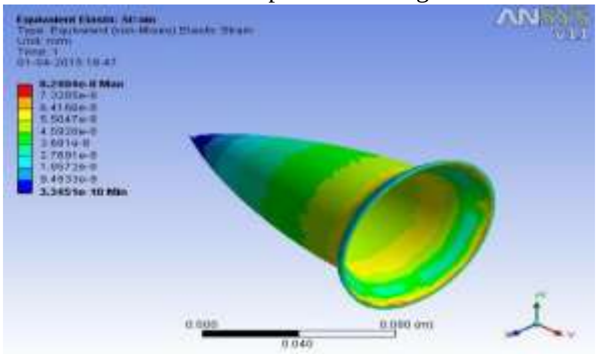

Fig .6 analyzed model f
High speed aircraft

Fig.6 explains about the analysis done in high speed aircraft with different pressure acting on it.

Analysis done in high speed aircraft radome of ceramic material with different pressure and thickness

Material	Stress (Pa)		Strain		Thickness (mm)	Pressure (Pa)	Deformation (m)
	Max	Min	Max	Min			
Ceramic material	32385	131.46	8.2404e-8	3.3951e-10	2	1230	2.5022e-9
	21616	39.93	5.5002e-8	1.016e-10	2.6	1230	1.9035e-9
	18497	69.149	4.7065e-8	1.7595e-10	3	1230	1.5353e-9

Table.1 analysis result of high speed aircraft radome

CONCLUSION

The design and analysis of radome had been successfully carried out the material property was taken using its various electrical and mechanical properties. The design of radome of the aircraft has been successfully carried out in CATIA V5 and analysis operation was also carried out successfully. Out of three different type of radome, the high speed radome found to be the best one, because the stress value is low when compared to other two radome.

FUTURE WORK

The work has thrown open multiple avenues which are nothing but the off-shoot of the work carried out on the different aircraft radome. There could be many marks which could not be carried out during the project. In the future work, we can go through the fluid analysis of the radome. As radome is the front part of the aircraft, the flow analysis is a very important parameter in the aircraft lift. In this project we have gone only through the mechanical properties of the radome materials. By using the mechanical properties, we are only finding the total deformation, equivalent elastic strain and the equivalent stress. Again we can use the electrical properties of the radome materials to find out the insertion loss, reflection loss and absorption loss. In this project we have taken only one material for each radome. But in the future work we can take different materials for each type of radome.

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