# Three Meter Antenna Structural Design and Analysis. Part 2: Static Analysis

**Om Gadhave[1], Mr. Manish Patil (Guide)[2]**

*[1]Department of Mechanical Engineering,*
*[2]Goverment college of engineering and research avasari (kh),*
*[3]Giant Metrewave Radio Telescope (GMRT) Khodad, (NCRA)-(TIFR).*

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**Abstract -** *This research paper investigates the structural analysis of a three-meter antenna dish, integrating wind and static analyses to evaluate its performance under real-world conditions. Drag and lift forces were analyzed at varying wind speeds and positions, providing insights into external forces. Using Ansys software for static analysis, the study assessed the dish frame's resilience and identified potential failure points, focusing on stress levels and deformation magnitudes. Comparison of wind and static analyses determined the critical wind speed for potential dish failure, offering valuable insights for design modifications to enhance reliability and performance against wind-induced stresses.*

***Key Words***: **Static analysis, Potential failure points, Antenna dish frame, Deformation and stress, Ansys simulation**

## 1.INTRODUCTION

The second part of this research paper focuses on the static analysis of the antenna dish frame in the three-meter antenna structural design and analysis project. This analysis aims to evaluate the structural integrity of the dish frame and assess its ability to withstand the wind forces exerted on it. By subjecting the dish frame to calculated wind forces obtained from the wind analysis conducted in the first part of the research, this static analysis simulates real-world conditions to predict the structural response of the frame.

Using Ansys software, this static analysis calculates the deformation and stress experienced by the dish frame under the applied wind forces. By identifying critical areas of deformation and stress concentration, indicative of potential failure points within the frame structure, this analysis helps determine the maximum stress levels and deformation magnitudes experienced by the dish frame. These results are then compared against predefined safety factors and design criteria to assess the frame's capability to withstand anticipated wind loads without structural failure.

Moreover, the static analysis enables analysts to iteratively refine the design of the dish frame, optimizing its structural performance and enhancing reliability. By identifying weaknesses or areas of concern through static analysis, analysts can implement design modifications or structural reinforcements to mitigate potential failure risks and ensure the overall robustness of the antenna system.

One of the key objectives of this static analysis is to calculate the wind speed at which our dish will fail or break by comparing the results of wind and static analysis. This comparison provides valuable insights into the critical wind speed threshold, aiding in the design optimization process to enhance reliability and performance under wind-induced stresses.

In summary, the static analysis of the dish frame plays a crucial role in the structural performance design and analysis process of the three-meter antenna system. It allows analysts to assess the structural integrity of the frame under wind loading conditions, identify potential failure points, and optimize the design to enhance reliability and performance while determining the critical wind speed for potential failure.

## 2. PHYSICAL DESCRIPTION OF STATIC ANALYSIS.

### 2.1 Geometry

For the static analysis of the dish frame, the geometry was meticulously crafted using SolidWorks software. This involved creating a detailed 3D model of the dish frame, capturing its intricate structural features and dimensions accurately. The geometry was optimized to reflect the real-world characteristics of the frame, including its shape, size, and connection points. Once the dish frame model was completed in SolidWorks, it was saved as an STP (Standard for the Exchange of Product Data) file format. This format ensures compatibility and allows for seamless importation into other engineering software, such as Ansys, for further analysis. The geometry of the dish frame is illustrated in Figure 1. In summary, the geometry for static analysis was meticulously designed and created using SolidWorks, ensuring accuracy and fidelity to design specifications. Importing the model into Ansys facilitated detailed structural analysis, providing valuable insights into the behavior of the dish frame under different operating conditions.

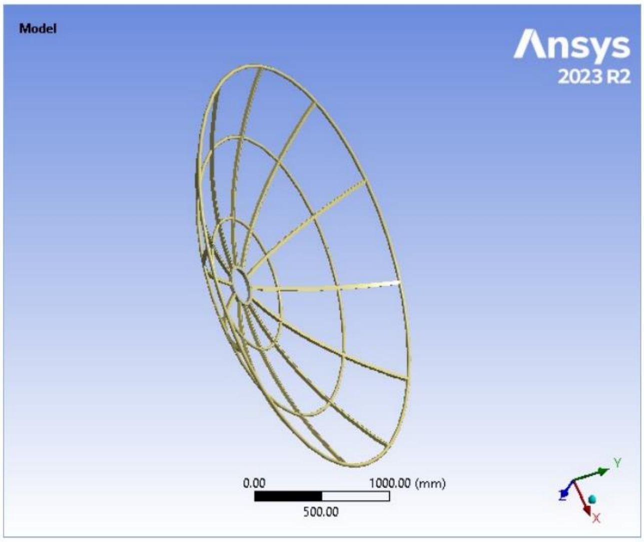


**Fig-1:** The geometry of the dish frame.

## 2.2 Material Properties.

Material Data

*Aluminum Alloy*

TABLE 26
Aluminum Alloy > Constants

| | |
|---|---|
| Density | 2.77e-006 kg mm^-3 |
| Coefficient of Thermal Expansion | 2.3e-005 C^-1 |
| Specific Heat | 8.75e+005 mJ kg^-1 C^-1 |

TABLE 27
Aluminum Alloy > Color

| Red | Green | Blue |
|---|---|---|
| 138 | 104 | 46 |

TABLE 28
Aluminum Alloy > Compressive Ultimate Strength

| Compressive Ultimate Strength MPa |
|---|
| 0 |

TABLE 29
Aluminum Alloy > Compressive Yield Strength

| Compressive Yield Strength MPa |
|---|
| 280 |

TABLE 30
Aluminum Alloy > Tensile Yield Strength

| Tensile Yield Strength MPa |
|---|
| 280 |

**Fig-2:** Properties of material selected for dish frame.

## 2.3 Meshing

In the static analysis of the project, the dish frame was meshed using Ansys software, employing tetrahedral meshing techniques. A uniform element size of 10 mm was applied to the mesh to balance computational efficiency with accuracy. Additionally, high smoothing techniques were utilized to refine the mesh and enhance its quality. Default meshing parameters in Ansys were employed, resulting in the generation of a mesh comprising 5,57,976 elements. Of these nodes, 2,72,821 were utilized in the analysis, reflecting efficient computational resource utilization while maintaining adequate mesh density for accurate simulation results. The utilization of tetrahedral meshing techniques ensured the creation of a robust finite element mesh, providing a reliable representation of the dish frame geometry for static analysis.

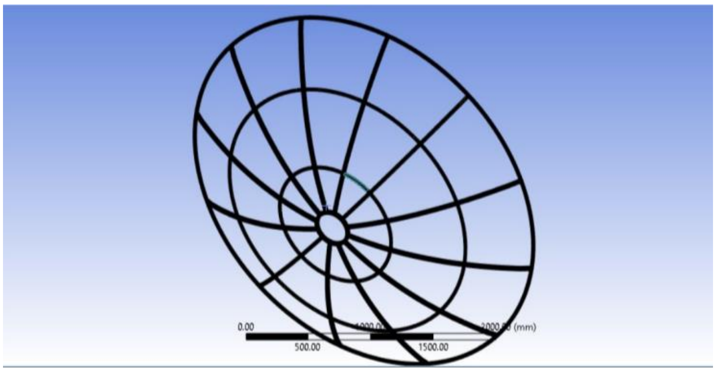

**Fig-3:** Meshing of the dish frame.

## 2.4 Boundary conditions.

**In the static analysis of the dish frame, the following boundary conditions are applied:**

**1. Fixed Support:** A fixed support is employed to firmly fix the dish frame in place, restricting its movement in all translational and rotational degrees of freedom. This ensures that the frame remains stable and anchored during the analysis.

**2. Applied Pressure on Arms:** Pressure loads are applied to the arms of the dish frame to simulate the external forces acting on it. These pressure loads represent the environmental conditions or operational requirements that the dish frame is subjected to in real-world scenarios. By applying pressure to the arms, the structural response of the dish frame to external loads can be accurately analyzed and evaluated. These boundary conditions are essential for accurately simulating the behavior of the dish frame under various loading conditions and for obtaining meaningful results from the static analysis.

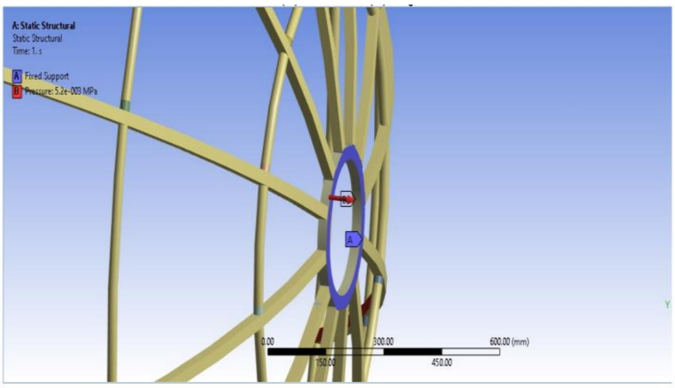

**Fig-4:** Boundary conditions used for static analysis.

## 2.5 Solution

In the static analysis of the dish frame conducted using Ansys, the following solutions were obtained:

**1. Deformation Analysis:** Ansys was utilized to calculate the deformation of the dish frame under applied loads. By employing finite element analysis techniques, the software accurately predicts the displacements and deformations experienced by the structure. This analysis provides crucial information regarding the deflection and deformation patterns, allowing for the assessment of structural integrity and performance.

**2. Equivalent Stress Calculation:** Ansys enables the computation of equivalent stress distribution throughout the dish frame. By combining different stress components (such as axial, bending, and shear stresses) using appropriate stress transformation equations, the software calculates the equivalent stress at each node or element of the finite element model. This facilitates the identification of regions experiencing high stress levels and assists in ensuring that the structure meets safety and design criteria.

**3. Maximum Shear Stress Evaluation:** Ansys facilitates the determination of the maximum shear stress experienced by the dish frame. By analyzing the stress distribution within the structure, the software identifies critical locations where shear stresses are most pronounced. This information aids in identifying potential failure points and guiding design modifications or reinforcement strategies to enhance structural robustness.

## 3. RESULTS AND DISCUSSION OF STATIC ANALYSIS.

The project on three-meter antenna structural design and analysis focused on assessing wind forces exerted on the dish at various positions and wind speeds. Through calculations, it was determined that the maximum force was experienced at the 0-degree positions. This maximum force was then utilized as input for the static analysis of the dish frame, conducted using ANSYS software. By converting the force into pressure units, it was found that the dish frame would fail under a pressure of 22000 Pascal. To provide context, this pressure was converted back into force by multiplying it with the dish's surface area of 0.475 $m^2$.

The results of the static analysis shed light on the structural behavior of the dish frame under extreme wind loading conditions. By applying the maximum force at the critical 0-degree positions, the analysis accurately simulated real-world scenarios. The identified failure pressure of 22000 Pascal serves as a crucial parameter for evaluating the structural integrity of the antenna system.

The discussion section of the project report should emphasize the importance of robust structural design in ensuring the resilience of antenna systems against environmental factors such as wind. The findings underscore the need for ongoing monitoring and maintenance protocols to safeguard the long-term functionality of the antenna system. Recommendations may include structural enhancements or modifications aimed at mitigating the risk of failure under extreme wind conditions. Overall, the static analysis provides valuable insights into the structural performance of the antenna system and informs decision-making processes for optimizing design and operational efficiency.

**Table-1** Statis analysis results at various pressure

| Sr.no. | Pressure (Pa) | Total Defor-mation (mm) | Equi-valent Stress (MPa) | Maximum Shear Stress (MPa) |
|---|---|---|---|---|
| 1 | 5200 | 1.56 | 60.06 | 31.905 |
| 2 | 6000 | 1.8 | 69.3 | 36.813 |
| 3 | 7000 | 2.1 | 80.85 | 42.949 |
| 4 | 8000 | 2.4 | 92.4 | 49.084 |
| 5 | 9000 | 2.7 | 103.95 | 55.22 |
| 6 | 12000 | 3.6 | 138.6 | 73.626 |
| 7 | 15000 | 4.5 | 173.25 | 92.033 |
| 8 | 20000 | 5.9999 | 231. | 122.71 |
| 9 | 22000 | 6.5999 | 254.1 | 134.98 |

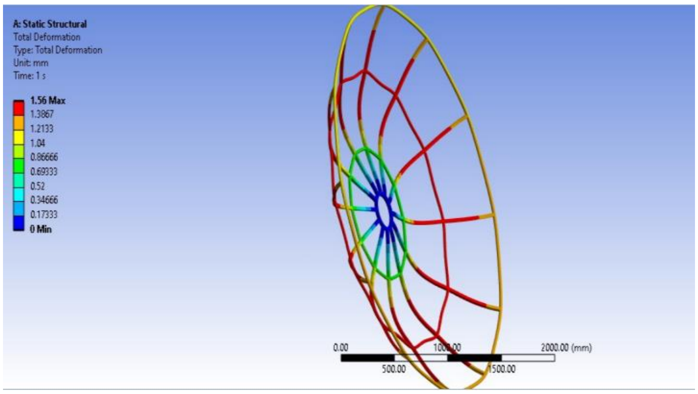


**Fig-5:** Deformation of dish frame.

## 4. COMPARISON OF WIND AND STATIC RESULTS

The analysis of both wind and static conditions for the Three Meter Antenna Structural Design project provides valuable insights into the dish's performance and potential failure points.

During the wind analysis, calculations were conducted to determine the drag and lift forces acting on the dish at various wind speeds and positions. Notably, it was observed that the maximum forces were exerted on the dish when it was oriented at 0 degrees. This finding suggests that the dish is most vulnerable to wind loading when facing the oncoming airflow directly.

In the static analysis phase, critical parameters such as maximum shear stress, total deformation, and equivalent stress were evaluated. Of particular significance was the determination of the failure point, identified at a pressure of 22000 Pascal because the yield strength of aluminum is 250 MPa. This failure point, derived from the maximum shear stress theory. This result serves as a crucial reference point for assessing the dish's structural integrity under different loading conditions.

Upon comparing the pressure threshold obtained from static analysis with the wind analysis results, it was revealed that the dish is susceptible to failure at wind speeds exceeding 87 kmph. By converting the pressure threshold into forces, approximately 10000 Newtons were estimated, indicating the magnitude of the forces exerted by the wind on the dish.

Overall, the combined wind and static analyses offer a comprehensive understanding of the structural behavior of the antenna dish, enabling informed decision-making regarding its design and operational parameters.

## 5. CONCLUSIONS

Our project aimed to meticulously analyze and design the structural integrity of a three⍰meter antenna for the Giant Metrewave Radio Telescope (GMRT). Leveraging advanced engineering tools like SolidWorks and ANSYS, we embarked on a comprehensive journey to ensure the stability and reliability of the antenna under various environmental conditions.

**Virtual Modeling and Wind Analysis:**

- Utilizing SolidWorks, we crafted a detailed virtual model divided into dish and antenna base assemblies.

- Wind analysis was conducted at different dish angles (0°, 30°, 45°, 60°, and 90°) to assess drag and lift forces.

- The highest wind forces were observed at 0°, prompting further analysis at high wind velocities up to 90 kmph.

**Wind and Static Analysis:**

- In the wind and static analysis using ANSYS software, the dish was subjected to high wind velocities of up to 90 kmph at a 0-degree angle. This analysis, conducted with an aluminum alloy as the dish material (tensile yield strength of 250 MPa), revealed crucial data such as deformation, maximum shear stress, and equivalent stress.

- The critical failure point was identified at 22000 Pa pressure, corresponding to a wind speed of 87 kmph, where the maximum shear stress reached 254 MPa, surpassing the alloy's yield strength. This indicates that the dish would fail at that wind speed, resulting in a deformation of 6.6 mm. This deformation could significantly impact the accuracy of astronomical observations and radio frequency measurements

**Determining Safe Operational Limits:**

- Given the deformation's potential impact on observation accuracy, we established a safe wind speed limit of 40 kmph. At 40 kmph wind speed the deformation of dish frame is 1.25 mm and equivalent stress is 55 MPa. We consider a safety factor of 1.8 for antenna design. At 40 kmph wind speed, the factor of safety is 2.2 indicate that our design is at safest limit.

- At this threshold, the dish deflects minimally, ensuring stable and accurate astronomical observations and radio frequency measurements.

**Project Conclusion:**

Our project's culmination underscores the meticulous engineering efforts invested in ensuring the structural robustness and operational efficiency of the three-meter antenna for GMRT. By integrating advanced simulation tools and thorough analyses, we've delineated safe operational limits, critical failure points for seamless antenna functionality in astronomical observation and radio frequency measurements.

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**BIOGRAPHIES**

Om Ramesh Gadhave
Mechanical Engineering Student
Government College of Engineering and Research Avasari (kh)