Finite Element Analysis Of Radar Antenna Mounting Swinging Platform Structure

Maruthi.B.H [1], Darshan.K.B[2], Prashanth.K.P[3]
[1, 2, 3] East West Institute of Technology, Bangalore, India

Abstract

In this research work radar mounting platform structure is designed under heavy loading conditions. The added mass and vibration effects, due to transportation condition are incorporated. In addition deployed effect and wind loading effect on radar antenna are accounted. Method used in this research is large mass method and direct method for designing radar mounting platform structures. The effect of transportation and deployed conditions is analyzed and discussed. Both static and dynamic analysis is carried out. The optimal shape of the design boundary with constant stress is achieved iteratively by adjusting the design boundary shape based on a simple logic and algorithm. For various 'g' values the structure is analyzed to ensure no non linearity exits in radar mounting platform structure. New formulation is validated comparing with mode superposition and full mode analysis. Vibration characteristic and natural frequency are computed using finite element analysis. In addition wind loads effect is also considered. The research work concludes that proposed radar mounting platform structure decreases stresses level and increases natural frequencies. Designed values are within the safe region and structure can withstand active vibration conditions.

Keywords: Finite Element Analysis, Radar, Vibration, Antenna, Structure

1. Introduction

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also used naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools. The word "RADAR" is an acronym coined in 1942 (II world war) by U.S Navy for Radio Detection and Ranging. It is basically a means of gathering information about distant objects or targets by sending electro-magnetic waves at them and analysing reflected waves or the echo signals. [1]

2. Mounting platform specification

The design and testing requirements which have to be satisfied for every radar structure that pretends to be used by defence are stated in [2]. Those of interest for this work can be subdivided in two categories: dimensional and mass requirements and structural requirements. The first one states that each mounting platform must have a nominal length 2600 mm and width of 2400 mm per side. The second one specifies some design criteria which have to be met in order to avoid transportation vibration. Aluminium alloys 6061-T6 is suggested for the main structure although it is possible touse other materials with similar yield stress. In addition [3], [4] the guidelines for vibration qualification test are presented.

2.1 Load Types

Two types of mechanical loads are identified through the whole transportation process: static and dynamic. These are result of different accelerations on the transportation vehicle. Each transportation vehicle user guide specifies its particular vibration and acceleration levels. [5]

2.2 Design Considerations

The following considerations were used in the design:

- Maximum static acceleration of 3 g.
- Antenna will have the maximum specified mass of 1800kg and main electronic enclosure 150 kg each around two components placed at each end of the structure.

Now, some design guidelines are presented. Each radar mounting platform must have a minimum mass and according to the literature 30% of this is allocated for the structure. The main goal of the design is to obtain a sufficiently stiff structure which supports its own weight, the components at side and the weight of antenna. It has to be as light

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as possible and easy to manufacture and assemble at a low cost.

2.3 Methodology

First, the extreme loading conditions of a structure were identified. Fig. 1 describes the maximum and minimum loading conditions on the structure.Loads and boundary conditions applied to the structure is show in fig 1. Center of the structure is fixed .i.e. hexagonal part is fixed. Using direct method the structure is analyzed. Because the position of antenna on the structure during transportation is not known exactly, the worst case was considered

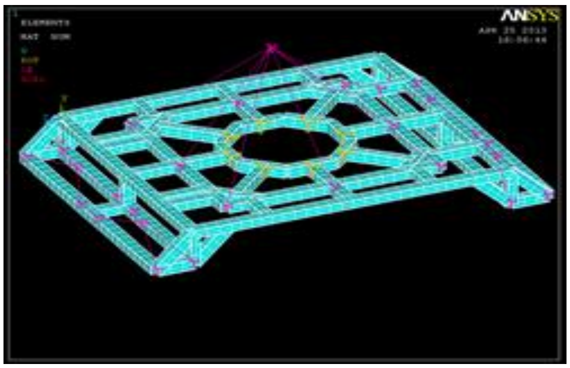

Fig 1: Boundary condition applied to structure

According to the previously stated considerations the worst static case is described by a load of 17658 N applied to the upper structure on the transportation arrangement.

Different 'g' values are applied for transportation mode in order to ensure that structure is within the linear mode. There is a variety of materials and compounds that might meet the requirements of the yield stress, however, the cheaper and sort of commercial is the aluminium 6061-T6 -commercial availability was the main reason of choosing it. Table 1 shows some of the material properties of this aluminium alloy.

Table 1: Properties of the aluminium alloy 6061-T6

Material property	Magnitude
Modulus of elasticity	68.9 GPa
Tensile Yield Strength	276 MPa
Poisson's ratio	0.33
Density	2700 kg/m3

After material selection, first design was obtained and analysed. In order to determine the maximum stress due to static loads in each part of the structure, individual finite element based analysis were performed.

3. Simulation Results

All the methods which will be mentioned in this work can be found, for instance, in [6]. The finite element modelling criteria can be found [7]. The first individual analysis of stress is presented and then stresses and natural frequencies are determined for the overall structure.

3.1 Transportation mode

This mode occurs when the truck is travelling on the road. Usually in defence this type of radar are only used in war field where one cannot get a smooth or a flat road. These are to be travelled on the dirt road were plenty of vibration occurs this may damage the radar structure. Hence while designing this condition is to be considered and designed such a way that it can withstand all vibration produced during transportation mode. Different loading conditions are taken in order to make sure that the structure is safer and is within the linear region. Following shows the results of analyzed structure.

Displacement vector sum indicates the total displacement caused by x, y and z and are plotted in one plot. Fig 2 shows the displacement plot showing that maximum displacement will be at the side causing bending stress at the end. Since middle of the structure has it is fixed no displacement will take place. Von Mises stress is plotted because it gives the most accurate result of stress or in other words the value of stress that are within the failure region.

Fig 3 shows that at the supports and junctions the stress will be more. But the stresses which are produced are much below the failure region. Fig 3 shows the Von Mises total strain.

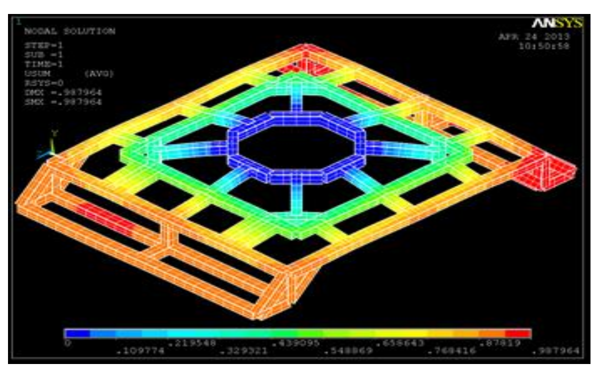

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Fig 2: Displacement vector plot of structure for 1g load condition.

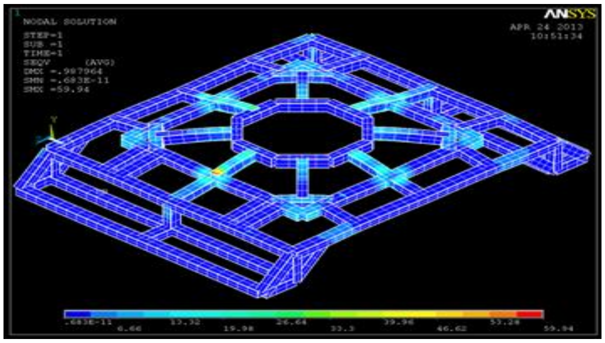

Fig 3: Von Mises stress plot of structure for 1g load condition

Similarly analysis are made for different ‘g’ values and the results are given in the below table 2.

Table 2: Analysis result for different ‘g’ values

Sl no	**Type of ‘g’ value**	**Displacement Vector sum (mm)**	**Von Mises stress (MPa)**
1	1g	0.98	59.94
2	1.5g	1.48	89.91
3	2g	1.97	119.88
4	3g	2.96	179.82

3.2 Deployed mode

It is second loading condition to which the structure is subjected in this the antenna is reciprocated up and down along its bed. Deployed referee to opening mode of antenna in which the antenna is subjected to different loading such has wind load and the weight will be applied only on ¾th of structure. Considering all this condition the analysis is made and the results are plotted. Boundary conditions are applied and structure is analyzed. Fig 4 shows the boundary conditions applied to the structure.

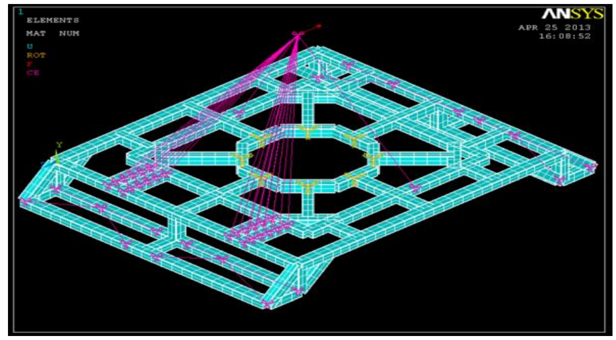

Fig 4: Boundary conditions applied on the structure for deployed mode.

Same loads are applied as in Transportation mode but the difference is only load are applied on ¾th part of the structure along with that wind load is applied due to deployed mode. Using all the above condition and inputting the results are obtained and are shown below.

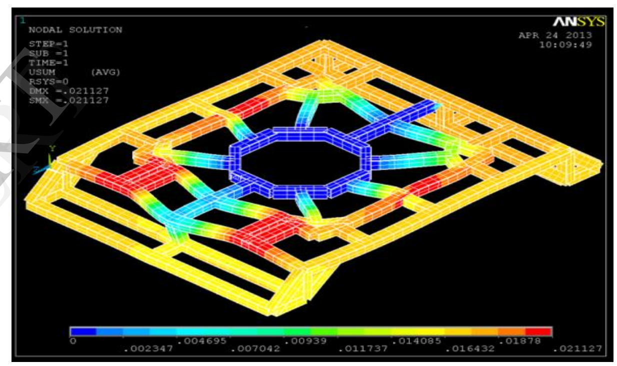

Fig 5: Displacement vector plot of structure for 1g load condition.

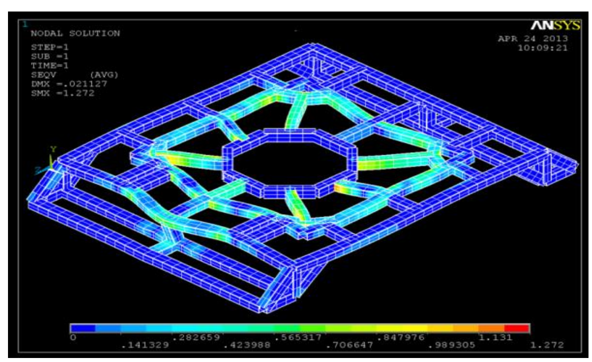

Fig 6: Von Mises stress plot of structure for 1g load condition.

Displacement sum vector plot is shown in Fig 5 indicating maximum displacement at the junction and supports of the structure. Fig 6 shows that at the supports and junctions the stresses will be

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more. But the stresses which are produced are much below the failure region.

3.3 Stresses and natural frequencies in the structure

Due to the complex analysis of the assembled structure with all its mechanical components, the finite element method was used to verify and validate the static and dynamic specifications. Beam and plate finite elements with six degrees of freedom in each node are suitable for this, purpose. Simply supported boundary conditions as well as an axial compression load of 17658 N were applied at the upper part. Moreover, displacements in its cross section plane and axial rotation were constrained to be zero.

The natural frequencies in the 0 to 100 Hz bandwidth are shown in Table 3, whereas the first mode of vibration is depicted in Fig 7. The symmetry of the structure causes that some natural frequencies are almost equal.

Table 3: Natural frequencies of the structure in the 0 to 100 kHz range

Mode	**Natural Frequency (Hz)**	**Mode**	**Natural Frequency (Hz)**
1	24.079	6	74.821
2	26.707	7	89.818
3	28.515	8	91.415
4	30.255	9	102.85
5	64.416	10	115.28

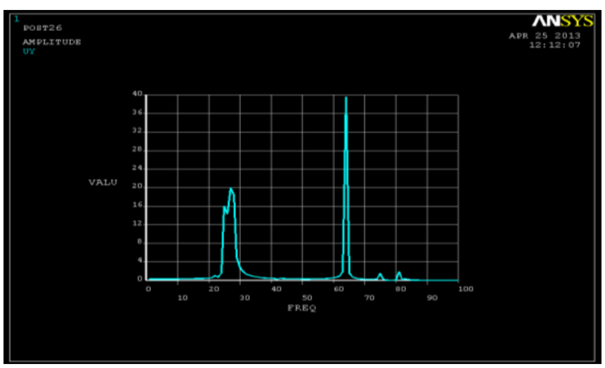

Fig 7 Displacement v/s frequency plot for node 22 Structure.

4. Conclusion

The mechanical design of low-cost mounting platform structures, which comply with the radar program specification was developed using finite element methods. The resulting designs have less mass than the budgeted.

Table 4: Total mass of the prototypes

Design	Mass (kg)
1	440
2	240

Two of the resulting designs have less mass than the budgeted (see Table 4). Finite element analysis of a simplified structure is currently being performed and dynamic tests will be done in order to experimentally validate the designed prototypes.

5. Acknowledgment

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