ISSN 2229-5518

Effect of Thermal Stresses on Self-Supporting Telecommunication Mast

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ABSTRACT: This work has studied the effect of thermal stresses on four-legged Self Supporting telecommunication mast. ANSYS software was used in studying the displacement patterns due to daily fluctuating temperatures over a period of 5 yearsusing Ibadan, Nigeria metropolis environment as a case study.

The telecommunication mast was geometrically modelled using AUTOCAD and imported into ANSYS for the finite element analysis. The mast was loaded with antenna loads of 2,755N and thermal load. The temperature data was collated in Microsoft excel and converted into .dat file format using MATLAB, before loading into ANSYS workspace for use.

The loaded telecommunication mast was displaced from its original position at the top due to thermal load with maximum displacement of 0.022851 mm and minimum displacement of 0mm at the bottom of the mast. The model results showed cyclicdisplacement pattern of the telecommunication mast for the period under study but will not result into collapse of the mast in the period studied.

Key words: Telecommunication mast, ANSYS, Thermal Fatigue, AUTOCAD, MATLAB.

1. INTRODUCTION

Masts are typically tall construction (structural frames) specially designed to support antennas for wider transmissions in television, radio, telecommunications (GSM), internet traffic, also used for floodlight projectors, wind turbines, street light poles and platforms for inspection [11]. Masts and Towers are often used for the same type of structure but in this work Masts would be used. Also, mast are among the tallest man-made structures in the world today, used largely everywhere. There are three most common types of masts that are used in the world today; which are: Monopoles, Self-supporting and Guyed Mast [11]. The most widely used among these three types ofmasts for telecommunication system is the self-supporting Mast [9]. Telecommunication Mast are self-supporting tall structural frames, designed to support antennas for transmission in order to aid interlink age connectivity for wider coverage. In Nigeria, the self-supporting mast are used for telecommunication mast, which are highly spread throughout the villages, towns and cities for effective connectivity and wider coverage of the telecommunication network. This work is actually targeted at doing a real life modeling of four-legged telecommunication mast subjected to daily fluctuating temperatures, thereby coming up with a study of the effect of these thermal induced fatigue stresses on the telecommunication masts. In achieving this, a Finite Element Analysis is used [7]

Modeling is said to be the process of producing a model (a model is a representation of the construction and working of some system of interest), which can then be simulated to see the operation of the model of the system [1]. According to Robert, Modeling is the simulation of a physical structure or process by means of a substitute analytical or numerical construct [14]. In this work, the simulation platform is where the telecommunication mast model would be performed to see the real life application of the effect of the daily fluctuating temperature on the mast. A Simulation of a system is the operation of a model of the system [1]. It creates a platform or environment where the model can be tested, analyzed and different operations can be performed on it to know some certain reasons why engineering products behave the way they do in real life situations. Finite element analysis and simulation package (software) provides a fast accurate and innovative approach to solving most challenging design problems in engineering.

2. MATERIALS AND METHODS

2.2 Materials

The Mast structure was modelled using structural mild steel material. Generally, for Mast design in real life construction, mild steel is always used.

Properties of mild steel:

Young Modulus, E = 205 GPa

Thermal Coefficient =1.2×10^{-5}°C^{-1}

Density, ρ =7 g/cc

Tensile Strength, S = 4.98GPa

Yield Strength=3.55GPa

Poisson's ratio= 0.3

2.3 Methods

ANSYS performs its analysis operation on step by step approach, which includes the following:

Analysis system (Static structure), Engineering Data, Geometry, Model, Set up, Solution and Results.

2.3.1 Analysis System

The Mast was designed as a stationary structure , therefore static structure was used. The mast was first modeled in AUTOCAD® environment and was imported into ANSYS environment. The mast is a four sided structure.

2.3.2 Engineering Data

The engineering Data is where the properties of materials to be used are defined and selected. For this work, the material used is structural mild steel, which possesses the following properties stated in section 2.2.

2.3.3 Geometry

This is where the design modeler is used to create designs of different type, for any engineering drawing. In this work, the geometry was designed and imported into ANSYS from AUTOCAD environment. It is where the measurement units like centimeter, meter are selected and the coordinates plane as well. The view of the geometry of this work is displayed below(Fig. 1), it is a four sided mast modelled with structuralmild steel.

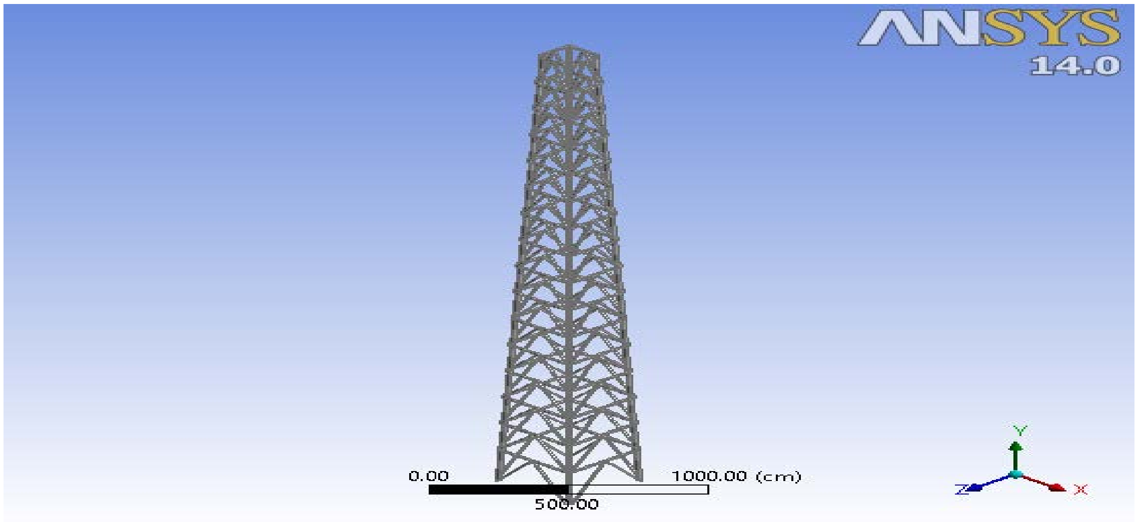

Fig 1 Geometry of the four legged mast

2.3.4 Model

The Model aspect has to do with the further analysis of the mast structure, which majorly has to do with the meshing of the mast structure. Meshing is the process of breaking up a physical domain into smaller sub-domain (elements) in order to facilitate the numerical solution of a partial differential equation. The mesh analysis of this mast is shown below(Fig.2)

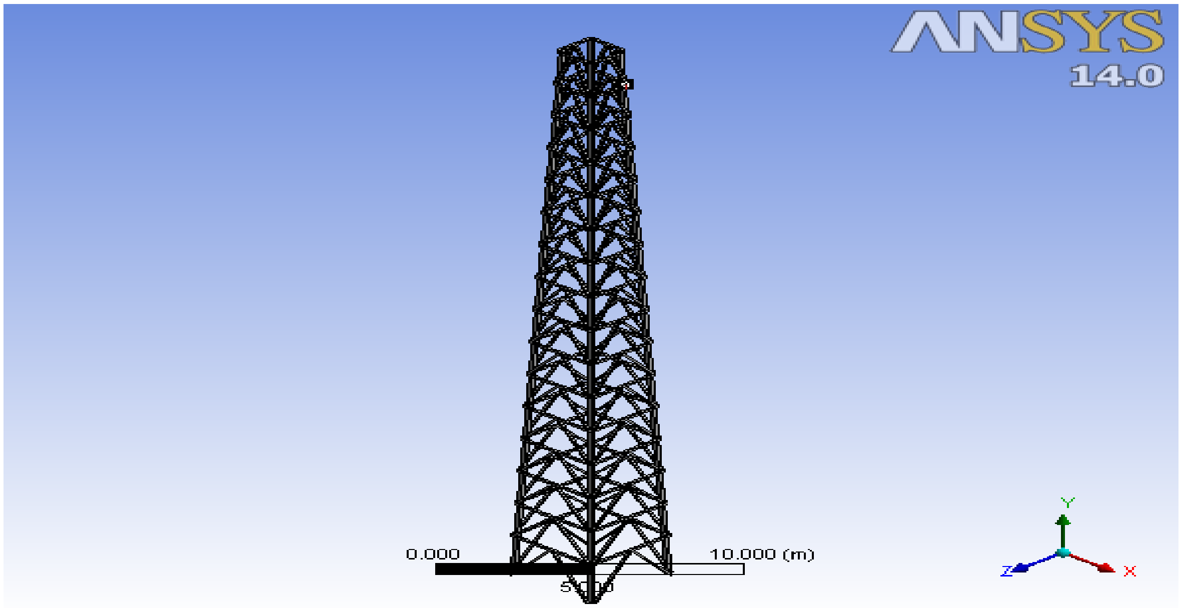

Fig 2: The meshing of the telecommunication mast. (The meshing size is 0.2m)

2.3.5 Setup

2.3.5.1 Fixed Points

The Setup is where the loads are defined and applied, the boundary conditions are applied too and the running of the analysis is done. In this work, there are different loads that were applied (the thermal load and the antenna loads). The boundary condition at the base for this work were all fixed dirichlet boundary conditions (Ux) = 0, (Uy) = 0, (Uz) = 0.

2.3.5.2 Body Loads

The fixed boundaries were first done before any other further analysis. After the fixed points were applied, which served as the boundary conditions, the antenna load force were introduced. There were about six different antenna loads introduced on the mast to make it fully loaded. The total antenna load applied on the mast is 2,755 N in addition to the thermal load as well, which was derived from the daily fluctuating temperatures of Ibadan metropolises. The attached loads on the mast are shown in Fig.3.

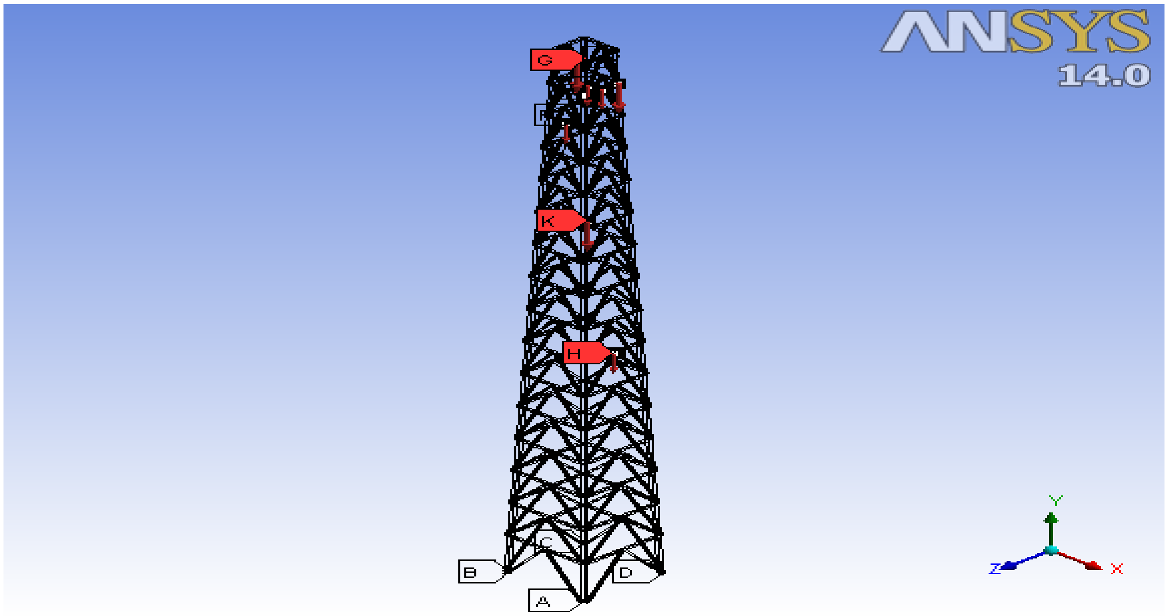

Fig3: The mast showing the antenna loads and the fixed points (boundary condition).

2.3.5.3 The Governing Equation

The FEM Analysis for this mast structure is a 3-dimensional truss . Fig.4 shows a 3 dimensional space truss.The governing equation is shown in equation (1).

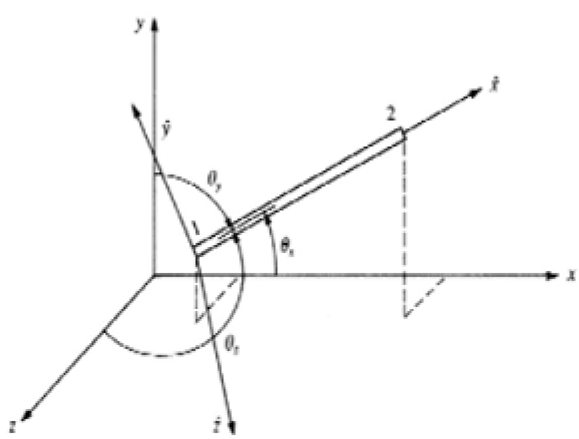

Fig 4. A bar in a 3-D Truss (space truss) [5]

$$K = \frac{EA}{L}\begin{bmatrix} C_x^2 & CxCy & CxCz & -C_x^2 & -CxCy & -CxCz \\ CxCy & C_y^2 & CyCz & -CxCy & -C_y^2 & -CyCz \\ CxCz & CyCz & C_z^2 & -CxCz & -CyCz & -C_z^2 \\ -C_x^2 & -CxCy & -CxCz & C_x^2 & CxCy & CxCz \\ -CxCy & -C_y^2 & -CxCz & CxCy & C_y^2 & CyCz \\ -CxCz & -CyCz & -C_z^2 & CxCz & CyCz & C_z^2 \end{bmatrix} \ldots(1)$$

Where K is the element stiffness matrix in the global coordinate, A is the area of cross section of the bar, L is the length of the bar.

l_1, m_1 and n_1 are the direction cosines of χ l_1= Cos θx, m_1= Cos θy, n_1= Cos θz

F = Kd, Where F is the Load vector of the truss element, K is the element stiffness and d is displacement [17].

The Boundary condition of this mast structure are at the feet of the mast, fixed to the ground which is known as the Dirichlet boundary condition, this includes the (Ux) = 0, (Uy) = 0, (Uz) = 0.

2.3.5.4 Thermal Loads

For the thermal load analysis, using the thermal stress equation from equation 1, we have:

Thermal stress (σ) = α E ΔT …………………… …………………(2)

But the thermal force (thermal load) can be expressed from equation of stress which is:

Stress, (σ) = force / area = F/A, therefore, deriving the Force, gives

Force, (F) = (σ) x A, now substituting for the thermal stress in the equation of Force to get the

Thermal force or thermal load, gives, Thermal Force, (F) = Thermal stress x Area = **(σ) x A**

Therefore, Thermal Force, (F) = **α E ΔT A = AEαΔT……………………… (3)**

Also, this equation can also be written in the FEM form, $\{F\} = \begin{Bmatrix} -AE\alpha\Delta T[C] \\ -AE\alpha\Delta T[S] \\ AE\alpha\Delta T\ [C] \\ AE\alpha\Delta T[S] \end{Bmatrix}$

Where $\{F\}$ is the thermal force applied to the mast system for the analysis, A is the area of the mast, E is the Modulus of elasticity of the material of the mast, α is the thermal stress, ΔT is the change in temperature, S is the sine of angle and C is the cosine of angles of the bar of the mast.

Thermal Force Data Collation

The daily temperature difference data was collated in Microsoft excel and converted into the thermal loads using equation (3). The excel file was converted into .dat file format by importing into MATLAB. The MATLAB .dat file was then imported into ANSYS workspace for use.

The fluctuating daily thermal loads as shown on ANSYS is presented in Fig. 5.

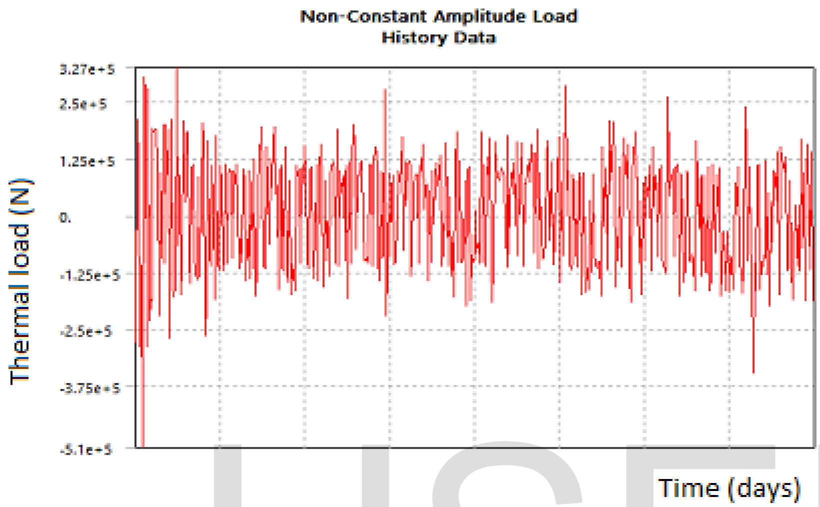

Fig 5. Random Force cycle Graph showing fluctuating thermal loads calculated from fluctuating daily temperatures (Force, N against Time, day)

3. Result and Discussion

3.1 Results

The following results were obtained and observed.

3.2 Total Deformation

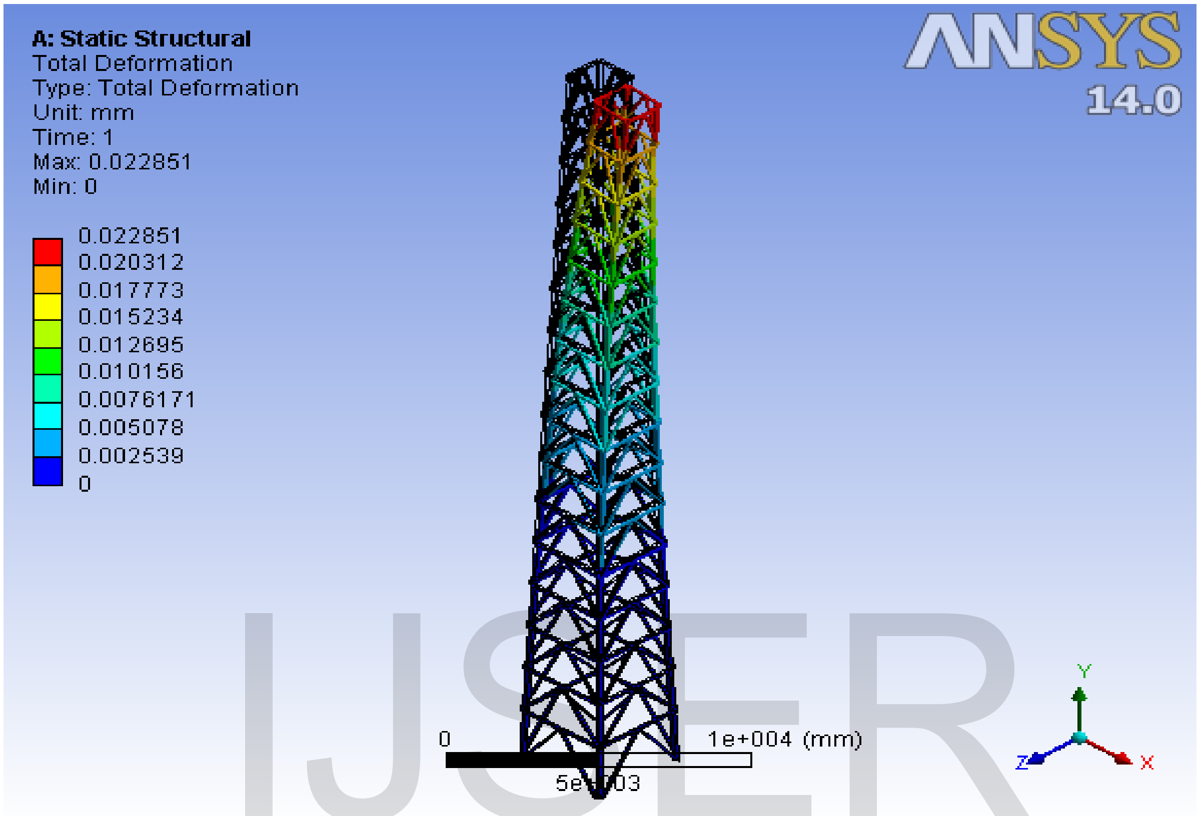

Fig 6. Mast displacement after the analysis from the original mast.

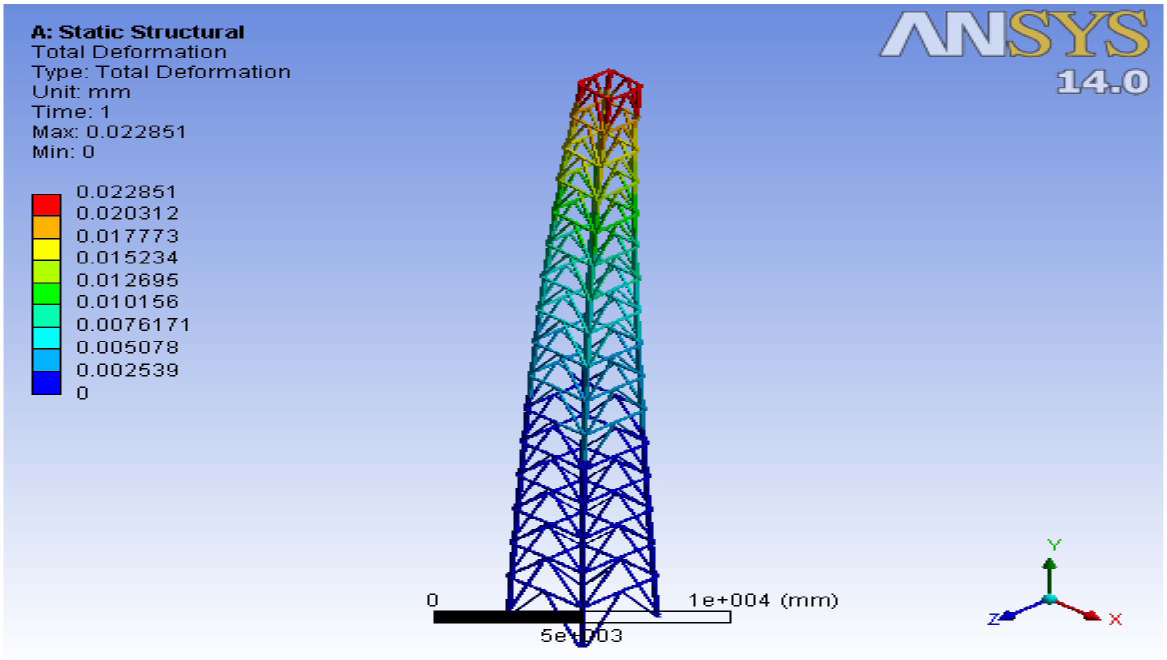

Fig 7. Mast displacement showing displacement values as well.

3.2 Discussion

Effect of loads on the self-supporting Telecommunication mast

Figures 6 and 7 show the displacement of the mast from the top down the mast. The deformation value was highest at the top. The value of the minimum displacement was recorded to be 0mm at the fixed base while the maximum value of displacement was 0.022851mm. The maximum loading on the structure which is 0.35 MN gives a stress value of 8.8 MPa which is much much lower than the fatigue limit of mild steel (25MPa) showing that the structure is not likely to fail due to antenna and thermal loads alone. It has been shown however that minute stresses lower than fatigue limits do cause eventual damage after a very very long time but this is indeterminate.

4. Conclusions

The results of modeling thermal fatigue on self-supporting telecommunication mast using ANSYS, with a total of antenna loads of 2,755N and thermal load of a period of five years of Ibadan metropolis has revealed from the analysis that:

- There was displacement pattern on the mast at the top part with maximum deformation of 0.022851mm.

- The minimum deformation value was recorded to be 0mm, which shows that displacement is minimal at the bottom, most especially at the fixed section.

With this ANSYS analysis, we can deduce what would happen to the telecommunication mast of the area of Ibadan metropolis within the period of five years of the daily fluctuating temperatures.

Finally, this study shows that there was displacement on the telecommunication mast within this period of time for the daily fluctuating temperatures of Ibadan metropolis but there will be no sudden collapse of these telecommunication mast.

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