

Design and Analysis of Mast Diagonal Mounting for Incessant Communication

¹Yugandhar GARAPATI, ²Venkateswara Rao GURRALA
and ³Srinivasa Rao KARUMURI

¹Department of Computer Science & Engineering, GITAM University, Hyderabad-502329 India

²Department of Information Technology, GITAM University, Vishakhapatnam-530045 India

³Department of Electronics, LBR College of Engineering, Mylavaram-521230, India

¹E-mail: yugandhar.garapati@gmail.com

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Abstract: The paper reports about the design and stiffness analyses of communication mast's diagonal mounting using COMSOL MultiPhysics v 4.2 a. This model presents the stiffness effect of a mast's diagonal mounting for incessant communication. When operating under a given wind load at a specific location, the antenna's total rotation angle should stay below a certain limit to ensure uninterrupted communications. For most of the masts being are exhibiting very low torsional stiffness that might be due to the geometry of the diagonal mountings. An attempt has been made to increase the stiffness of such a diagonal mounting by first analyzing a parameterized geometry followed by an updated geometry. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Diagonal mounting, Rotation angle, Stiffness ratio, COMSOL.

1. Introduction

With the rapid growth of technology, microscale devices are playing a dominant role in mechanical and optoelectronic devices. Characteristics like miniaturization, multiplicity and microelectronics help these devices to sense, control and actuate on micro scale with effects on macro scale. A micro-electromechanical system (MEMS) is a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components [1-3]. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a few micrometres to millimetres. These devices (or systems) have the ability to sense, control and actuate on the micro scale, and generate effects on the macro scale [4-6].

Generally, mast is comprised of an antenna for signal reception, a power amplifier and a transceiver

device, which acts as a combined transmitter and receiver. The transceiver/receiver manages and sends signals back and forth between mobile communication devices and also between communication devices and higher entities such as the base-station controller. Without communication mast, even the wireless communication is not possible. Masts are typically tall structures designed to support antennas for telecommunications and broadcasting. These are the tallest man-made structures. The steel lattice is the most widespread form of construction. It provides great strength, low weight and wind resistance, and economy in the use of materials. Communication masts usually have a framework with a bolted triangular lattice design. The diagonals of the framework are assembled from several parts and welded together. Within the last decades, the need for tall structures has accelerated with the requirements for effective communication

especially the advent of radio, radar and television. Most up-to-date, the exponential growth in the use of cellular phones has meant a new era for towers and masts, however smaller in height but very larger in number. Now days mobile phone masts are found to provide effective communication. They increase the strength of signal transmission and coverage. This is vital for individuals in day-to-day social communication and businesses that depend on fast telecommunication connection.

There are many challenges viz., transmission, receiving losses and noise occurrence for the engineers those are associated with the tall and slender structures. The predominant loads of masts and structures are natural loads as wind and ice, loads that affects the structural behaviour. The wind load is a dynamic load and the slender structures are sensitive to the dynamic part in the wind. Ice on a tower or mast will by its weight change the dynamic behaviour, as well as it may increase the wind drag of a lattice tower or mast dramatically. When the communication masts operating under a given wind load at a specific location, the antenna's total rotation angle should stay below a certain limit to ensure uninterrupted communications. The masts being used are found to exhibits very low torsional stiffness that might be due to the geometry effect of the diagonal mountings. Thus the present work is mainly focused to increase the stiffness of such a diagonal mounting by first analyzing a parameterized geometry followed by an update of the proposed geometry and a new analysis leads to the solution for stiffness problem

2. Materials and Methods

The software package selected to model and simulate the communication mast is COMSOL MultiPhysics Version 4.2 a. It is a powerful interactive environment for modelling of various devices because there was previous experience and expertise regarding its use as well as confidence with its multiple physical interfaces. This software is also capable of facilitates for structural analyses which is highly essential for making present design.

For any device to be constructed by using COMSOL software, it is required to follow four fundamental steps (a) defining geometry (b) adding physical interfaces (c) adding material to the solid structure and finally (d) meshing, simulation of model with inputs provided.

Communication mast was designed and analyzed by following above steps using COMSOL. Initially, geometry is defined for the proposed model, after forming the complete structure, suitable material from the available built in Materials Library is added to the proposed structure. Then depending up on the analysis to be carried out, required physical parameters are selected (discussed below). Finally the model is simulated; results are observed and analyzed with different geometries to get better communication along with enhanced stiffness ratio.

2.1. Model Construction

The model geometry includes only a short section of the diagonal tubing together with the other parts of the mounting. Even symmetry exists in both the geometry and load for the problem, this case models the entire assembly for illustrative purposes. After obtaining the stiffness of the diagonal mounting, assume that the geometry has been updated to improve the stiffness. Originally 10 mm, the plate thickness and mount thickness have been changed to 12 mm and 15 mm, respectively. The constructed diagonal model is bolted to the leg of the communication mast.

2.2. Geometry Details

Communication mast tube of height 200 mm, outer radius 50 mm, inner radius 40 mm, plate thickness 10 mm, plate radius 60 mm, plate hole radius 5 mm, plate hole distance 65 mm, mount thickness 10 mm, mount width 55 mm, mount hole radius 12 mm, mount hole distance from base 70 mm, distance between mounts 37 mm and mount thickness 10 mm is to be designed to analyze the effect of stiffness ratio based mast mounting with various geometries.

Initially select a cylinder of height 200 mm, outer radius 50 mm and inner radius 40 mm. Select the work plane and choose y-z work plane section. Build a rectangle of width 55 mm, height 70 mm. Then construct a circle of radius 27.4 mm. Form the union of both circle and rectangle. Construct another circle of radius 12 mm. Choose second circle for difference. Resultant geometry was shown below in Fig. 1.

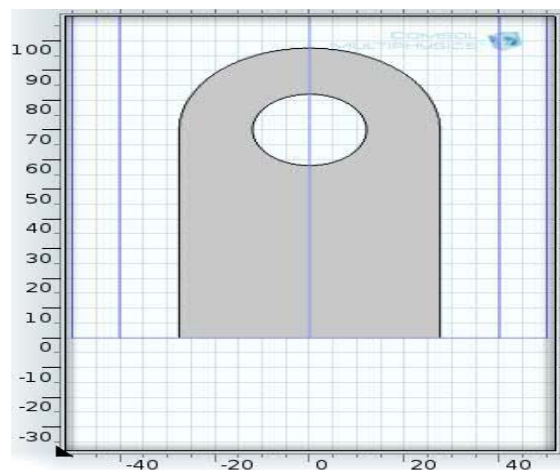


Fig. 1. Geometry after union & difference of Circle and Rectangle.

Form the union of two such work planes with the cylinder and select the option wire frame rendering on the tool bar. Then, in the graphics window, model appears as shown in the Fig. 2 given below.

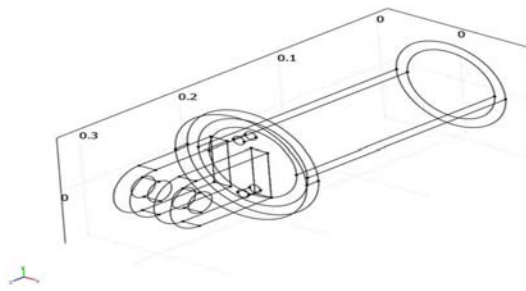


Fig. 2. Model in graphics window after wire frame rendering.

COMSOL Multiphysics provides a number of features for creating geometric primitives and for operating on them, from the available geometry structures in COMSOL Multiphysics, cylinder is chosen for construction of the tube (simulation can also be carried out for other structures). Next step is addition of material to the proposed geometry.

2.3. Material Addition for Solid Structure

Browsing the available built in Material's library, a specific material (steel) is chosen and properties are assigned to the material selected. For the present model, structural steel is chosen from the material browser.

Addition of material to the proposed structure from inbuilt material's library is done. 'Steel' material has chosen which is highly suitable for the structure and assigned to get complete solid structure. The physical properties of steel are presented in Table 1. By default the material (structural steel) is applied on all domains so any settings need not be altered. After the addition of material to the proposed model, the finishing geometry in solid form appears as shown in the below Fig. 3.

Table 1. Physical properties of structural steel.

S. No	Property	Value
1.	Young's modulus	$2.0 \times 10^{11} \text{ N/m}^2$
2.	Poisson's ratio	0.33

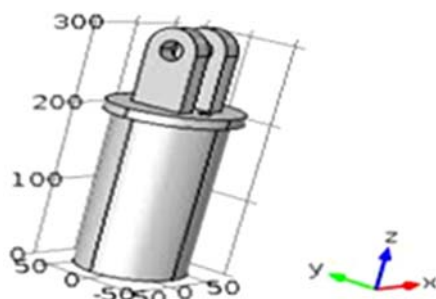


Fig. 3. Finishing geometry appeared.

Mesh section illustrates how we can mesh different parts of the model individually to get a suitable mesh.

2.4. Addition of Physical Interfaces

This model is carried out in structural mechanics. After completion of building the mast structure and addition of the material along with necessary physical interfaces, final step left over to carry out the simulation. In order to carry out simulation it is necessary to set suitable boundary conditions and inputs like thickness of plate and mount.

2.5. Boundary Conditions

The boundaries with an applied load and constrained displacements. Assume that the diagonal is loaded in tension by a force, $F = 30 \text{ KN}$, which is transferred through the bolt to the mounting.

2.6. Simulation

The process of simulation is carried out in two steps. Initially communication mast is constructed and deformation is carried out. The stiffness ratio, $S_R = S/S_{id}$ is 0.41 for the case when the plate thickness and the mount thickness are 10 mm.

As a second step, deformations are carried out with the updated geometry when plate thickness set to

12 mm and the mount thickness set to 15 mm. the stiffness ratio increases to 0.53. Fig. 4 shows the deformed shape of the diagonal mounting with a boundary plot of the displacement in the axial direction of the diagonal.

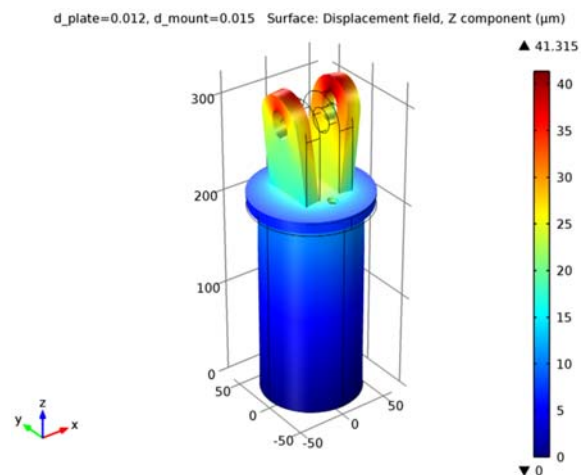


Fig. 4. Deformed shape & boundary plot of the axial displacement for the mounting assembly with an end plate thickness of 12 mm and mount thickness of 15 mm.

2.7. Changes in the Dimensions

By adding parametric sweep, the variations in the mount thickness and plate thickness have been done.

In study section, parameter values are assigned as 10 mm, 10 mm, 12 mm and 15 mm to compute the stiffness of diagonal mounting with the dimensions provided. After changing the dimensions of the plate and mount, it is found that the shape of the diagonal mounting has been deformed which can be seen very clearly in the following figure. It also indicates the increase in stiffness ratio with increase in thickness of mount and plate. The comparison of stiffness ratio with ideal stiffness ratio for the diagonal mounting has also been done and corresponding formulae are also presented with all the necessary parameter labelling. Fig. 5 shows the deformed shape of diagonal mounting for the updated model geometry.

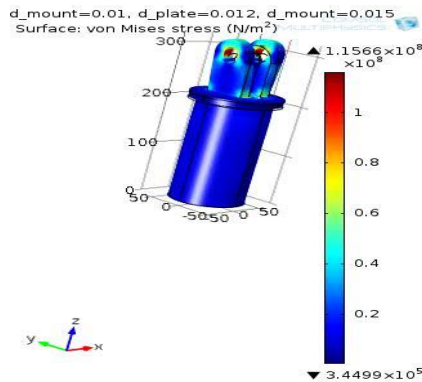


Fig. 5. Deformed shape of diagonal mounting of updated geometry.

3. Results and Discussions

Let us assume that the bolt fills out the entire hole volume. The load is distributed on the appropriate halves of the hole surfaces according to

$$p = \frac{F}{2(2r_{mh}b_{mh})} \cdot \frac{3}{2} \left(1 - \left(\frac{y}{r_{mh}} \right)^2 \right), \quad (1)$$

where r_{mh} and b_{mh} are the holes radius and the thickness, respectively.

Neglect contact conditions between the bolt and the mounting hole, and also neglect the constraint imposed on the mount by the bolt.

The stiffness of the mounting is calculated with the equation

$$S = \frac{F}{d_z}, \quad (2)$$

where d_z is the average axial displacement at the midplane of the holes, and F is the applied load. Compare this formula for the stiffness to an ideal stiffness, which would result if the diagonal tube were welded to the framework and placed under the

same load. Calculate the ideal stiffness with the equation:

$$S_{id} = \frac{E\pi(R_{tb}^2 - r_{tb}^2)}{L} \quad (3)$$

where r_{tb} and R_{tb} are the tube's inner and outer radii, and L is the total length measured in the axial direction up to the mid-plane of the mount holes.

For the material under study, the Young's modulus, E , equals 200 GPa. The stiffness ratio has been estimated by using stiffness of diagonal mounting before updated geometry (S) and stiffness after updated geometry (S_{id}). The analyses of results of stiffness have indicated that with increase in the thickness of plate and mount from 10 mm (both) to 12 mm and 15 mm, the stiffness ratio, $S_R = S/S_{id}$ is found to enhance to 0.53 from 0.41. Thus the analyses help us in estimating the stiffness ratio enhancement for the diagonal mounting such that to get incessant communication for the signal without noise at low cost effectively.

4. Conclusions

Communication mast is designed using COMSOL v 4.2. From the analyses of stiffness of mast by changing plate and mount thickness, we conclude that the stiffness ratio has been raised to 0.53 from 0.41 with increase in the dimensions of plate and mount. This kind of mast would be highly useful for incessant communication.

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