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Study on Stability of Isotrussed Grid Wind Turbine Tower

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Abstract— **We are currently living in an era where we are meeting severe energy crisis. For meeting these energy requirements, we have been relying on renewable resources of energy especially the wind energy for the past few decades. This has lead to the development of wind turbine technology all across the world. The decreasing cost of wind power and the growing interest in renewable energy sources should ensure that wind power will become a viable energy source in the world. Wind turbines are being used to generate electricity as an alternative energy source to conventional fossil fuels and it is well known that wind towers must to sustain continuous vibration forces throughout their operational life. This thesis explores the stability of isotrussed grid structures as a wind turbine tower. Isotrussed tower is a type of free standing lattice tower and are constructed with fiber filaments that are interwoven in an open lattice design. This new generation tower offer light weight, high strength and cost effective type of construction. The paper discusses about three different types of isotrussed wind turbine tower models. These three models are developed by varying the positions of longitudinal members. Different stability criterion will be explained and analysed both analytically and numerically with the help of different standards. For analytical analysis all tasks will be performed on finite element package ANSYS.**

Keywords—Wind Turbine Tower; Isotruss; Static Analysis; Dynamic Analysis.

I. INTRODUCTION

One of the bigger challenges for today's society is the change from non-renewable energy resources, such as fossil fuel consumption to renewable sources such as wind power. In the recent years, due to the worldwide interest on renewable energy resources, there has been significant advancement in wind energy technology. Therefore, the construction of wind turbines and its relevant research will rapidly increases in coming decades. The increased capacity of the wind turbines also lead to the increase in the height of the supporting towers since more energy can be extracted at higher elevations.

In a typical wind turbine project, the cost of the tower constitutes about 30 - 40 % of the total cost of the project. Therefore, selection of the tower structural system is still very important to develop a structurally and economically reliable wind turbine. A wind turbine is a complex system in which design is a matter of constant tradeoff between the competing demands of lower cost, better energy productivity, increased life time, reliability and durability and maintenance cost.

Here the wind turbine towers are proposed using IsoTrussed grid structures since they are give more stability to tower against the wind loads and to save the material. IsoTruss structures offer a lightweight and efficient alternative to traditional wood, steel, aluminium and composite structures. The highly symmetric and redundant nature of IsoTruss structures provides an attractive, efficient, and damage tolerant design. This unique form of advanced composite grid structure is revolutionizing structures as they exist today, resulting in lighter, more architecturally appealing, and more environment friendly structures.

The Isotruss is a three dimensional lattice structure and is woven with a distinct helical configuration that employs isosceles triangles to support axial, bending and torsional loads. In an isotruss structure, the helical members carry torsion and transverse shear loads and the longitudinal members carry axial and flexural loads. The helical members also stabilize the longitudinal members and are interwoven to provide highly redundant load paths, which create a damage tolerant Isotruss structure. These advantages offer significant advantages in a variety of applications.

II. METHODOLOGY

A. General

The methodologies adopted are;

The finite element procedures are done using ANSYS WORKBENCH 16.2. The geometry of the models were developed. The next step was specifying the required mesh density which determines the accuracy of the results obtained after analysis. A highly refined mesh greatly improves the accuracy while a less refined mesh decreases the accuracy of results obtained.

Next is assigning the material properties to the structural members. The various loads acting on the structure as well as the boundary conditions were applied and the analysis was done. A point load acting in the downward direction was applied at the free end of the tower. The tower is fixed at the bottom and free at the top.

The parameters like stress and deformations of the elements were noted and tabulated. The major results and findings of the project are then discussed in detail using figures and tables. The major findings of the project are again enlisted at the end under the title conclusions. Also the future scope of the project is discussed.

The different optimization strategies considered are:

a) Light weight design

The reduction in structural weight is advantageous from the production and cost points of view

b) High stiffness

Maximization of the stiffness is essential to enhance the overall structural stability and decrease the possibility of fatigue failure

c) Design for minimum vibrations

Minimization of overall vibration level is one of the most cost effective solutions for a successful wind turbine design. Reduction of vibration can be achieved by separating the natural frequencies of the structure from the exciting frequencies to avoid large amplitudes caused by resonance. Another method for reducing vibration is the direct maximization of the system natural frequencies.

B. Description of the structure

Three different isotrussed grid wind turbine towers were modeled for 1.5 Mw. They are designed as isotruss with helical and longitudinal members having 10 cm diameter. The cross section remains constant throughout the height of the tower. The structure of isotruss (8 node) has a cross sectional view having two square mutually aligned at 45°. This cross section is formed by helical winding of the fibre along the squares. The height of the tower is constant and is 60m.

C. Modeling

The tower is modelled as isotrussed grid tower and the three models were developed by varying the positions of the longitudinal members. Three different types of eight nodded IsoTruss models are developed for finite element analysis as follows;

Tower 1: IsoTruss with internal longitudinal members
Tower 2: IsoTruss with external longitudinal members
Tower 3: IsoTruss with both internal and external longitudinal members

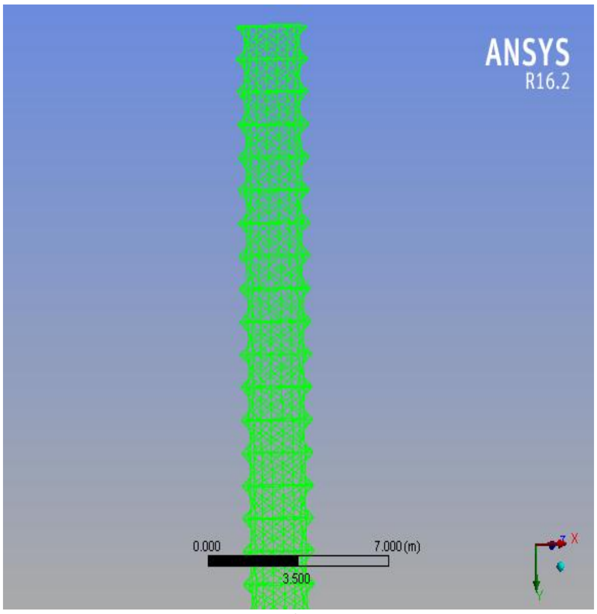

Fig. 1. Geometry of the tower in ANSYS

D. Meshing

To achieve high accuracy the meshing of the meshing of the element should be fine as possible. The results are highly depends on the quality of mesh.

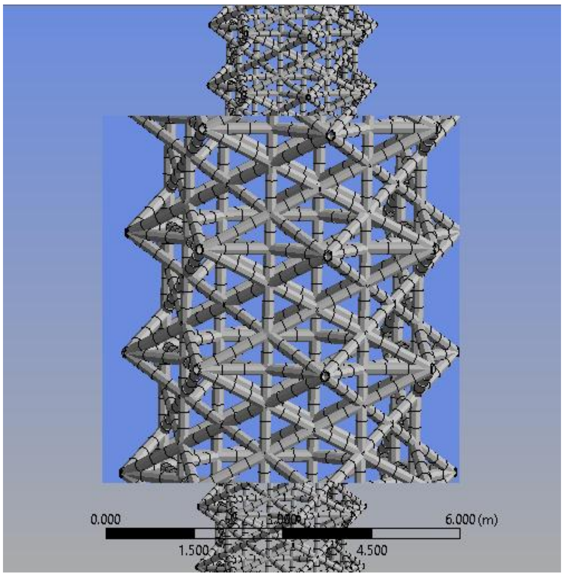

Fig. 2. Meshing of the tower in ANSYS

E. Loads and Boundary Conditions

The tower is rigidly attached to the ground, fixed – free boundary condition is applied. That is tower is fixed from the base and free at the top.

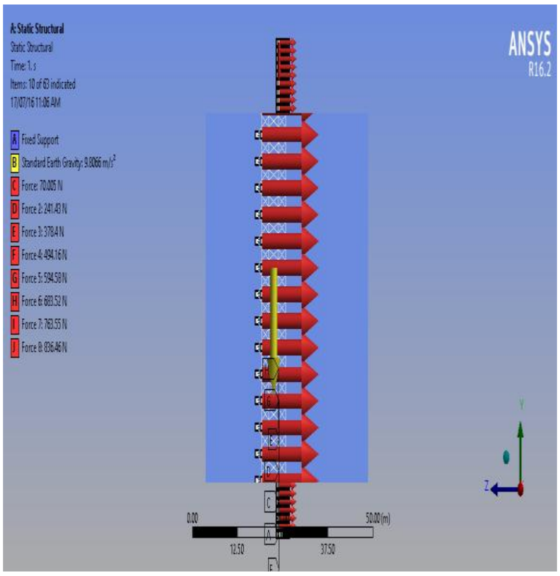

Fig. 3. Loads on the tower

F. *Finite element analysis*

The static and seismic analysis was performed on the three tower models. In static analysis only aerodynamic and gravity loads are considered. Wind load along the tower is calculated for each node up to 60m height. In this analysis the loads which are not varying with time is calculated which includes displacement analysis, principal stress and Von Mises stresses. Seismic analysis is used to determine the effect of earthquake on the structure. The material of the tower is modeled as beam 188 element. Tall towers are usually designed considering the effect of wind load as the only source of environmental dynamic disturbances. The effect of earthquakes is often neglected, even in high risk seismic areas. However, neglecting earthquake effects should at least be justified by means of appropriate methods of analysis

III. RESULTS AND DISCUSSIONS

A. *static analysis*

For tower model 1, the maximum deflection in the direction of wind comes out to be 430.68mm. For tower model 2, the maximum deflection is 256.93mm and for model 3, the maximum deflection is 164.68mm. All these deflections are well within the safe zone. The maximum Von-Mises stresses for tower model 1 comes out to be 147MPa, for model 2 it is 116MPa and for model 3 it is 73 MPa. The principal stresses are from 65MPa tensile stresses to 147MPa compressive stresses for model 1, 42MPa tensile stresses to 116MPa compressive stresses for model 2, and 30MPa tensile stresses to 73MPa compressive stresses for model 3. All these stresses are within safe zone. Graphical representation of static analysis results are shown in figure 7.

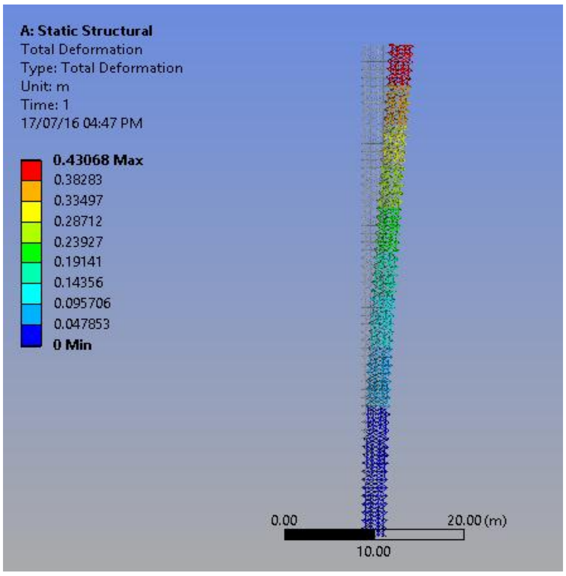

Fig. 4. Maximum horizontal deflection for tower 1

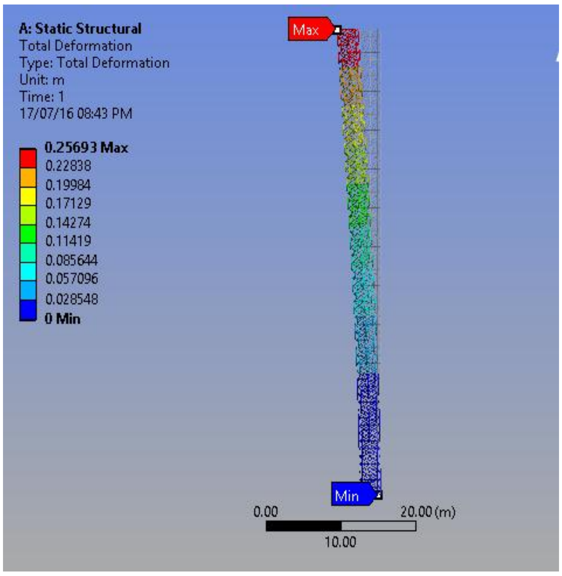

Fig. 5. Maximum horizontal deflection for tower 2

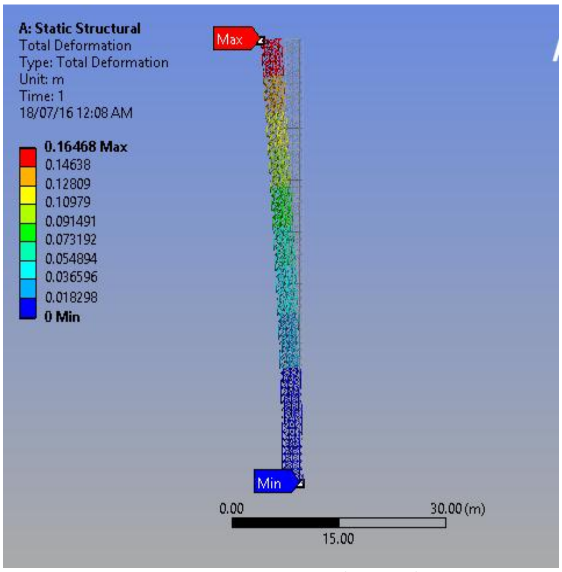

Fig. 6. Maximum horizontal deflection for tower3

TABLE I. STATIC ANALYSIS RESULT

	Maximum horizontal deflection (mm)	Maximum Von-Mises stresses (MPa)	Maximum principal stress (Mpa)	Minimum principal stress (Mpa)
Model 1	430.68	147	65	147
Model 2	256.93	116	42	116
Model 3	164.68	73	30	73

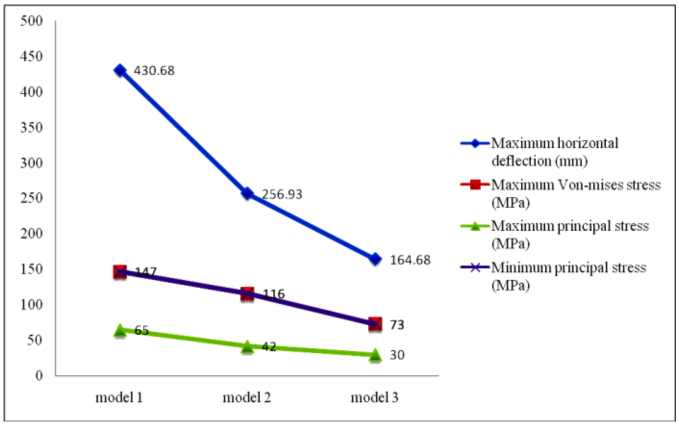

Fig. 7. Comparison of maximum horizontal deflection of models

B. Seismic analysis

Seismic analysis is performed to find out the vibration characteristics of isotruss towers. The time – displacement graph obtained for the models are given below. Tower model 1 has maximum displacement of 1.88 m. For model 2 maximum displacement is 1.64m and for model 3 it is 1.12m. The comparison of displacement of models is also given in the figure 11.

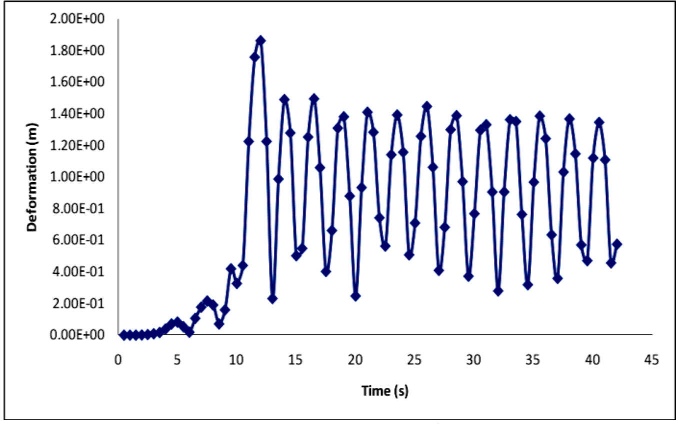

Fig. 8. Time-displacement graph for model 1

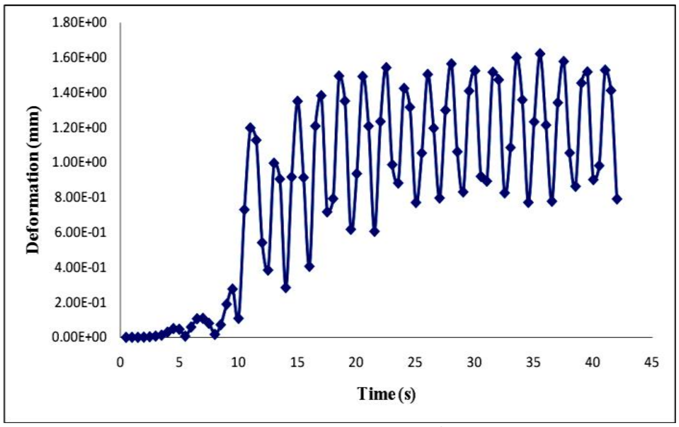

Fig. 9. Time-displacement graph for model2

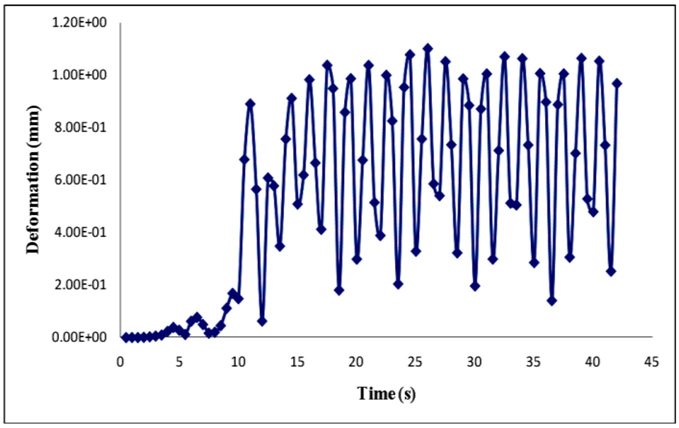

Fig. 10. Time-displacement graph for model 3

TABLE II. SEISMIC ANALYSIS RESULT

	Maximum displacement (mm)
Model 1	188
Model 2	164
Model 3	112

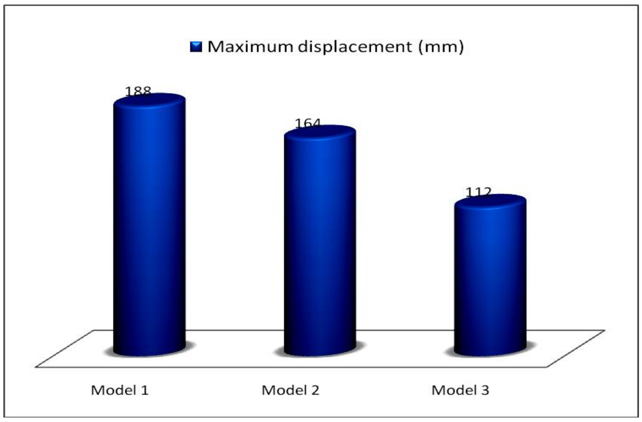

Fig. 11. Graphical representation of variation of displacement for different models

IV. CONCLUSIONS

In this work different tower models were developed based on the positions of longitudinal members. It is also observed that IsoTruss tower with both external and internal longitudinal members have better compressive buckling load carrying capacity and better strength to weight ratio in compare to other two types of IsoTruss towers.

The isotrussed tower require lesser materials for construction which reduces the material cost and it become more economical than steel tubular towers of same cross section.

In seismic analysis time – displacement graph is obtained. From this analysis it is clear that the isotruss tower with both internal and external longitudinal members show lower displacements as compared to other two types of towers.

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