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Analysis of Steel Alloy 1040 Cold Drawn Material in the Appication of Windmill Turbine

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ABSTRACT
Energy is one of the crucial inputs for social-economy and human lives. Global population is increasedday to day this result of development of activities the energy demand is also increased. Energy source is mainly from fossil fuel like oil, coal etc and also from renewable energy is like wind hydro, Geothermal energy etc.
The tower of the windmill mainly affected by various loads acting over on it such as air forces, rotating of rotors develop forces, blades weight and atmospheric temperatures. Therefore the towerwould be getting failure soon. Practically it is impossible to check the failures of the components in running condition. And also it is very difficult and makes lot of losses (material, cost, time etc).
Hence with the help of FEA SOFTWARE different materials where analyzed and found that the Steel Alloy 1040 Cold Drawn material deflection was low

I. INTRODUCTION

It was a gaint - the world's largest with a rotor diameter of 17 m (50 ft) and 144 rotor blades made of cedar wood. Note the person mowing the lawn to right of the wind turbine the turbine ran for 20 years and charged the batteries in the cellar of this mansion. Despite the size of the turbine, the generator was only a 12 kW model. This is due to fact that slowly rotating wind turbines of the American wind rose type do not have a particularly high average efficiency.

La Cour was one of thepioneers of modern aerodynamics and built his own wind tunnel for experiments. He was concerned with storage of energy, and used the electricity from his wind turbines for electrolysis in order to produce hydrogen for the gaslight in his school.
One basis drawback of this scheme was the fact that he had to replace the windows of several school buildings several times as the hydrogen exploded due to small amounts of oxygen in the hydrogen

II. LITERATURE REVIEW

T. Aravinthan& T. Omar [1] they proposed to concepts of designing fibre composite structures highlighting some of the challenges faced in the design and development. The background of the project and the design considerations are discussed showing the importance of the early coordination between the design and manufacturing. With the main structural system based on sandwich construction, its behavioral issues and failure modes are presented. As there is no design codes or guidelines can be located in the literature, engineering judgment, understanding of the basic modes of failure of the structure and the manufacturing limitations and tolerances are essential in developing the appropriate design. The paper concludes with general discussion of using fibre composites as main structural elements in complex shaped structures.

Ching-Wen Chien, Jing-Jong Jang [2] they proposed to during the last decade, many wind turbine towers damage were caused by typhoons strike repeatedly. As the cost impact of buckling failure, this study starts to investigate the characteristics of wind turbulence and buckling resistance procedure is presented. The theories of the dynamic wind loading in along-wind and across-wind with/without the tensional force are applied to analysis the total wind force. Furthermore, the finite element analysis is used to obtain the across-wind force of the response. The total wind force without considering tensional force will be underestimated 4.2%, therefore when the maximum deflection is closed to 1 %, the tensional force should not be ignored for the safety design.

Jasbir S Arora [3] he had formulated to optimal results taking into consideration the cost, computational time, construction techniques and precision of structural models. Finite element dynamic model was carried out to accomplish the structural analysis. The design variables are geometrical properties and reinforcement steel area of the structural elements. To compute the cost function, consider the costs of concrete and steel. Constraints related to stress, displacements and frequencies of vibration are applied. To solve the optimizations problems, used the augmented Lagrangian Method for dynamic structural problems.

Leithead [4] he had explained the exploiting the pitch control capability of variable speed turbines to alleviate tower fatigue loads. The most direct method is to modify the blade pitch angle in response to a measurement of tower acceleration. It is shown that the _flap mode has a central role in determining whether this approach is effective since there is a strong interaction between the blade flap-wise mode and the tower fore-aft mode. Several different approaches to the design of the controller for the tower speed feedback loop are investigated. It is concluded that a reduction in the tower loads of up to 18% is possible for multi-megawatt sized wind turbines.

J. Peeters [5] he had demonstrated the application of a generic methodology, based on the flexible multi body simulation technique, for the dynamic analysis of a wind turbine and its drive train, including a gearbox. The analysis of the complete wind turbine is limited up to 10 Hz, whereas the study of the drive train includes frequencies up to 1500 Hz. Both studies include a normal modes analysis. The analysis of the drive train includes additionally a response calculation for an excitation from the meshing gears, a Campbell analysis for the identification of possible resonance behavior and a simulation of a transient load case, which occurs as a sudden torque variation caused by a disturbance in the electrical grid.

A.F. Abdel [6] he had a computing package that combines finite element methods for evaluating the resonance frequencies and modes of turbine subcomponents (blade, tower and shaft) together with the aerodynamic calculations for forces and moments taking into consideration the dynamic stall as well as the dynamic response is developed. This method was applied to a realistic VAWT; namely; the PIONEER built in the Netherlands by Fokker Company. A reasonable agreement between the calculated and field results was predicted.

Scott Larwood Mike ZuteckUC Davis MDZ Consulting Davis, CA Clear Lake Shores, TX [7] they proposed a work is part of a Department of Energy contract for increased wind energy capture at low-wind speed sites. The blade works by twisting to feather under aerodynamic loads at the outboard region. Comparisons were made to an upswept rotor of the same diameter and a baseline 50-m rotor. The results demonstrated the twisting and load-reduction behavior of the swept rotor. Little detriment in the power curve was shown with the swept blade, and substantial power increase over the 50 m baseline was obtained in below-rated power.

Serdaryildirim, Ibrahim ozkol [8] they proposed to the impact loads on tower is calculated within the highest safety conditions against buckling strength of each sections of tower by each means of GA codes. The stiffness along tower is ensured entirely while the mass of tower is mitigated and optimized.

A.N. Singh [9] he had explained the increasing emphasis on sustainability, the providers of electrical energy has recognized the need to tap wind energy for power generation. To meet the ever increasing demand, the wind energy towers will have to become taller so that the rotors receive more wind and currents. Concrete as a material of construction can play an important role in realizing the potential of wind energy. This paper provides the scenario of wind energy in India and also an overview of design concepts of concrete towers used for hoisting the rotors.

III. DESIGN CALCULATION OF WINDMILL TOWER

1. Design Input for Tower:

Rated power of wind turbine
= 350 MW/hr

Load due to blade
= 1100 kg

No of blades
= 3

Total load due to blades W_1
= 3300 kg

Load due to gear box and Shaft W_2
= 5500 kg

Load due to generator W_3
= 1030 kg

Total load on the tower W_4
= $W_1 + W_2 + W_3$

= 3300+5500+1030

= 9830 Kg

Factor of safety F.S
= 1.25

Working load on the tower
= F.S X (W_4)

= 1.25 x 9830

= 12287.5 Kg

Basic wind speed
= 55 m/sec

Height of the tower
= 50 m

2. The Following Materials Are Selected For Construction Of Tower

- IS 1161 YST 315 steel
- Steel alloy 1040 cold drawn

3. 1st material is 1161 yst 315 steel material properties

1. Material = AS PER IS 1161
2. Young's modulus (E) = 1.99 x 10^5 N/ mm^2
3. Yield strength = 315 N/ mm^2
4. Tensile strength = 500 N/ mm^2
5. Poisson Ratio = 0.3

4. Dimension Of Tower

Base diameter of tower = 3500 mm
Top end diameter = 2275 mm
Thickness of the tower shell = 25 mm
Standard formulae for Moment of inertia of Round hollow section I = $(\pi/64) \times (D^4-d^4)\ mm^4$
Area a = $(\pi/4) \times (D^2-d^2)\ mm^2$

At section 1-1
Moment of inertia at Section 1-1 I_1 = $4.119 \times 10^{11}\ mm^4$
Area a_1 = $272.925 \times 10^3\ mm^2$
At section 2-2
Moment of inertia at Section 2-2 I_2 = $3.308 \times 10^{11}\ mm^4$
Area a_2 = $253.68 \times 10^3 mm^2$
At section 3-3
Moment of inertia at Section 3-3 I_3 = $2.611 \times 10^{11}\ mm^4$
Area a_3 = $234.441 \times 10^3\ mm^2$
At section 4-4
Moment of inertia at Section 4-4 I_4 = $2.0197 \times 10^{11}\ mm^4$
Area a_4 = $215.199 \times 10^3\ mm^2$
At section 5-5
Moment of inertia at Section 5-5 I_5 = $1.524 \times 10^{11} mm^4$
Area a_5 = $195.956 \times 10^3\ mm^2$
At section 6-6
Moment of Inertia at Section 6-6 I_6 = $1.118 \times 10^{11}\ mm^4$
Area a_6 = $176.71 \times 10^3\ mm^2$
Average moment of inertia I = $2.449 \times 10^{11}\ mm^4$
Averagearea a = $224.819 \times 10^3\ mm^2$

5. Crippling Check

Tower is fixed foundation on bottom the entire load act on the top of the tower so the tower may buckle due to this static load so check for buckling is required Check for buckling According Euler's theory

Crippling Load

One end is fixed other end is loaded
Crippling load P = $(\pi^2 \times E \times I) / (L)^2$
= $\{(2x10^5)^2 \times (1.99 \times 105) \times (2.449 \times 10^{11})\} / (2x\ 50 \times 10^3)^2$
P = 48.099×10^6 N
y = (y1 +y2 +y3 +y4 +y5 + y6)/6
= 1192.92 mm
Section modulus Z = I/y
= $205.29 \times 10^6\ mm^3$
Bending stress σ = M_{net} / Z
Induced stress = 54.83 N/mm^2

Therefore induced bending stress in the tower is less than the allowable stress hence the design is safe ($s_{induced} < s_{allowable}$)

6. Check for Deflection at the End of the Tower:

Due to wind W = 226.372×10^3 N
Load per unit length = $(226.372 \times 10^3) / (50 \times 10^3)$
w = 4.527 N/mm
δ = $(w \times L^4) / (8 \times E \times I)$
δ = 17.5085 mm

IV. COMPUTATIONAL ANALYSIS

To solve any problem in ANSYS it mainly follows the following steps. These are common steps to all problems except material properties and type of analysis used.

1. Preliminary decisions:
2. Pre processing:.
3. Solution:
4. Post processing:

The above steps are briefly explained in the following section.

The preprocessor modeling enables us to build the geometric of the part to be analyzed and which generates the finite element model and their data required for solver module. It reads the geometric parameters, loading characteristics, and boundary condition and material properties.

The solution module enables us to solve the elemental solution by reading the type of analysis to be made.

The post processor module enables us to access the results of finite element analysis in various forms types. Printing of all/selected nodal displacement values of stress values. As the definition goes the structure is modeled in the preprocessor module.

In all the analyzing packages, the actual model is built with plane, shell or solid elements that represent the orientation of the structure in the actual environment. For the blades a total of 4 elements are taken by follows:

- PLANE 42.
- SOLID 45.

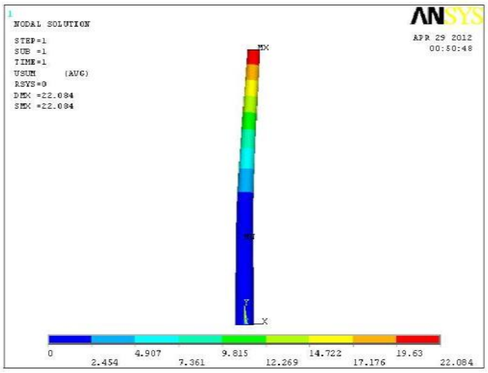
Zero volume elements are not allowed.
Elements may be numbered either as shown in "SOLID45 Geometry" or may have the planes IJKL and MNOP interchanged.
The element may not be twisted such that the element has two separate volumes. This occurs most frequently when the elements are not numbered properly.

Sl.No	Material Type	Yield Strength (N/mm^2)	Tensile Strength (N/mm^2)	Young's Modulus (N/mm^2)	Poisson ratio
1	IS 1161 YST 315 Steel	315	500	1.99x10^5	0.3
2	Steel Alloy 1040 Cold Drawn	490	590	2.07x10^5	0.3

Table 5.1 : The Two Types of Material Properties

V. RESULT AND DISSCUSSIONS

5.1. Comparison of Four Materials Displacement Vector Results:



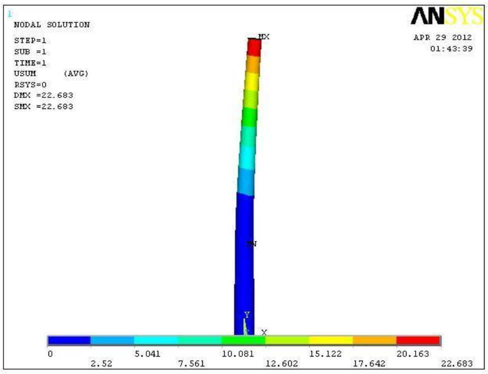
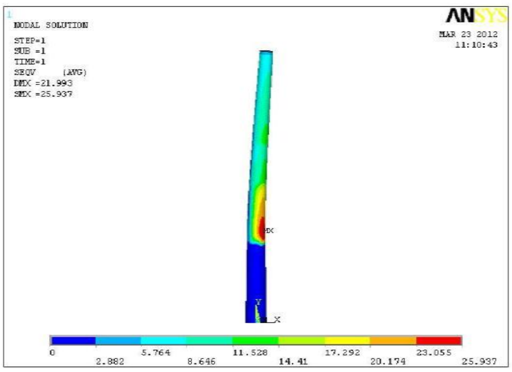


Figure 5.1: Displacement Vector.

Figures 5.1 show the displacement vector. The first figure is IS 1239 MTD Steel deformation valve is varying from base to the top. In the figures the blue colored are shows the less deformation i.e. **-0.229E^{-03} mm** and at the middle of the tower colored green shows the some more greater than the base i.e. **19.554 mm** and at the top of the tower the deformation is **35.2mm** these value lie in allowable value of 0.05 degree hence the design is safe.

5.2. Comparison of Four Materials Stress Results:



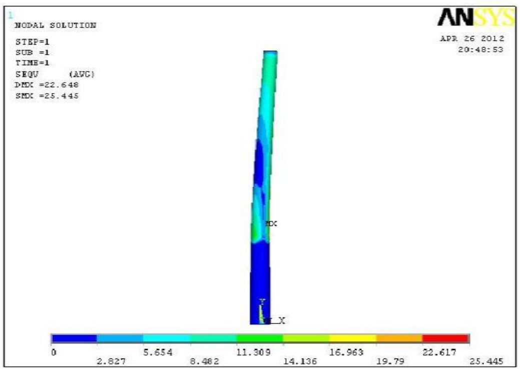
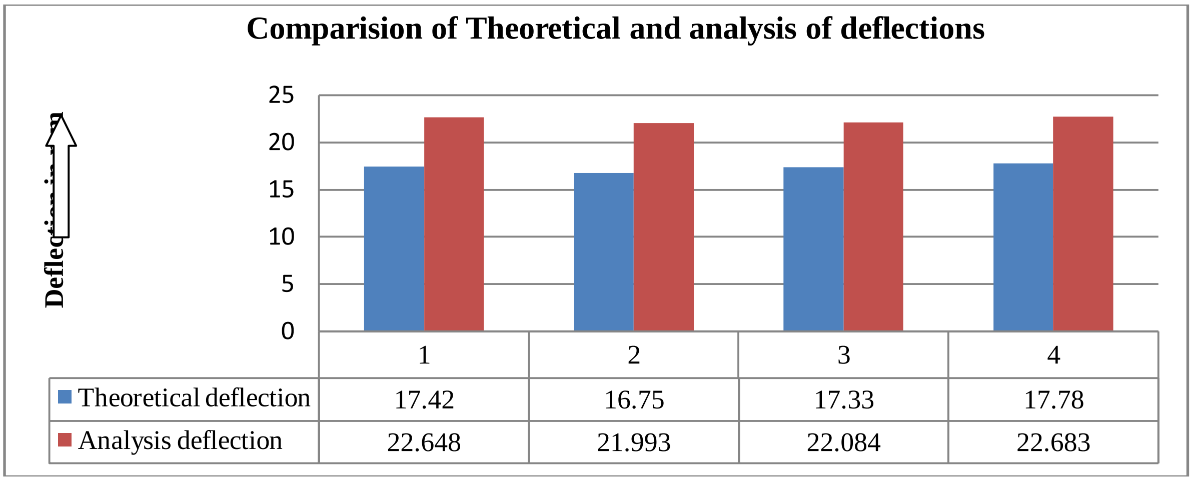


Figure 5.2: Von Misses Stress

The Von Misses stress is used as criteria in determining the failure in ductile material. The failure criterion states that the VonMisses stress is should be less than the yield stress .Of the material. (s_{vm}<s_y). Here above result shows that the stresses induced in the tower is gradually decreasing from middle to the top. The maximum stress induced at the middle of the tower is **31.417 N/mm^2**that is show as red colored region. This maximum induced stress is less than the allowable stress.

5.3 Deflections of Four Materials:



No of Materials

Figure 5.3: Deflections of Four Materials

- The above graph represents the theoretical and analysis deflections of different materials.
- The above graph represents in x-axis are shown no of materials and y-axis are shown deflections in mm.
- The Steel Alloy 1040Cold Drawn and 1239 MTD Steel graph represents minimum and maximum deflections respectively.

5.4 RESULTS OF DIFFERENT MATERIALS:

SlNo.	Material Type	Yield Strength (N/mm^2)	Tensile Strength (N/mm^2)	Young's Modulus (N/mm^2)	Poisson Ration	Crippling load (N)	Theoretical Deflection (mm)	From Ansys Deflection (mm)	Stress (N/mm^2)
1	IS 1161 YST 315 Steel	315	500	1.99x10^5	0.3	45.009x10^6	17.50	22.645	25.445
2	**Steel Alloy 1040 Cold Drawn**	**490**	**590**	**2.07x10^5**	**0.3**	**50.033x10^6**	**16.75**	**21.993**	**25.937**
3	IS 1161 YST 310 Steel	310	450	2.00x10^5	0.3	48.341x10^6	17.33	22.084	25.757
4	IS 1239 MTD Steel	235	410	1.95x10^5	0.3	47.132x10^6	17.78	22.683	25.425

Figure 5.4: Results of Different Materials

VI. CONCLUSION

- Concluded that the **Steel Alloy 1040 Cold Drawn Material** have little **deflection** when compared to other materials.
- The obtained theoretical, analysis deflection values of the**Steel Alloy 1040 Cold DrawnMaterial**and **IS 1239 MTD Steel**are 16.75 mm, 21.993 mm and17.78mm ,22.683mm respectively.
- From the above it is confirmed that the **Steel Alloy 1040 Cold Drawn Material** is best for construction of the windmill tower.

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