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Finite Element Analysis On 302 Stainless Steel To Avoid Failure Of Windmill Tower

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Abstract

The wind energy is converted to electrical energy by means of wind turbine, the turbines are installed in regions where the wind speed is more and there are many components that are mounted on the steel structured tower. The tower of windmill is mainly affected by various loads acting over on it, such as air forces, rotating of rotors develops forces, blades weight and atmospheric temperatures. Therefore the tower would be getting failure soon. The reduction on deflection of the wind mill tower is necessary for reducing the occurrence of failure. The material is also one of the reasons for occurring failure in wind mill tower. The five materials are taken into the consideration and analysed using finite element package ANSYS. The deflection value is calculated by analytical and also using finite element package ANSYS for that five materials. It is found that 302 stainless steel gives low deflection value when compared to other materials.

Keywords:302 stainless steel,Windmill tower,Failure, Deflection,ANSYS

Introduction

Each of the components has it function to run wind turbine successful nacelle, gear box, rotor, tower, main shaft or low speed shaft, control mechanism, generator, yaw mechanism, anemometer and wind vane, brake system. [3] The 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 & manufacturing, the important structural based on sandwich construction [4], its behavioural issues and failure modes are obtainable. It 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 [5]. The paper concludes with general discussion of using fibre composites as main structural elements in complex shaped structures. [6] They proposed to during by typhoons strike repeatedly. In last decade, continuous typhoons strike lot of wind turbine tower damaged. [7] In this study, investigation is carried out for the characteristics of wind turbulence and buckling resistance. [8] In this 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 and the finite element analysis is used to obtain the across-wind force of the response [9]. 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 [10]. The suggested 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 [11]. The stiffness along tower is ensured entirely while the mass of tower is mitigated and optimized.

2. Design Calculation of Wind Mill Tower

2.1 Design Input for Tower

Rated power of wind turbine = 350 MW
Load due to blade = 1100 kg
No of blades = 3
Total load due to blades P_1 = 3300 kg
Load due to gear box and Shaft
P_2 = 5500 kg
Load due to generatorP_3 = 1030 kg
Total load on the towerP_4 =P_1+P_2+ P_3 = 3300+5500+1030 = 9830 Kg
Factor of safety F.S = 1.25
Working load on the tower = F.S X (P_4)
= 1.25 x 9830 = 12287.5 Kg
Basic wind speed = 55m/sec
Height of the tower = 50 m

2.2 Selection of Materialsfor construction of Tower

1. IS 1239 MTD steel
2. IS 1161 YST 310 steel
3. IS 1161 YST 315 steel
4. Steel alloy 1040 cold drawn
5. AISI 302 stainless steel

The deflection at the end of the tower for the **IS 1161 YST 315** steel is calculated theoretically by following procedures

2.3 Dimensions of Tower

Base diameter of tower = 3500 mm
Top end diameter = 2275 mm
Thickness of the tower shell = 25 mm

The tower cross section is conical so standard moment of inertia is calculated by taking 6 section and average of 6 sections.

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

$I_1 = (\pi/64) \times (D_1^4 - d_1^4)$

$= 4.119 \times 10^{11}\ mm^4$

Area, $a1 = (\pi/4) \times (D^2 - d^2)$

$= 272.92 \times 10^3\ mm^2$

Average moment of inertia

$I = (I_1 + I_2 + I_3 + I_4 + I_5 + I_6) / 6$

$= 2.44 \times 10^{11}\ mm^4$

Average area

$a = (a_1 + a_2 + a_3 + a_4 + a_5 + a_6)/6$

$a = 224.81 \times 10^3\ mm^2$

2.4 Deflection at the End of the Tower

End of tower $\delta = (w \times L^4) / (8 \times E \times I)$

Total load on tower Due to wind

$W = 226.37 \times 10^3$ N

Load per unit length

$= (226.372 \times 10^3) / (50 \times 10^3)$

$w = 4.52$ N/mm

$\delta = (w \times L^4) / (8 \times E \times I)$

$\delta = 17.508$ mm

3. FEA Model of Tower

3.1 Define the structural problem:

The above mentioned materialsis taken one by one and modelled and applies the several loads on the top and side and bottom of the tower. **Modelling-**The tower is modelled by using ANSYS.

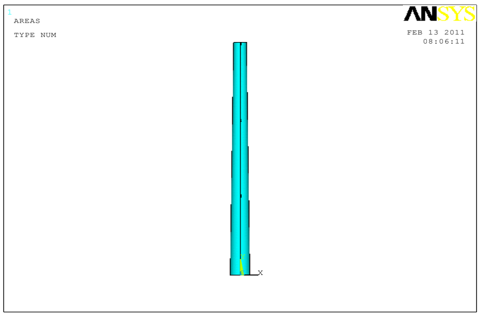

Fig.3.1 FEM model of tower.

Meshing-The element type is solid brick 8node plane45 and the mesh type is global size of element edge length is 500 Volume mesh.

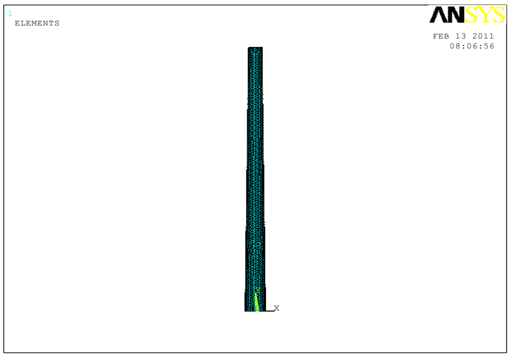

Fig.3.2 Meshed model of tower.

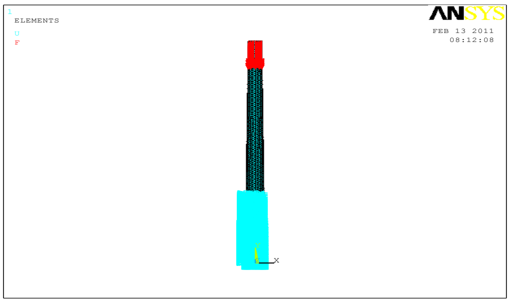

Fig .3.3 Loads applied on tower.

Figure 3.3 shows the loads are applied on tower. The total load is 12287.5kgs is applied top end of the tower and normal pressure is 0.003645 N/mm^2 applied in the side of the tower and the up to 15 meters at bottom of the tower is constrained because of with stand the deflection.

4. Comparison of Displacement Vector results

The first figure is IS 1239 MTD Steel deformation valve is varying from base to the top. In the figures the blue coloured are shows the less deformation i.e. **-0.229E^{-03} mm** and at the middle of the tower coloured 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.

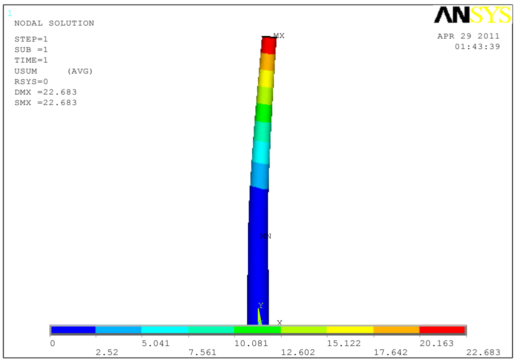

Fig.4.1 displacement value of IS 1239 MTD Steel

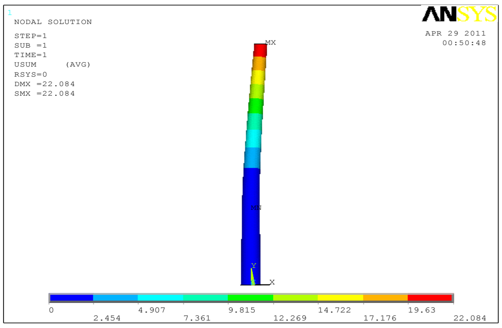

Fig.4.2 displacement value of IS 1161 YST 310 Steel

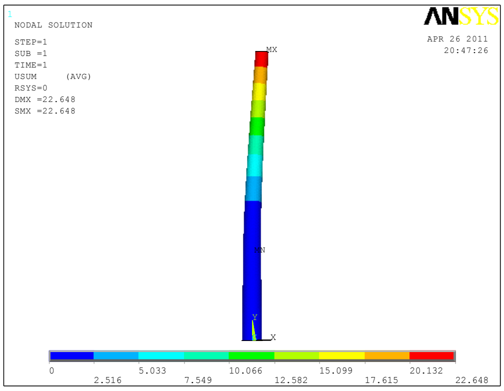

Fig.4.3 displacement value of IS 1161 YST 315 Steel

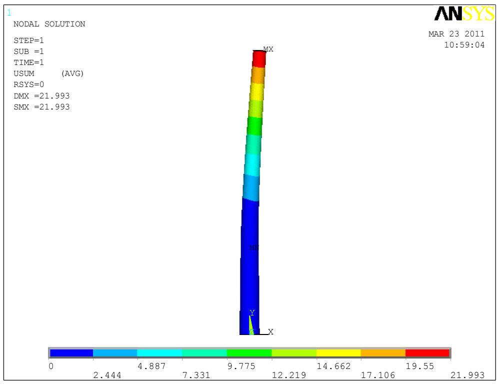

Fig.4.4 displacement value of Steel Alloy 1040Cold Drawn

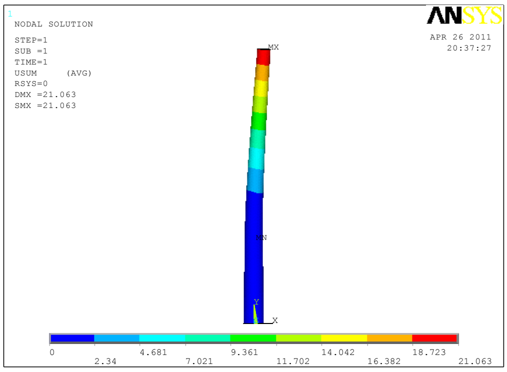

Fig.4.5 displacement value of AISI 302 stainless steel

The above figures show the results of displacement of IS 1239 MTD Steel,IS 1161 YST 310 Steel, IS 1161 YST 315 Steel, Steel Alloy 1040Cold Drawn, AISI 302 stainless steel deformation valves is varying from base to the top.

5. Comparison of Stress results:

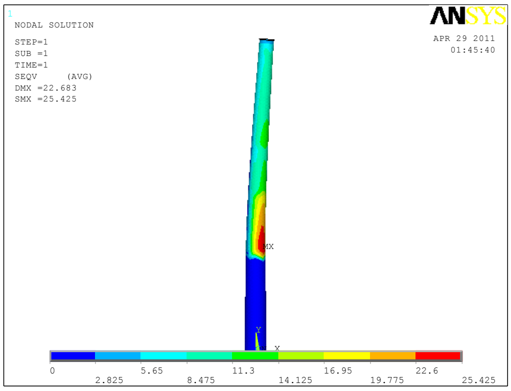

Fig.5.1 Stress value of IS 1239 MTD Steel

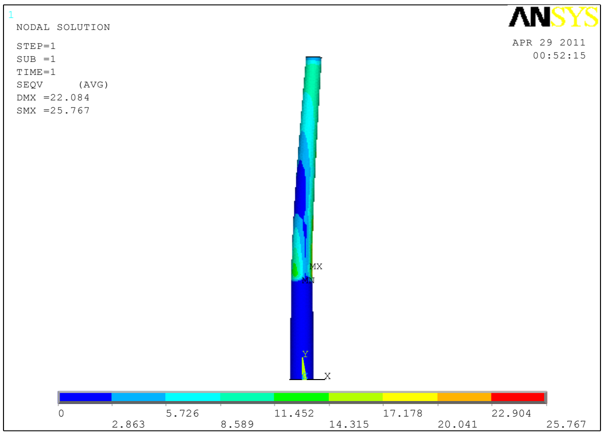

Fig.5.2 Stress value of IS 1161 YST 310 Steel

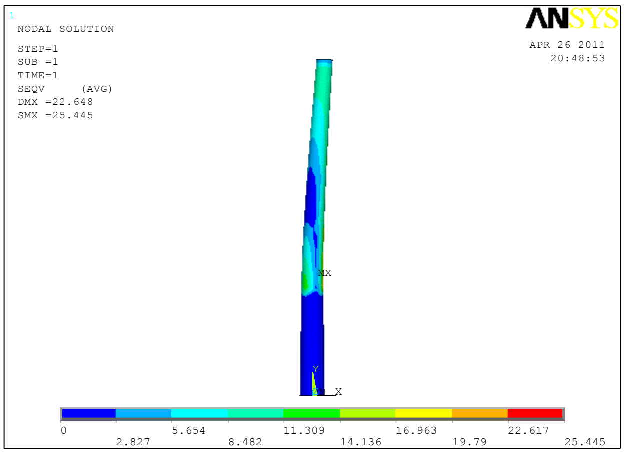

Fig.5.3 Stress value of IS 1161 YST 315 Steel

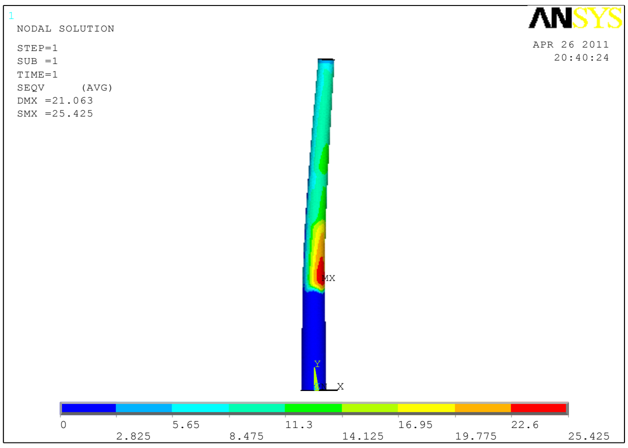

Fig.5.4 Stress value of Steel Alloy 1040Cold Drawn

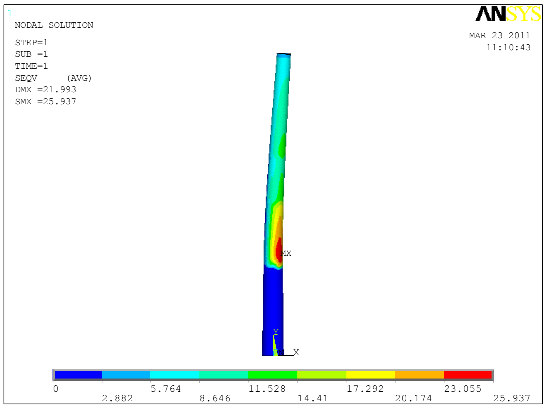

Fig.5.5 Stress value of AISI 302 stainless steel

The Vonmises stress is used as criteria in determining the failure in ductile material. The failure criterion states that the Vonmises stress is should be less than the yield stress of the material. ($\sigma_{vm} < \sigma_y$). Here above result shows that the stresses induced in the tower is gradually decreasing from middle to the top. This maximum induced stress is less than the allowable stress.

Deflections of Five Materials

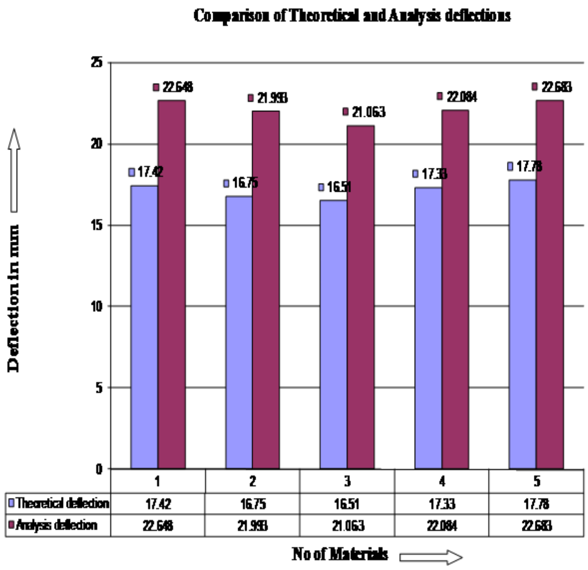

Fig.5.6 Deflections of five materials.

- The figure 5.6 shows the deflections of five different materials.
- It is seen from the above figure theAISI 302 Stainless Steel and 1239 MTD Steel represents minimum and maximum deflections respectively
- It is seen from the above figure theSteel Alloy 1040Cold Drawn and IS 1161 YST 310 Steel represents minimum and maximum deflections respectively.

S.No	Types of Material	Yield strength N/mm^2	Tensile Strength N/mm^2	Young's modulus N/mm^2	Poisson ratio	Theoretical Deflection Mm	Deflection (Ansys) mm	Stress N/mm^2
1	IS 1239 MTD STEEL	235	410	1.95X10^5	0.3	17.78	22.68	25.42
2	IS 1161 YST 310 STEEL	310	450	2X10^5	0.3	17.33	22.08	25.76
3	IS 1161 YST 315 STEEL	315	500	1.99X10^5	0.3	17.50	22.64	25.44
4	STEEL ALLOY 1040 COLD DRAWN	490	590	2.07X10^5	0.3	16.75	21.99	25.93
5	AISI 302 STAINLESS STEEL	520	860	2.1X10^5	0.3	16.51	21.06	25.54

Table1: Deflection and stress values of different material

6. Conclusion
It is concluded that the theoretical and FEA deflection values of AISI 302 stainless steel material are 16.51 mm and 21.063 mm. These are the lowest deflection values when compared to other materials such as IS 1239 MTD Steel, Steel Alloy 1040Cold Drawn, IS 1161 YST 315 Steel, IS 1161 YST 310 Steel. From the table 3.2 it can also be observed that the tensile strength increases, which directly reflects in reduction of deflection. The percentage of **Mn** in **AISI 302 stainless steel** material slightly increases the strength of ferrite and the hardness of steel, similarly the percentageof **Cr** in the material increases the toughness and wear resistance of steel. From this discussion it can be concluded that the **AISI 302 stainless steel Material** isbest for construction of the windmill tower.

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