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Design of Steel Tower Prototype of 3KW Wind Turbine in Jarmh City

Altaher O. Alreda[1*], Zakareia A. Alarabi[2], Abduesslam A. Maki[3]

[1,2,3] Department of Petroleum Instrumentations Higher Institute of Petroleum Technology Awbari, Libya

[*]*Corresponding author: redaaltaher708@gmail.com*

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Abstract:

To extract energy from wind, wind turbines emerged as one of the most efficient ways of converting the kinetic energy in wind into mechanical power. In order to take advantage of the wind speed increases are available at these heights, and access to design the most efficient and safe or optimization of the structures that support them will become increasingly important for the successful spread of wind power. This study tries to provide the design to create a tower of small wind turbines in rural areas in the South of Libya in the context of limited access for homes or small companies. The objectives of this study are: 1) determination of technical specification of steel tower; 2) general design of tower construction; 3) design support bearings at the top of the tower; 4) design of bearings and calculation its lifetime.The technology of finite element and numerical analysis is used to find different criteria to determine the response of structural and dynamic in terms of the distribution of maximum stress and deflection. Both static and buckling analysis of towers are used; in which static analysis, the loads not varying with time is calculated with analysis of principal stress and Von Mises stresses. Whereas, in buckling analysis, the eigenvalues and the buckling modes are obtained under the axial compressive load, by ignoring otherloads and gravity effects.Based on findings of this study, it can be concluded that the tubular tower with variable diameters is better than a fixed diameter tower; as firstly, related with D/t Ratio should be minimum as possible and should be chosen with respect to both critical buckling load and allowable buckling stress. Secondly, from maximum stresses it should have high strength at the base. Finally, by the variable thickness along the tower height, it is concluded that tapered tubular tower has high strength at the base, as it has an economical option in which reducing both material and cost.

Keywords: buckling, finite element, numerical analysis, steel tubular tower, static analysis.

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1. INTRODUCTION

The importance of renewable energy is recognized. Actually, the only renewable energy which grown faster is wind energy. Its used to produce energy is one of the major forms of renewable energy. One major advantage of wind energy is that it is substantially economic way of producing energy.

Renewable energy is energy which comes from natural resources such as sunlight, wind, rains, tides, waves & geothermal heat which are renewable (naturally replenished).[1] About 16% of global final energy consumption comes from renewable, with 10% coming from traditional biomass, which is mainly used for heating, & 3.4% from hydroelectricity.

To extract energy from wind, wind turbines emerged as one of the most efficient ways of converting the kinetic energy in wind into mechanical power.[2] Many energy providers invested in research and development of wind turbines. As, nowadays, they are installed in many countries.

However, during the last decade many wind turbine damage occurs due to the structural failure of wind turbine towers. Majority of these failures are caused by the strong wind striking the structure or wind induced vibrations. Others are caused by high stresses and buckling loads.[3]

Wind turbine towers are designed as thin-walled structure having thickness very less than the diameter. In order to reduce the weight of tower, the vertical dimensions of the tower is relatively large compared to its horizontal dimensions. This slender nature of wind turbine tower makes it more sensitive to wind loading. There are many different configurations in which wind turbine support structure is designed. It common practice to design wind turbine towers as taper tubular column since they are give more stability to tower against the wind loads and to save the material.

2. METHOD

The methodologies of this study can be seen as the following figure 1.

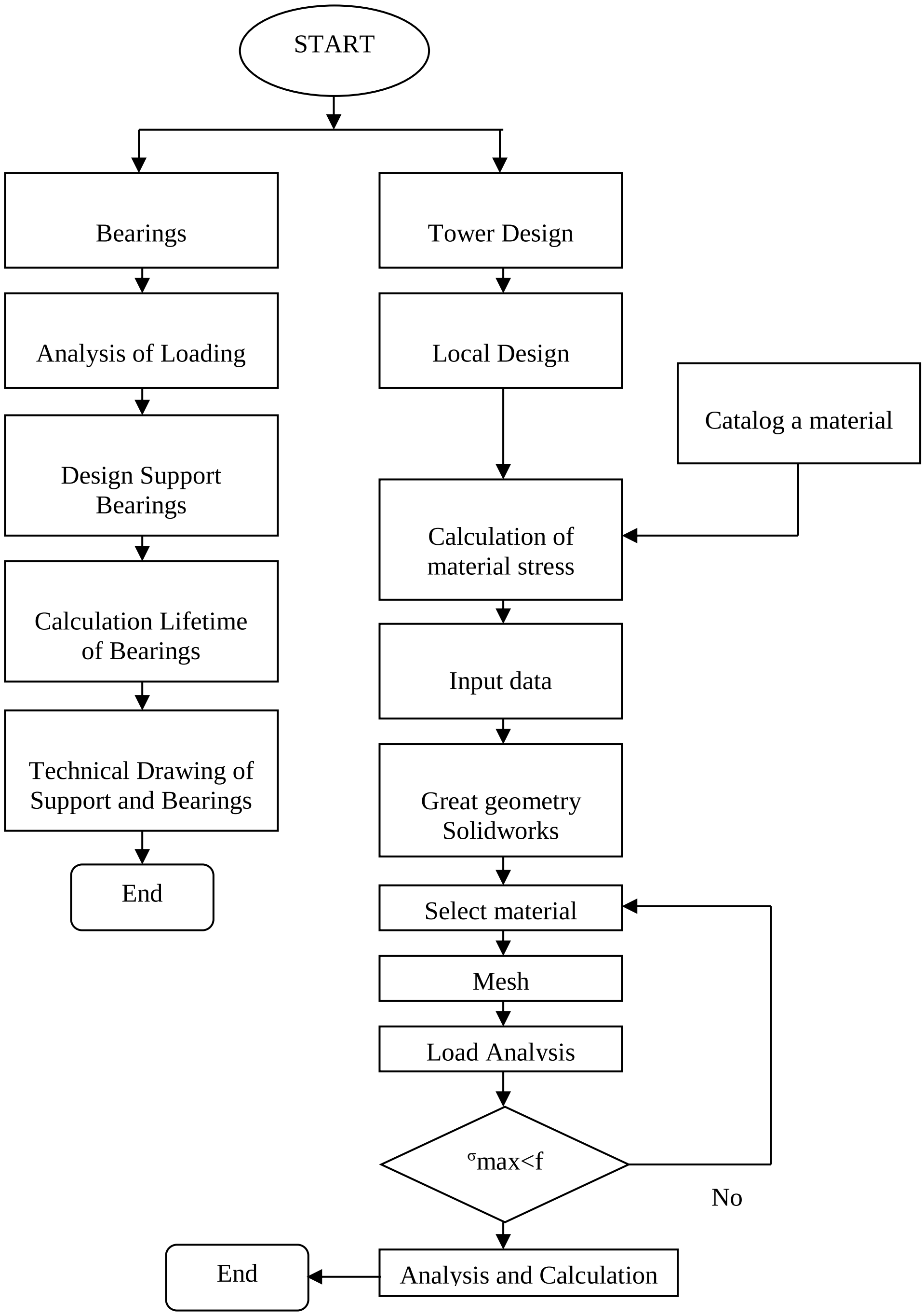

Figure 1. Flowchart of the Methodology.

2.1. Methodologies of Tower

Tower design process of wind turbines involves a conceptual implementation of a number of basic steps followed in this process until it is gotten the best results by analyzing loads using simulation program.

2.2. Design Procedures

The first step in the design is to determine the type of application from entering data through a combination of special design in order to get the best results.

2.3. Review Previous Experience

This section of the process deals with the review and investigation of the previous design of similar wind turbines. Reviewing previous work helps for troubleshooting and allows the designer not only to narrow down the available options, but also gain some direction as to conducting the design process.

2.4. Build Prototype

Building the prototype is done through the free sample of the tower, which has a component of three sections. Each section is circular in shape but differs from the other for the length and diameter and thickness.

2.5. Preliminary Loads Estimate

In the early stages of design it is important to have an approximate idea of what sort of loading the wind turbine will be subject to. It helps in narrowing down the design of individual components and employed techniques such as scaling and 'rule of thumb'. The estimates made in the preliminary stages of design are adjusted throughout the project duration to conform to the required design specifications. It will be done with the use of FEA programs such as Solidworks.

2.6. Material Used in Wind Turbine Towers

ASTM 572 is most commonly used material in wind turbine towers. ASTM A572 Grade 50 is considered a "workhorse" grade and is widely used in many applications. ASTM 572 is a high strength, low alloy steel that finds its best application where there is need for more strength per unit of weight. Less of this material is needed to fulfill given strength requirements than is necessary with regular carbon steels. In addition, ASTM A572 is noted for its increased resistance to atmospheric corrosion. Particularly Grade 50 contains more alloying elements than plain carbon steel and thus is somewhat more difficult to form. Grade 50 is more difficult to cold work, but can be successfully bent or shaped but requires more force than plain carbon steel. It is commonly used in structural applications, heavy construction equipment, building structures, heavy duty anchoring systems, truck frames, poles, liners, strength per weight ratio.

Table 1. Material Properties for A572

Material	Composition	Thickness	Elastic Modulus (Mpa)	Yield Stress (Mpa)	Percentage Elongation (Gauge Length)
ASTM 572	0.18C,1.2Mn, 0.44P,0.05Si	25	200	350	25

2.7. S355 JR (Equivalent to ASTM 572)

S355 structural steel plate is a high-strength low-alloy European standard structural steel covering four of the six "Parts" within the EN 10025 – 2004 standard. With minimum yield of 350MPa, it meets requirements in chemistry and physical properties similar to ASTM A572 / 709. Careful attention should always be placed on the specific variation of S355 required if considering substitute material. S355 is used in almost every facet of structural fabrication. Typical applications such as structural steel-works: bridge components, components for offshore structures, power plants, mining and earth-moving equipment, load-handling equipment, wind tower components,

In this study, it is used ASTM 572 for the wind turbine tower design, so its design and calculations are based on its material properties.[4]

2.8. Tower Stress

The turbine tower supports the nacelle containing the gearbox, braking system and electric generator along with the rotor. It experiences both compression and a bending moment aboutits footing. The compression is due to the weight of the nacelle and rotor whilst the bending moment is induced by the thrust caused by drag forces on the rotor. The tower itself also experiences an unevenly distributed force due to the drag forces created by the oncoming wind. In comparison to the thrust of the rotor, the force experienced by the pole due to drag is quite small.[5]

Figure 2. Loading of Tower.

For the above turbine with a 6 m tower, loading is calculated for the maximum windspeed of 5 m/s (Table 2).

Table 2. Loading on the Tower

Trust force	Axial load
116.5711 (N)	100kg*9.81=981 (N)

2.9. Methodologies of Bearings Support

2.9.1. Analysis of Loading System

It is calculated the effect of loads hanging over support depending on the weight of the nacelle and rotor for axle load and trust force of the wind.

2.9.2. Support Design

Support design aims so it fits with the bearings, which connects the lower end of the support to the upper end of the tower through the flange. And also, upper limb for supporting the based upon the nacelle.

2.9.3. Calculation of the Vertical Axis Bearings

In this part is for calculating the static capacity of the vertical bearings, but is not calculated the dynamic-capacity because the rotation speed of the vertical axis is going to be low. The bearings chosen are angular contact ball bearings and taper rolling bearings, it because that type of bearings are design to support high axial forces.

Table 3. Types of bearings

No	Type	SKF
1	Angular contact balls bearing	QA50
2	Taper roller bearing	30210

2.9.4. Calculation of the Lifetime for the Bearings

In this case, it is calculated the length of time for the work of bearings according to the previous equations and based on the values taken from the tables for the life factor and speed factor.

2.9.5. Drawing Support Bearings

Based on the diameters it is drawn the support bearings, including bearings and flange structure associated with the highest tower. As shown in Fig 3a, 3b, and 3c.

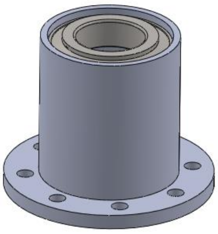

Figure 3a. Support Bearing.

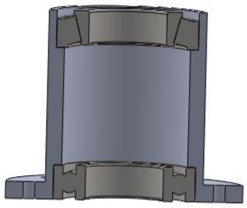

Figure 3b. Cross Section of Support.

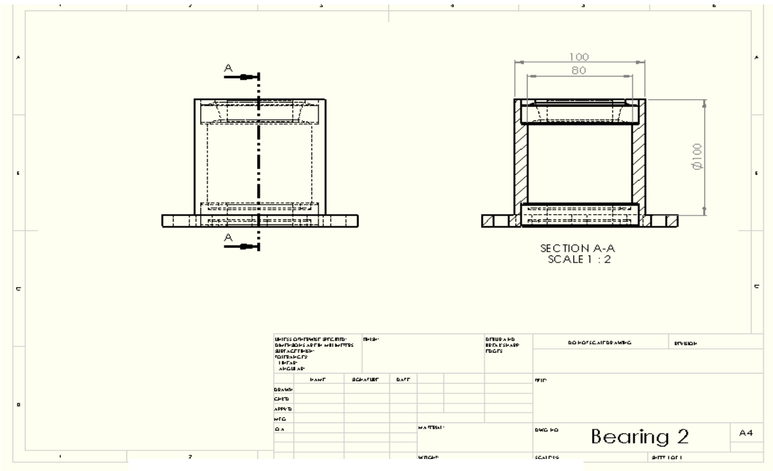

Figure 3c. Dimensions of Support.

3. DISCUSSION

In static analysis, the loads not varying with time is calculated with analysis of principal stress and Von Mises stresses. In buckling analysis, the eigenvalues and the buckling modes are obtained under the axial compressive load, by ignoring other loads and gravity effects.

The model of wind turbine tower as a solid 3D tapered tubular tower which shown in Fig 5. is composed of 3sections connected each other. The tower is modeled in three-dimensional space, and a Cartesian coordinate system is chosen for the finite element modeling.

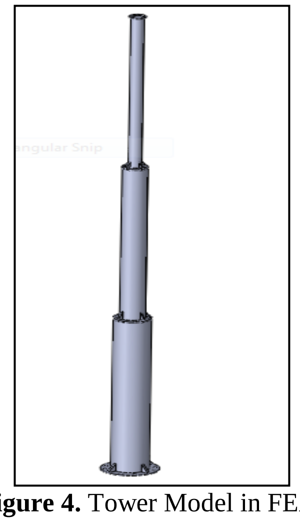

Figure 4. Tower Model in FEA.

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The tower is modeled as linear isotropic material and the ASTM 572 is used as a wind turbine tower material. The properties of the material are given as input to the Solidworks which are modulus of elasticity, E=200GPa and poisson's ratio, ν=0.3. It is important to note that the during analysis only elastic region of ASTM 572 is assumed.

When Meshing the Model, to achieve high accuracy the meshing of the element should be fine as possible. The results are heavily depends upon the quality of the mesh. The meshing of tower is done by applying approximate global size of 0.07. The meshed model of tower is shown in figure 5 below.

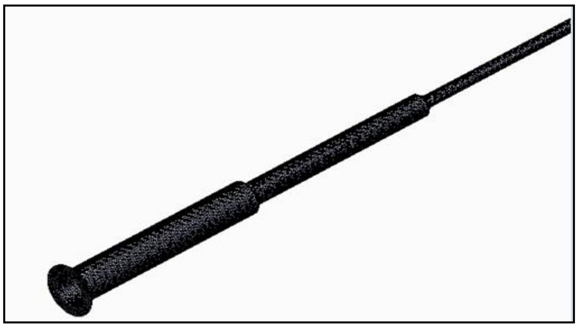

Figure 5. Meshing of tower.

The supporting conditions of the tower as shown in the figure above, it is assumed that the tower is rigidly attached to the ground, fixed-free boundary condition is applied i.e. tower is fixed from the bottom and free at the top.

In static analysis of wind turbine tower, von mises stresses and principal stresses are obtained under static loads (not varying with time). Tower the static load at the top of rotor/nacelle is applied whole at a concentrated load. Wind load along tower is applied at an wind conditions which is obtained at the hub height of 6 m at extreme wind speed of 5 m/s. it is then converted into pressure according to the equation:

$P = 1/2\rho V^2 C_d$

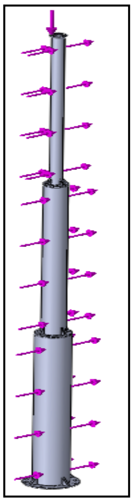

Figure 6. Loading conditions in static analysis of tower.

In buckling analysis of wind turbine tower eigenvalues are obtained under axial compression(static load of rotor/nacelle). All the other loads (wind load, gravity) are neglected. Results for tower analysis von mises stress and displacement in tower can be seen in the figure 7 and 8 below.

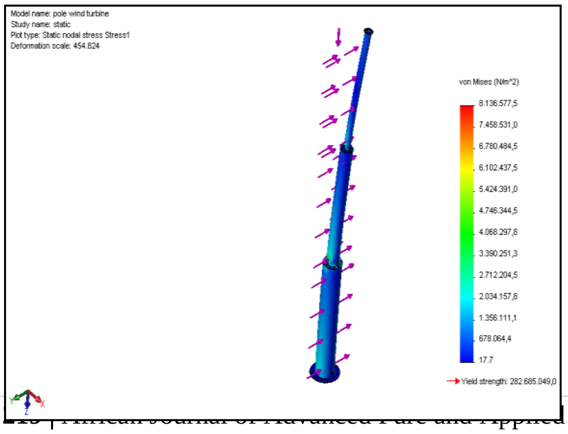

Figure 7. Von Mises stress in tower.

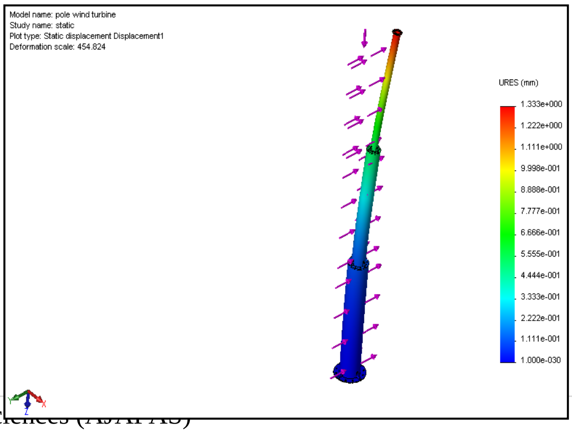

Figure 8. Displacement in tower.

Whereas, the analytical calculation is as shown in the following table:

Table 4. Analytical calculation of Tower

Elastic Buckling Load (Ncr)	Allowable Buckling Stress Method	Maximum Stress	Deflection of Tower
278.26KN	249,99MP_a	16.88 MP_a	1.84 mm

4. CONCLUSION

Based on findings of this study, it can be conclude that the tubular tower with variable diameters is better than a fixed diameter tower; as firstly, related with D/t Ratio, the tower becomes more prone to local buckling as the D/t ratio increases. In order to design the tower against local buckling the D/t ratio should be minimum as possible. However, it should be understood that at smaller cross-section the critical buckling load reduced significantly. So, D/t ratio should be chosen with respect to both critical buckling load and allowable buckling stress. Secondly, from maximum stresses occur at the base of the tower (fixed support end), so tower should have high strength at the base. Finally, by the variable thickness along the tower height, it is concluded that tapered tubular tower has high strength at the base. It has variable thickness; which is thicker at the base and as moving up along the tower height, the thickness gradually decreases. It is also known that the maximum stresses occur at the base and as moving up that the stress magnitude decreased. Thus, the tapered tubular tower with variable thickness is an economical option in which reducing both material and cost.

References

[1] Burton, T., Sharpe, D., Jenkins, N., & Bossanyi, E. 2001. *Wind Energy Handbook*. West Sussex, England: John Wiley & Sons Ltd.

[2] Burton, Tony and Nick, Jenkins. 2001. *Wind Energy Handbook Second Edition*.UK

[3] D. Malcolm, 2004. *Wind pact rotor design study: hybrid tower design*," tech. rep., National.Renewable Energy Laboratory (NREL), April.

[4] Gere & Timoshenko. Mechanics of material: *Design of wind turbine tower and foundation systems: optimization approach John Corbett Nicholson*.University of Iowa.

[5] Inam, Muhammad & Khan Dr.Muhammad Kashif. (SUPARCO). *Buckling of thin shells*: Recent advances and trends by Jin GuangTeng Department of'Civil and Structural Engineering, Hong Kong Polytechnic University, Hung Horn, Kowloon, Hong Kong.

[6] Lu, X., McElroy and M. B., Kiviluoma, J. 2009. Global potential for wind-generated electricity. *Proceedings of the National Academy of Sciences of the United States* 106, no. 27: 10933-10938.

[7] Negm, Hani M. and Maalawi, Karam Y. 1999. Structural Design Optimization of Wind Turbine Towers. *Computers and Structures* 74 (2000): 649-666.

[8] Riso National Laboratory and Wind Energy Department. 2002. *Guidelines for Design of Wind Turbines*, 2nd Edition Det Norske Veritas, Copenhagen

[9] Silva, Marcelo A., Arora, Jasbir S., and Brasil, Reyolando MLRF. 2008. Formulations for the Optimal Design of RC Wind Turbine Towers. *Engineering Optimization 2008– International Conference on Engineering Optimization* (June).

[10] The European Wind Energy Association, Economics of wind," in Wind Energy, The Facts (Wind Facts), 2009.

[11] Ugural, Ansel C. and Saul K. Fenster. 2003. *Advanced Strength and Applied Elasticity.*4th ed. New Jersey: Prentice Hall.

[12] Worcester polytechnic institute. 2010. *Wind turbine design and implementation*. EN 1993-1-1: eurocode 3: design of steel structures (EN 1993-1-1 Clause 6.3.1).