

# Design and Manufacturing of Composite Tower Structure for Wind Turbine Equipment

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**Abstract.** This study proposes the composite tower design process for large wind turbine equipment. In this work, structural design of tower and analysis using finite element method was performed. After structural design, prototype blade manufacturing and test was performed. The used material is a glass fiber and epoxy resin composite. And also, sand was used in the middle part. The optimized structural design and analysis was performed. The parameter for optimized structural design is weight reduction and safety of structure. Finally, structure of tower will be confirmed by structural test.

## 1. Introduction

In recent years, the wind generation technologies have been ameliorated by intent investment and researched work on improved technique based on former developed technique due to fossil fuel depletion, and become big size wind turbine technologies more than megawatt blade. Thus, a supporting tower structure of large class wind power plant equipment was became big size. The composite material is multiply used to reduce the blade's weight in the structural design for wind power plant blade. However, various large scale towers for wind turbine systems were made by steel. If a tower applied to composite is designed, the market of wind power plant will be increased.

According to literature survey results, M. Feyzollahzadeh studied investigation on wind load response of offshore wind turbine towers with fixed monopile platform [1]. N. Bazeos studied on stability analysis about tower manufactured by steel structure [2]. Dimos J. P. was performed the dynamic and static characteristics about glass fiber reinforced plastic towers [3]. From the literature reviewed results, many studies of tower made by steel were performed. In the research work, study on manufacturing procedure of glass and epoxy material tower was carried out.

## 2. Design requirement of tower

It is necessary to specify the specification of system for the purpose of wind turbine tower design. It is horizontal axis wind turbine system with rate output of MW class as for the specification of the wind turbine tower. A normal wind speed is 12.8m/s. The tower structure specification to be designed was shown Table 1. From the literature review of 2 megawatt class wind power plant blade, the most of towers are height of 80m [4]. But, the study chooses the height of 100m tower for application of 4 megawatt scale wind power plant blade system as well as 2 megawatt. Designed tower was partitioned as four parts for easy transportation. The first section is diameter of 3m. The diameter of second part is 3.4m. The diameter of third part structure is 3.7m. The section diameter of bottom structure is 4m. Structural analysis of load cases were performed for the tower design and manufacturing. The three



wind load cases were investigated. The one case is rated wind velocity condition. The two cases is cut-out wind velocity condition. The three cases is storm wind velocity condition. In the wind load cases, a thrust force condition occurred by wind turbine rotor system. And also, various equipment and tower weight will be reflected as design load cases [5,6]. Table 2 shows loads for tower analysis and manufacturing. A filament winding process was adopted for tower manufacturing.

**Table 1.** Design requirement of tower

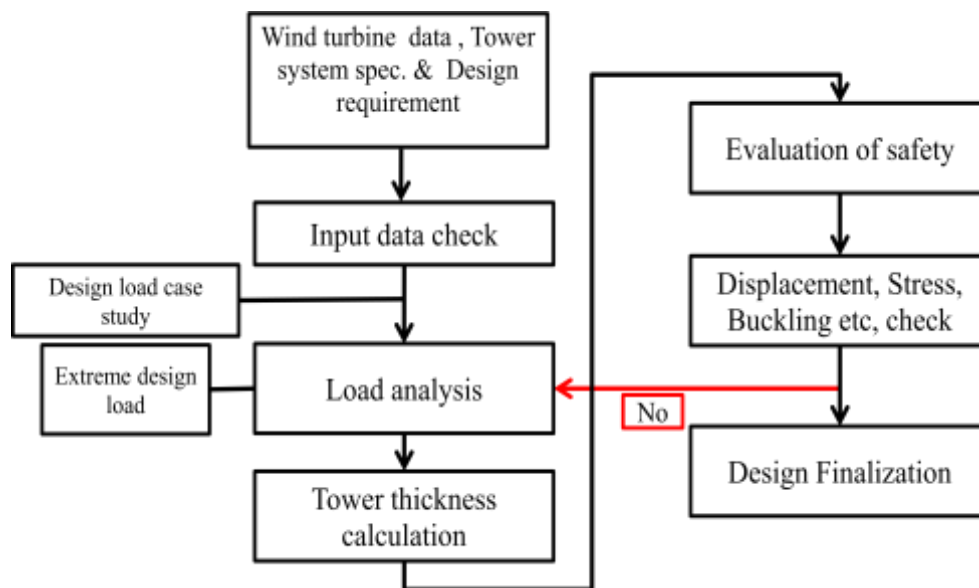
Design requirement	
Rated power	2MW
Diameter	3.0~4.0m
Height	100m

**Table 2.** Load case of tower

Load cases	Case 1	Case 2	Case 3
Wind velocity	8.0m/s	20.0m/s	55.0m/s

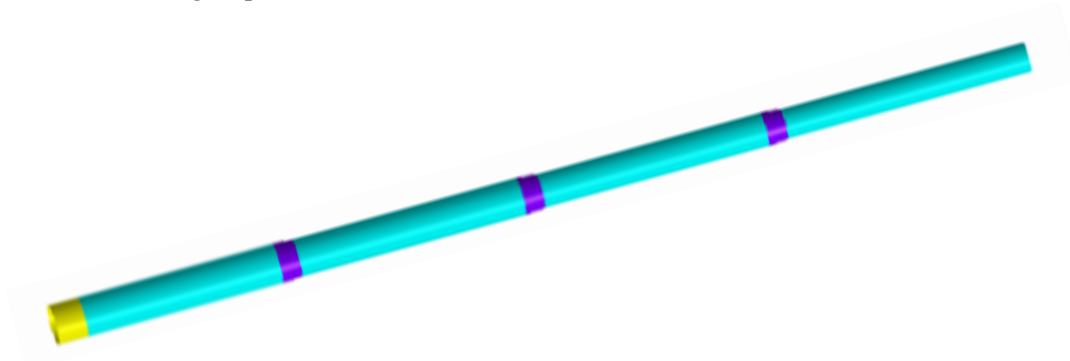
### 3. Structural design and analysis

Structural design was performed after tower load case analysis. The design of tower was previously performed using designed metal tower specifications, the structural shape and configuration, a manufactured process. After investigation on metal wind power plant structure, composite tower structure was designed. Fig. 1 shows a design method in this work. A section of tower was partitioned into four structures such as top section, second section, the third section and the bottom section. The jointed parts between each section part have a truncated shape. Fig.2 shows the designed tower configuration.

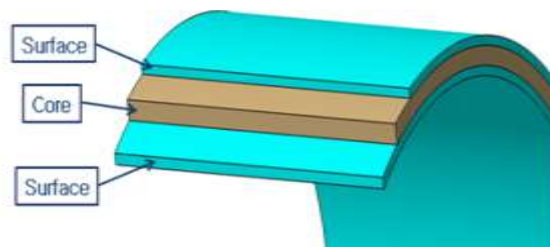


**Figure 1.** Design procedure of tower for wind turbine system

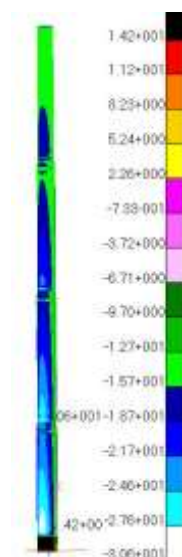
The structural analysis was performed to investigate structural safety of designed structural result. In this study, finite element method was adopted for structural analysis. The failure criterion analysis [4] was applied for the safety check. The result of structural analysis for each load cases confirmed that it has been designed with a safe tower structural configuration ensuring sufficient safety factor. Table 3 shows the result of load condition-specific finite element linear static analysis result. In this study, the optimized thickness and winding pattern is defined considering proper structural safety, deformation at the top of tower. Among the various stacking patterns, the pattern  $[0/90]_{20s}$  has the lowest displacement and stress. Fig. 4-7 show stress contour of each lay-up patterns. It is confirmed that the best stacking sequence condition is  $[0/90]_{20s}$ .



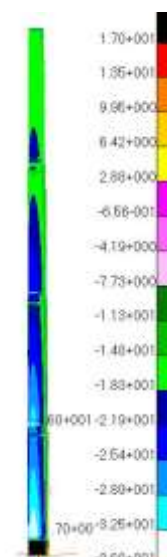
**Figure 2.** Configuration of designed tower



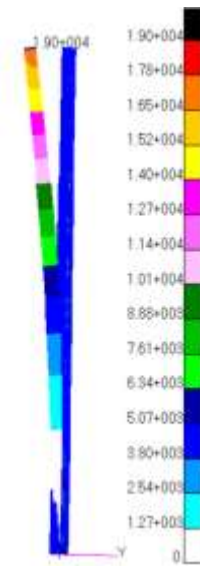
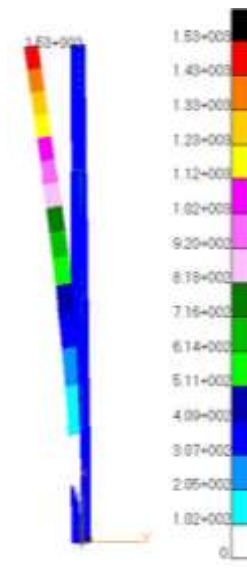
**Figure 3.** Section view and structural shape of designed tower



**Figure 4.** Stress analysis result of pattern 1



**Figure 5.** Stress analysis result of pattern 2

**Figure 6.** Deformation of pattern 1**Figure 7.** Deformation of pattern 2**Table 3.** Structural analysis results

Lay-up pattern	[0/90] <sub>20s</sub>	[45/90] <sub>20s</sub>	[0/90/45] <sub>20s</sub>
Compressive stress	31 MPa	36 MPa	43 MPa
Tensile stress	14 MPa	17 MPa	21 MPa

#### 4. Structural optimization, manufacturing and structural test

According to the deformation and stress analysis, tower deformation is large deformation. Thus, both applying composite structural type applied to glass, epoxy and sand core and increasing thickness is adopted to decrease the deformation as well as to get the safety of tower. The optimal design of tower thickness was conducted by the increasing through confirming both the structural deformation and the stability. Among ten design results, the 10th case is selected as final tower designed results that satisfy both the safety and structural stability and the top deformation. Finally, the weight of proposed 100m height tower applied to composite is 270ton. That is lighter than the 80m metal tower having from 450 to 700ton. In order to analyze the cost of the composite material tower, the cost of production is compared with the metal tower's manufactured cost. A filament winding manufacturing process was adopted for cost effective manufacturing. After manufacturing tower, it was performed the structural test. The compressive strength test of prototype tower was performed by UTM equipment. The compressive analysis result is 3.41MPa and the test result is 3.42MPa. Therefore, it is investigated that the composite structure is safe through stress analysis and test result. Fig. 8 shows the manufacturing process of composite tower using filament winding manufacturing method. Fig. 9 shows compressive strength test of manufactured tower.



**Figure 8.** Manufacturing process of composite tower



**Figure 9.** Compressive strength test of manufactured tower

## 5. Conclusions

This study performed the design and analysis of composite tower about two megawatt scale wind power plant system equipment. A glass and epoxy skin part and sand core composite structural shape was applied to considering on manufactured expense. And also, optimal tower designed reducing the weight with structural safety, structural stability. It was investigated that the composite material wind power plant tower structure is safe through analysis results of stress contour, deflection and eigen value, and lighter than metal structures.

## Acknowledgments

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## References

- [1] M. Feyzollahzadeh, M. J. Mahmoodi, S. M. Yadavar-Nikraves and J. Jamali 2016 Wind load response of offshore wind turbine towers with fixed monopile platform (*Journal of Wind Engineering and Industrial Aerodynamics* vol 158) pp 122-138
- [2] N.Bazeos 2002 Static, seismic and stability analyses of a prototype wind turbine steel tower (*Engineering Structure* vol 24) pp 1015-1025
- [3] Dimos J. Polyzois, Ioannis G. Raftoyiannis and Nibong Ungkurapinan 2009 Static and dynamic characteristics of multi-cell jointed GFRP wind turbine towers (*Composite Structure* vol 90) pp 34-42
- [4] Spera D. A. 1994 *Wind turbine technology* (ASME Press)
- [5] Desire Le Gourrieres 1982 *Wind Power Plants Theory and Design* (Prefamon Press: Oxford)
- [6] Robert M. Jones 1999 *Mechanics of Composite Materials* (Taylor and Francis: London)