A PARAMETRIC STUDY OF WINDTURBINE SPARCAP IN BASALT FIBER USING FINITE ELEMENT ANALYSIS

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ABSTRACT

In a wind turbine blade the chief structure which is responsible for the resistance of the force and bending moment is spar cap, its size has a significant impact on the blade mass and the stiffness of the blade. This paper presents the design and analysis for a spar cap for a wind turbine rotor blade. These studies are conducted parametrically, examining a range of Hexagonal basalt fibre material with glass and hence exhibiting a superior of structural performance of wind turbinespar cap and also reduce the usage of glass fibre material costs. The length of the beam,, the locations of the spar cap and the thicknesses of shear webs are taken as design variables. These parametric studies are used to determine the stress distribution and deformation of spar cap and resulting from the hybrid materials studied..The concepts' of parametric FEA was determined using ANSYS and Compared with the existing glass fibre

Keywords: Wind Turbine Blades, Spar Cap Design, Finite Element Method Simulation

I **INTRODUCTION**

Bending moments and tension caused by different loads such as wind force, blade weight and centrifugal force as one of the most important parts of wind turbines and hence the blade is required to have a reasonable structural form, advanced materials to endure the superior structural performance [8].The spar cap is a load-carrying aerodynamic structure, which consists of the suction and pressure, aerodynamic shells together with shear webs as shown in Fig. 1. Therefore, the superior and lightweightmaterials have a decisive influence on the structural performance of the blade. Because of the light-weight, high-strength, good corrosion resistance and designable characteristics, composite materials are broadly used in virtually every area of our life, from aerospace to medicine applications, and also in wind turbine industry. However, the structural design analysis of these blades is very complex and are high cost too. Decreasing the use of the materials and minimizing the blade mass by optimizing the blade structure or layer orientations of the materials, is the only way of the effectively reducing the cost. Which means to improve the structural performance, the upper shell is the aerodynamic suction side and the lower shell is the aerodynamic pressure side. The aerodynamic shells and the shear webs are separately manufactured and then assembled to the final blade [2-4]. As such, the present paper proposes a solution that provides a resultant product that is a hybrid of glass and basalt fibre that achieves good performance of blade as compared with existing material. In general, the cost advantage or disadvantage of glass fibre replacement will depend on the cost ratio of labour to materials. In order to take advantage of glass properties, the basalt fibre is embedded to the glass fibre as an alternate layer. This basalt composites is as a novel materials and, ease manufacturing methods must provide reduced labour time. LihueLv et al.17 studied the mechanical properties of glass/ basalt fibre composite materials with experiments and the Finite Element Method (FEM) and The results showed that the glass/hybrid structure composite with a hexagonal cross-section shape had the maximum load than triquetras cross-section shape[5].

The spar cap is the chief structure to endure the force and bending moment in a blade, its size has a significant impact on the blade mass and the stiffness of the blade [3]. To ensure the security and stability of the blade under different load cases, the spar cap layup is generally thicker, thus the blade could not make full use of the materials. Hence, the material layup numbers of the spar cap can be properly decreased to reduce the cost of production.

The bending loads are highest in the inboard region, near the root of the blade. Hence, the inboard region needs an efficient structure that can support the bending loads. These hybrid composite provide favourable aerodynamic performance and also limit the overall blade mass (and cost). Recent research suggests that improving performance in the inboard region of the blade may improve the overall blade performance. Conventionally, the inboard region used thick air foils to support large flap wise bending loads. While the aerodynamic performance of thick air foils is generally poor, this is the standard compromise between structures and aerodynamics in blade design. The inboard region is primarily designed for structures [1]

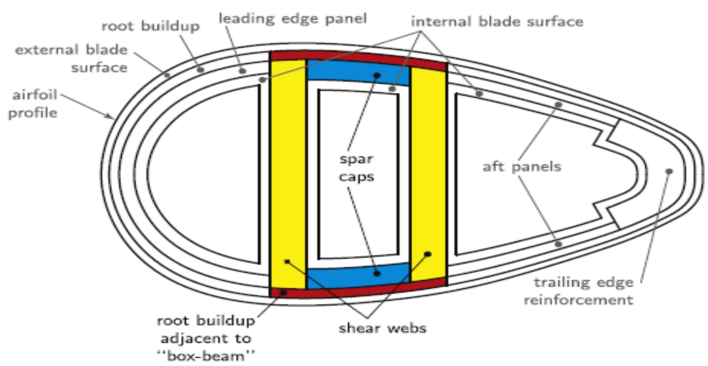

Fig 1.Spar cap of wind turbine blade

This paper describes the design,analysis, and properties of hybrid glass/basalt composite spar caps for wind blades. The main concept of this work is for reducing the mass and increase the mechanical properties of

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material. The present innovation satisfies a need for composite spar caps for wind turbine blade with increased stiffness and performance. Therefore high-performance basaltfibres can be used in wind turbine blade without increasing costs. So we need to incorporate the basaltfibre with glass fibre of spar cap structure. Based on this consideration, we propose a change in arrangement of basalt fibre with glass fibre [5]. This extends earlier research that considered simplified spars cap made of anisotropic materials and used uniform rectangular cross-sections (which did not taper the spar thickness from root to tip). Earlier research did not consider arrangement in basalt fibre with glass fibre is used to perform a parametric study of different uniform pressure spar configurations using Finite element modelling.

II PARAMETRIC FEA MODEL

2.1. Model description

A parametric FEA model of Spar cap of wind turbine is established using ANSYS software. It is a parametric model, which means that the structural parameters of Spar Cap can be easily modified to create various models. The parametric FEA model can be applied to the FEA modelling of both horizontal-axis and vertical-axis wind turbine composite Blades and its flow chart is presented in fig blades, and its flowchart is presented in Fig.2

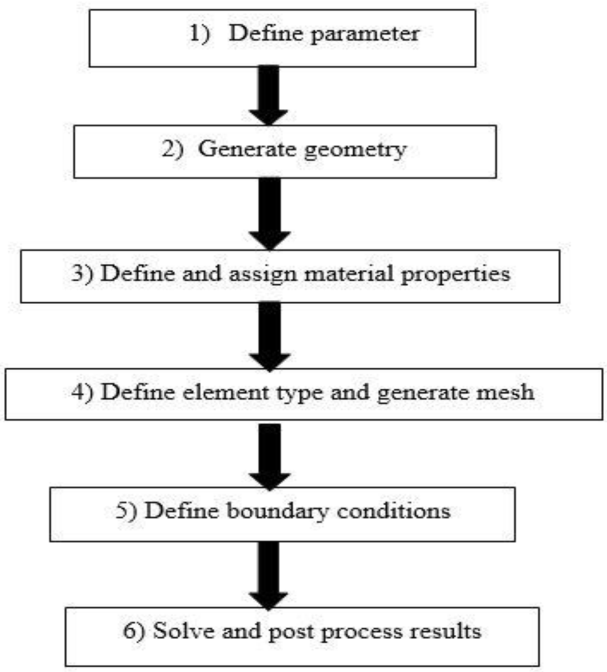

Fig.2.Analysis flowchart

Each step of the flowchart in Fig.2 is detailed below.

2.1.1 Define parameters

In the first step, parameters involved in the FEA modelling, such as Spar Cap thickness and geometry data, are defined

2.1.2. Generate geometry

The blade geometry is generated based on the bottom-up approach, which generates low dimensional entities (such as points) and build on top of them higher dimensional entities (such as lines and areas).

2.1.3 Define and assign material properties

In this step, material properties are defined and then assigned to the Spar cap of wind turbine blade

2.1.4 Define element type and generate mesh

In term of element type, BEAM188 Structural 3-D 2-Node Beam 2 nodes 3-D space, which has eight nodes with six degrees of freedom (UX, UY, UZ, ROTX, ROTY, ROTZ) at each node, is used. The BEAM288 element is well-suited for linear, large rotation, and/or large strain nonlinear applications. It is also suitable for layered applications for modelling composite model element can be found in ANSYS help documentation.Additionally, a regular quadrilateral mesh generation method is utilised to create high quality elements.

2.1.5 Define boundary conditions

In this step, boundary conditions is applied. The types of boundary conditions depend on the types of analysis.

2.1.6 Solve and post-process results

Having defined parameters, geometry, material, mesh, element properties and boundary conditions, can be performed. The analysis results, such as deformations and stress distributions, are then plot using post processing functions of ANSYS software.

2.1.7 Application of the parametric FEA model to the spar cap of wind turbine blade

The parametric FEA model is applied to the FEA modelling of the spar cap. The geometry, material properties, mesh, boundary conditions used in the FEA modelling are presented below.

III GEOMETRY

The spar is composed of spar caps on the top and bottom, and shear webs on the left and right. The spar caps are made of the primary load-carrying unidirectional fibres, and the shear webs stabilize the spar caps under shear forces; this creates a closed-box section.

Table 1. Geometric Parameters of Spar Cap

Symbol	Description	**Dimension (mm)**
lc	Length of the composite beam	24470
wc	Width of the composite beam	1500
tc	Thickness of the composite beam	13
t_u	Thickness of the upper Composite flange	13
t_l	Thickness of the lower Composite flange	13
w_u	Width of the upper Composite flange	5266
w_l	Width of the lower Composite flange	5266
t_{sw}	Thickness of the shear web	83

3.1. Material properties

The mechanical properties of this material is presented in Table. It should be noted that the materials for this study are obtained from Refs [5] Rather than manufacturing datasheets, as the real fabrication data are proprietary material and very challenging to obtain

Table 2.Mechanical Properties of Glass Fibre and Hybrid Fibre Materials

Mechanical properties	Glass fibre	Hybrid glass/basalt
EX GPa	35	39.6
EY GPa	6	7.7
EZ GPa	6	7.1
PRXY	0.25	0.30
PRYZ	0.25	0.30
PRZX	0.25	0.30
GXY GPa	2.78	3.82
GYZ GPa	2.78	3.05
GZX GPa	2.4	2.62
Density kg/mm^3	$1.63*10^{-6}$	$1.65*10^{-6}$

Where x E is the longitudinal Young's modulus; y E is the lateral Young's modulus; xy G is the shear modulus; xy u is the Poisson's ratio; r is the density.

3.2 Mesh

The mesh of the Spar cap component is presented in Fig.6.2. And a close view of Spar cap tip is presented in Fig.3.The Spar cap is meshed using structured mesh with shell elements.

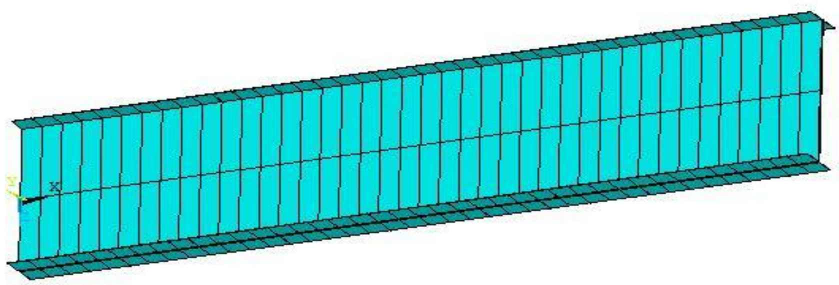

Fig.3. Mesh of Spar Cap for wind turbine blade

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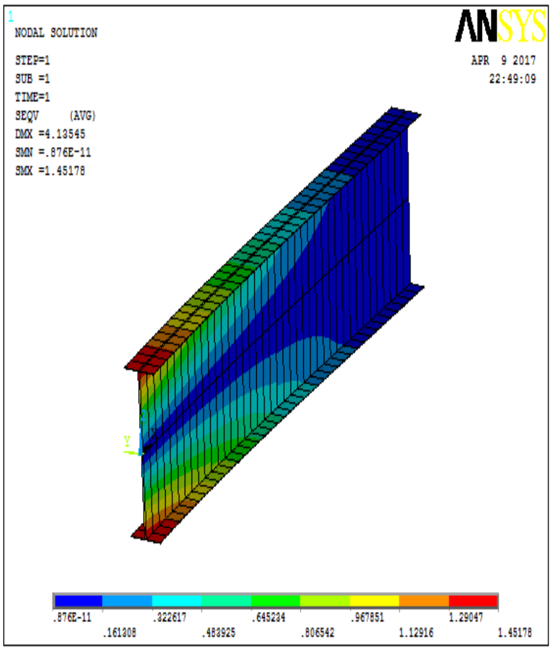
3.3. Boundary conditions

The calculated aerodynamic loads are considered as a pressure to be applied on the pressure-side of spar cap surface as distributed loads. In addition to aerodynamic loads, the gravity loads are considered in this study. Additionally, a fixed boundary condition is applied to the arm root.

IV RESULTS AND DISCUSSION

4.1. Stress Distributions

Figure 4 and 5 presents the normal stress distributions with in the Spar cap. From the Table 3. We can see that the maximum positive normal stress of spar cap for hybrid fibre (i.e. maximum tensile stress) is 2.651N/mm^2, which is 29.99% lower than the glass fibre of 3.787N/mm2 and average error is 25.0%.



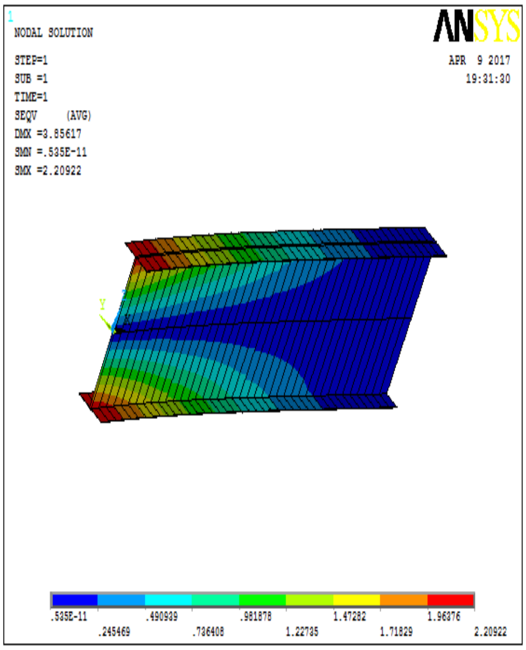


Fig.4.

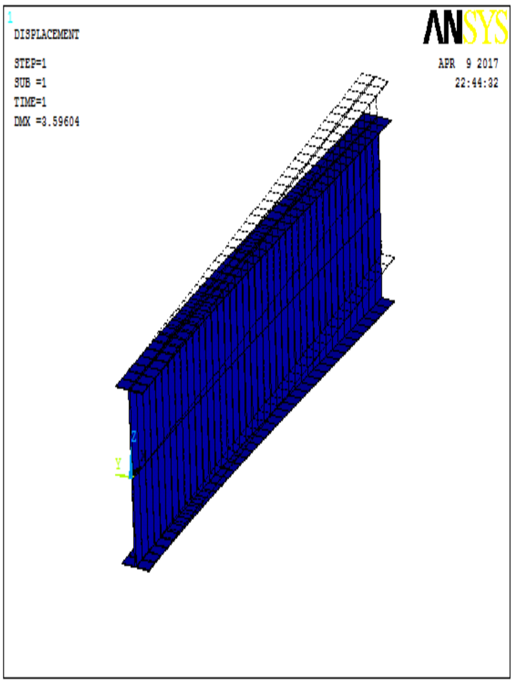
Stress distribution of spar cap glass fibre Fig.5. Stress distribution of spar cap forHybrid Fibre

Table.3. Consolidated of FEA Results for Stress Distribution

Pressure N/mm^2	Glass fibre N/mm^2	Hybrid fibre N/mm^2	% Error
1000	1.262	1.262	0
2000	2.209	1.451	34.3
3000	2.524	1.767	29.9
4000	3.156	2.146	32.0
5000	3.787	2.651	29.9
		Average error	25.22

4.2. Deformations

Figure 6 and 7 presents the total deformations of the Spar caps can be seen from Table.4. the maximum total deformation of Spar cap of glass fibre is about 7.55mm and hybrid fibre is about 6.61, observed at the tip of the Spar cap.This value is 12.4% lower than the glass fibre, indicating the present hybrid composite materials is quite stiff and is not likely to experience large deformations and average error is 10.58%



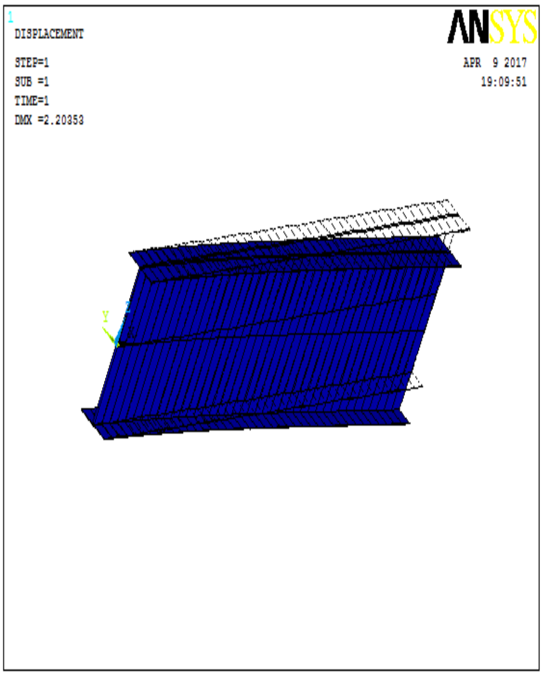


Fig.6. Total deformation of spar cap glass fibreFig.7. Total deformation of spar cap for hybrid fibre

Table.4. Consolidated of FEA Results for Deformation

Pressure N/mm^2	Glass fibre mm	Hybrid fibre mm	%Error
1000	3.59	3.23	10.0
2000	4.13	3.86	6.54
3000	5.03	4.40	12.52
4000	6.11	5.50	9.9
5000	7.55	6.61	12.45
Average error			10.28

The above shown Table 3 and 4 specifies the values obtained for stress and deformations for both the glass fibre and hybrid fibre. It shows that the hybrid fibre increases the strength and stiffness due good adhesion between fibre and matrix of spar cap when compared with the glass fibre

V CONCLUSIONS

A hybrid fibre could have many advantages, including ease of handling, light weight and transportation, as well as lowering tower head mass .It is observed from the finite element results.

- we can see that the maximum positive normal stress of spar cap for hybrid fibre (i.e. maximum tensile stress) is 2.651N/mm2 , which is 29.99% lower than the glass fibre of 3.787N/mm2 and average error is 25.0%
- The maximum deformation of the spar cap in hybrid fibre is 6.61mm, which is 12.4% lower than the glass fibre, this indicate that, the deformation can be significantly reduced by using the hybrid fibre with hexagonal structure and average error we found here is 15.86%.

REFERENCES

[1] Perry Roth-Johnson, Richard E. Wir ,. *''Edward L Structural design of spars for 100-m biplane wind turbine blades''* Renewable Energy vol.*71 (2014) pp 133-155*

[2[Haichen Lin.,*"Layup analysing of a carbon/glass hybrid composite wind turbine blade using finite element analysis Applied Mechanics"* and Materials *Vol. 87 (2011) pp 49-54*

[3] M Rosemeier and M Batge., *"A concept study of a carbon spar cap design for a 80m wind turbine blad*e" Journal of Physics vol.*24 (2014) pp 12-39*

[4] JieZHUa,XinCAIab,PanPANa,RongrongGUa.,*"Optimization design of spar cap layup for wind turbine blade"*Front. Struct. Civ. Eng. 2012, vol.*6(1) pp53–56*

[5] LihuaLv.,*"Bending properties of three-dimensional honeycomb sandwich structure composites: experiment and Finite Element Method simulation"*, Textile Research Journalvol.0 (00)*pp 1–8 (s) 2017*

[6] Griffin, D. A., and Zuteck, M. D., 2001, *"Scaling of Composite Wind Turbine Blades for Rotors of 80 to 120 Meter Diameter,"* AIAA-2001-0021, A Collection of the 2001 ASME Wind Energy Symposium, Technical Papers at the 39th AIAA Aerospace Sciences Meeting and Exhibit, American Institute of Aeronautics and Astronautics and American Society of Mechanical Engineers, NewYork.

[7] Joose, P., et al., 2000, *"Economic Use of Carbon Fibers in Large Wind Turbine Blades,"* A Collection of the 2000 ASME Wind Energy Symposium Technical Papers at the 38th AIAA Aerospace Sciences Meeting and Exhibit, American Institute of Aeronautics and Astronautics and American Society of Mechanical Engineers, New York, *p. 367.*

[8] Mohamed, Mansour, H., Zhang, and Zhonghuai, 1992, *"Method of Forming Variable Cross-Sectional Shaped Three-Dimensional Fabrics"*, United States Patent *5,085,252*.

[9] Brandt, J., Drechsler, K., Mohamed, M., and Gu, P., 1992*, "Manufacture and Performance of Carbon/Epoxy 3-D Woven Composites,"* Proceedings of the 37th International SAMPE Symposium, Society for the Advancement of Materials and Process Engineering, Covina, CA.

[10] Bogdanovich, A., Singletary, J., and Mohamed, M., 2001, *"A New Generation of Composites Reinforced with 3-D Woven Fabric Preforms,"* Proceedings of the 22nd International SAMPE Europe Conference, Society for the Advancement of Material and Process Engineering, Covina, CA, *pp. 305–316*