# ANALYZING STRUCTURAL BAHAVIOR OF A COMPOSITE WIND TURBINE BLADE USING SIMPLIMED MODELING

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## 1. Introduction

As the design of wind turbine blade become sophisticated, the severity of material selection to have safe performance is increasing. The uncertainties attributed to the material properties of the blade can manipulate the aeroelastic behavior of the blade and as a result, the output power and reliability of the turbine is affected. Analyzing aeroelastic behavior of a wind turbine blade plays an important role in designing a reliable structure against various loadings [1]. Prior to aeroelastic analysis, it is necessary to analyze the structural behavior of a wind turbine blade from different axial, bending and torsional behaviors [2].The main objective of this research is to investigate the degree to which variations in mechanical properties of constitutive composite materials can influence the structural behavior of a wind turbine blade. Firstly, a simplified model of a full-scale wind turbine blade is constructed to evaluate structural behavior of the blade. Then, a parametric study is performed to determine the most dominant mechanical properties which have a severe impact on the structural behavior of the blade. In other words, the influence of variations in mechanical properties of composite materials used for manufacturing a commercial wind turbine blade on its structural behavior is studied taking into account manufacturing uncertainties.

## 2. Simplified Modeling

Complexity of wind turbine blades including several layers of composite materials with shear webs makes structural analysis of the 3-D full scale blade difficult and time consuming, especially when a parametric study needs to be conducted. Beam property extraction (BPE) method is chosen in this research to construct simplified model of the wind turbine blade. The investigated blade in this study is a 23-meter blade belongs to a 660kW horizontal axis wind turbines manufactured by Vestas Wind System A/S [3]. Prepreg materials are utilized for fabrication of the mentioned wind turbine blades in the form of uni-directional (U-D), bi-axial and tri-axial fabrics. PVC foam and PMI foam are also used in the shell and spar structure of the blade. The natural frequencies of the blade obtained through simplified modeling and also experimental observations 1.81 and 1.97 Hz, respectively. A very good agreement between natural frequencies of simplified model and experimental data is evident. A very good agreement between natural frequencies of simplified model and experimental data implies on compatibility of simplified model with full-scale structure from all aspects of geometrical specifications, material properties of constitutive composite layers and lay-up configurations. Therefore, acceptable level of accuracy in reduced order modeling is achieved for the purpose of this study.

## 3. Dominant Mechanical Properties

The in-plane mechanical behavior of each composite laminate is introduced by characterizing four different mechanical properties as longitudinal modulus, transverse modulus, major Poisson’s ratio and in-plane shear modulus. As it was explained in previous section, three different composites fabrics (U-D, biaxial and triaxial) are employed for constructing the investigated blade. Thus, twelve different mechanical properties define the structural behavior of the blade. A parametric study is performed to nominate dominant mechanical properties (among mentioned twelve ones) contributing more considerably in defining the structural behavior of the blade from different viewpoints of axial, edgewise, flapwise and torsional stiffness. For each case, the investigated mechanical properties are changed while all others keep constant.

The results imply on this fact that the variations of all Poisson's ratios have insignificant effect on structural analysis of the blade. Therefore, the influence of normal modulus in longitudinal and transverse direction and in-plane shear modulus (Gxy) on the structural behavior of the blade is evaluated, separately. The longitudinal and transverse directions for all U-D, biaxial and triaxial fabrics are mentioned in Fig. 1.

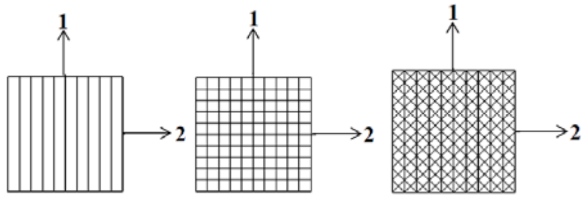


Fig. 1: Longtiduinal and transverse directions for U-D (left), biaxial (middle) and triaxial fabrics (right)

The impact of each fabrics mechanical property is shown in Table 1. In this table the mechanical properties are arranged in columns from "A" to "G" wherein "A" means highest influence and "G" denotes negligible influence.

Table 1: Influence of mechanical properties on structural behavior of the blade

| Fabric | Mechanical property | EA | $EI_{edge}$ | $EI_{flap}$ | GJ |
|---|---|---|---|---|---|
| U-D | $E_1$ | A | B | A | D |
| | $E_2$ | G | G | G | G |
| | $G_{xy}$ | D | C | C | F |
| Biax | $E_1$ | F | F | G | C |
| | $E_2$ | G | F | G | C |
| | $G_{xy}$ | G | G | G | A |
| Triax | $E_1$ | B | A | B | F |
| | $E_2$ | G | G | G | B |
| | $G_{xy}$ | C | D | G | D |

The identified dominant mechanical properties of the fabrics ($E_1^{tri-axial}$ and $E_1^{U-D}$) are changed simultaneously using stochastic analysis. The interval for variation of dominant properties is considered 20% variations. After considering sufficient number of realization, two cases which lead to highest and lowest natural frequencies are determined.

## 5. Conclusion

It is intended to extract the dominant mechanical properties influencing the structural behavior of a composite wind turbine blade. A simplified model of the blade is firstly constructed. Then, effect of uncertainties in material properties on the structural behavior of the blade is analyzed using a parametric study. From industrial point of view, it is very common that the structural behavior of the manufactured blade is deviated from the design values due to the uncertainties associated with production process. Furthermore, the mechanical properties of the purchased materials are not practically the same because of different industrial suppliers where materials are purchased from. Thus, the influence of different mechanical properties of constituent composite fabrics on the structural behavior of the blade is analyzed and the most dominant ones are identified by sorting the degree to which the behavior is affected.

## 6. References

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[3] Vestas Wind Systems A/S, 2002. Technical brochure of V47_660, Vestas Wind Systems A/S, Randers, Denmark.