

# Optimization of Wind Turbine Blades

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## ABSTRACT:

WT blade manufacturing cost of approximately 15 to 20% of the production cost of wind turbines. Expenses innovations in the design of the blades represent a small amount of the total cost of production of the wind turbines. The benefits from the best structural model, and the use of suitable fusing materials and better manufacturing techniques, both sheets and composite materials, necessitating the application of numerical modeling and optimization techniques. In the design of a wind turbine, the goal is to achieve greater output power possible under specific climatic conditions. Technically, this depends on the shape of the sheet. Changing the blade shape is one of the ways to adjust stiffness and stability, but can affect the aerodynamic efficiency of the wind turbine. Another way of changing the dynamic mechanical properties of the wind turbine is modified composite material, which is made from the blade. Problem determining the optimal shape of the blade and the determination of the optimum composite is a complex subject, since the mathematical description of the aerodynamic and complex load, and a number of limitations and objectives must be satisfied. These considerations have led the authors to address the problem from various optimum design of wind turbine blade standards. The objective of this study is to develop a software package that allows the optimization of wind turbine blades in a series of criteria

## INTRODUCTION:

### Properties of the blade

The aerodynamic profiles of wind turbine blades have crucial influence on aerodynamic efficiency of wind turbine. However, when blades are longer than 45m the dynamic behaviour of the blade must be also taken into account. Then, the position

and shape of spars have to be considered and analysed. In the article [9] is mentioned that the location of the main spar together with the location of the stiffening ribs will have the biggest influence on the bending modes of the blade. The model of blade (see Fig. 1) made of shell elements was used in multi-criteria optimisation procedure. According

to Ref. [8], the blade is to be twisted around the elastic axis. The position of elastic center can be changed by modifying the position of spars and its shape. The solid model of the blade is created in order to obtain required properties of the blade and position of spars. We are interested about the properties of the cross-sections. Using commercial software MSC Patran, there is possible to get information about area, moments of inertia, shear centers and centroids. The output data, for example, cross-section of the blade is presented in Fig. 2. The blade was divided to 26 cross-sections, for each of them were received the similar data. Now the cross-sections of the blade must be twisted along

the shear axis. But the question is what with the position of spars, if they are also twisted. The conclusion is that they are not twisted in similar way as aerofoils. Leaving the spars straight, the blade would have the form shown in Fig. 3. The commercial blades does not have the spars positioned in this kind. The reason is the aerodynamic damping phenomena. Twist of the blade decide about value of aerodynamic loads, but also the direction in which the blade will vibrate. The blade with twisted spars is presented in Fig. 4. The twist of spars decides about pitch of principal bending axes. Aerodynamic damping is a very important dynamic

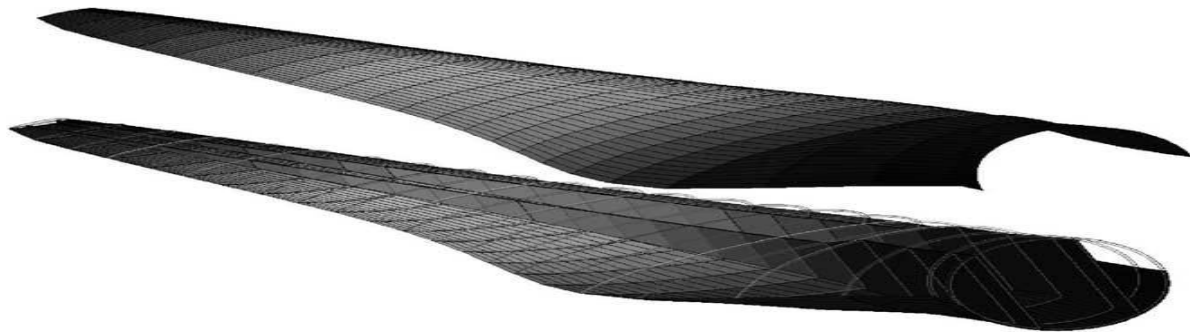


Fig. 1. The structural model of the blade with spars, before twist.

aspect. The negative value of aerodynamic damping means that some additional energy is added to the blade during vibration and the amplitude of vibration is increased. Aerodynamic damping has in plane and out of plane components. Damping in-plane direction will have the negative value if the blade section produce the power. If damping

in out of plane direction is positive, by twisting the blade the value of out of plane damping will decrease (but must be still positive) and the inplane damping will receive positives values. Due to the twist of spars, the blade will vibrate not clearly edgewise or flapwise [5].

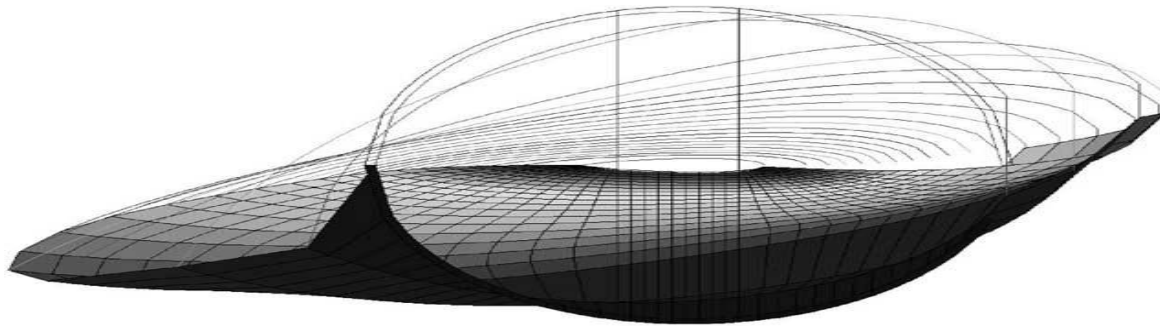


Fig. 3. The twisted blade with straight spar.

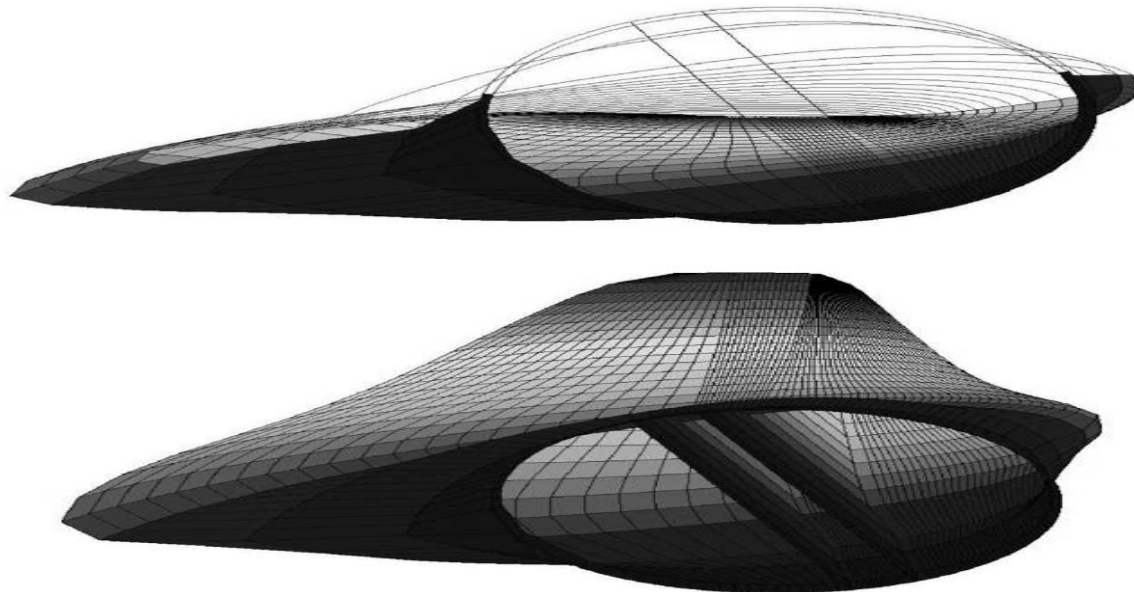


Fig. 4. The twisted blade with twisted spars.

### State of load on the blade

The analysis of the state of load on the wind turbine blade is intended to verify whether the turbine will withstand the action of load within appropriate safety range. Various cases of load on the blade, resulting from the action of various external factors on the turbine, have to be considered. The following types of states of load on a wind turbine blade can be distinguished:

- *Aerodynamic loads* of a wind turbine blade

- *Mass loads*, as the wind turbine blade is slender, the loads associated with its inertia are limited to the loads generated by its weight, which causes sinusoidal loads the frequency of which corresponds to the rotor . Both mass and aerodynamic loads were investigated.

### Material of the blade

The considered blade is made of composite materials containing more than one bonded material, each with different structural properties. One of the materials, called the reinforcing phase is embedded in the other material of the matrix phase. If the composite is designed and fabricated correctly, it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material. The main advantage of composite materials is the potential for a high ratio of stiffness to weight. Composites used for typical engineering applications are advanced fiber or laminated composites, such as fiberglass, glass epoxy, graphite epoxy and boron epoxy. Composites are somewhat more difficult to model than an isotropic material such as iron or steel. The special care must be taken in defining the properties and orientations of the various layers since each layer may have different orthotropic material properties. Majority of wind turbine blades is made of fiberglass reinforced with polyester or epoxy resin. Construction using wood-epoxy or other materials also can be found. Small turbine blades are made of steel or aluminum, but they are

heavier. Lighter and more effective blades decrease material requirements for other wind turbines component making.

### **FEM model of wind turbine blade**

The FEM model of the wind turbine blade with a NACA V63-212 airfoil was created using APDL language in ANSYS. It is a parametric model, as the thickness of the shell, composite material, which blade is made, number of stiffening ribs and their arrangement were the model parameters that were input from the authors' program that implemented a modified genetic algorithm. A given parametric file can be used to create various blade models, modify their thickness and basic dimensions.

The created FEM model of the blade consists of 124,042 elements, 55,044 nodes and 327 areas meshed. The 8-nodal shell of the SHELL 63 type with 6 degrees of freedom was chosen as finite elements, what enabling specification of any thickness at each node of the chosen element. Selection of elements in a numerical model of a blade enables specification of various thicknesses and material data and defining various types of elements.

The following simplifying assumption was made when creating the numerical model of the blade:

• the manner of connecting the shell with supporting webs and stiffening ribs was neglected. The blade was treated as a clamped beam with its geometry determined in the manner described in previous section.

## CONCLUSION

The developed numerical model of the wind turbine blade and the computer program package for performing multi criteria discrete–continuous optimisation of wind turbine blades are of general nature. Various blade models can be created by means of an ANSYS parametric file; thicknesses and main dimensions of the model blade can be varied. The authors' program that implements a modified genetic algorithm enables optimisation of various objective functions subjective to various constraints. Subsequent to determination of the optimised profile of the wind turbine blade could be machined using Pre-Pregs

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