Optimization design of blade shapes for wind turbine rotors

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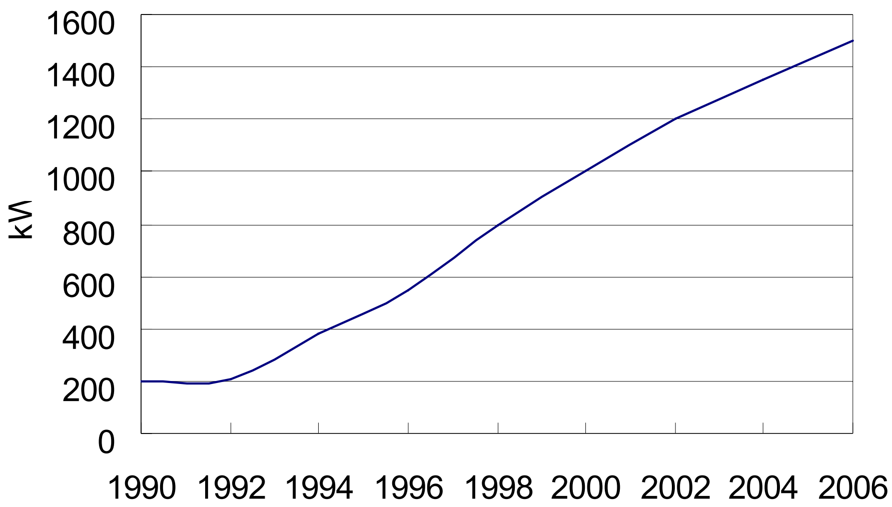
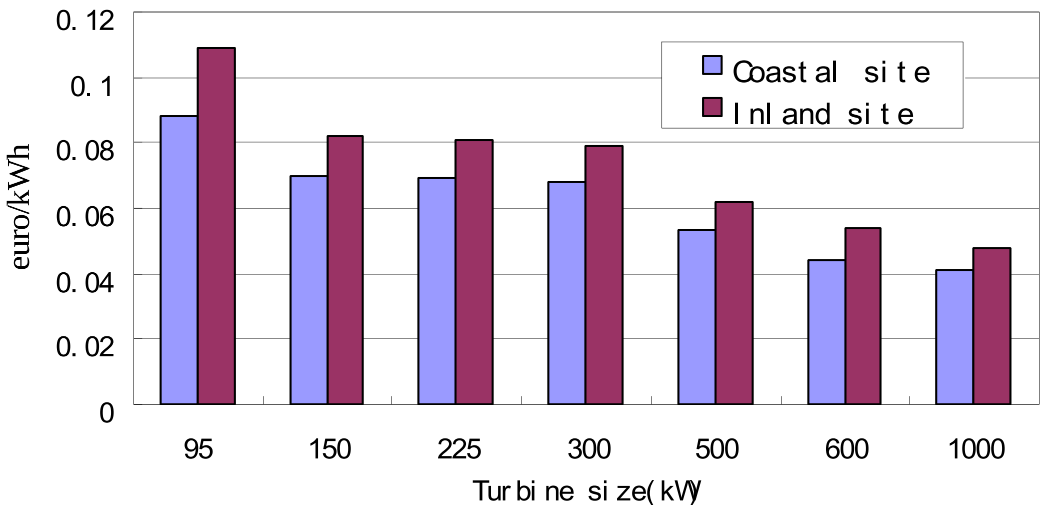
Introduction

1. Wind turbine gets energy from the rotor, so how much energy that can be extracted depends directly on the shape of the blades.

2. Wind energy has a relatively young but rapidly expanding industry. The global installed capacity has increased from 2,500 megawatts (MW) to over 40,000 MW at the end of 2003. Until 2007, it is more than 90,000 MW.



Development of the averaging wind turbines size



Total costs of wind energy per turbine size

In the development of new large megawatt size wind turbines, aerodynamic and structural optimizations have become interesting and important subjects for reducing the cost of wind turbines.

Optimization

Before making the optimization, an aerodynamic code for wind turbines must be available.

There are many commercial programs existing in the market. Such as: GH Bladed; FLEX; HAWC; …

A new aerodynamic code based on the BEM (Blade Element-Momentum) theory and the structural dynamics of the blades has been developed for computing the aerodynamic performance of wind turbines.

Dynamic Structural Model

The aerodynamic loads on wind turbine blades are calculated using the BEM theory. In order to accurately predict the characteristics of a real wind turbine, the vibrations of the wind turbine needs to be taken into account.

$$M\ddot{x} + C\dot{x} + Kx = F_g$$

$$x = (w, \varphi, x_1^{1f}, x_1^{1e}, x_1^{2f}, x_2^{1f}, x_2^{1e}, x_2^{2f}, x_3^{1f}, x_3^{1e}, x_3^{2f})$$

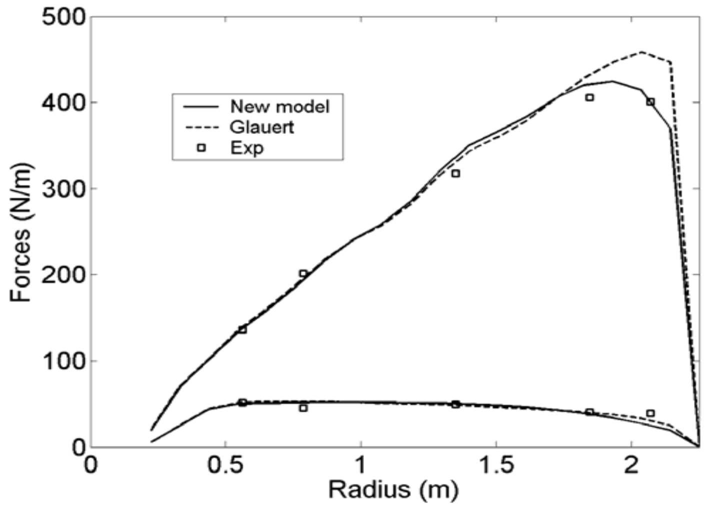
$$\dot{\vec{u}} = \dot{x}^{1f} \cdot \vec{u}^{1f}(x) + \dot{x}^{1e} \cdot \vec{u}^{1e}(x) + \dot{x}^{2f} \cdot \vec{u}^{2f}(x)$$

$$\vec{V}_{rel} = \vec{V}_0 - \vec{V}_{rot} + \vec{W} - \dot{\vec{u}}$$

Aerodynamic Model

The aerodynamic model used here is based on the 1D Blade Element-Momentum theory (BEM) with the improved tip loss correction introduced in Shen et al.

Compared the traditional correction models, an extra correction of 2D force coefficients near the tip is included.



Comparison of the axial forces and the tangential forces using the two tip loss correction models with the MEXICO experiment data at a wind speed of 15m/s, corresponding to a tip speed ratio of 6.7, and pitch angles of -2.3°

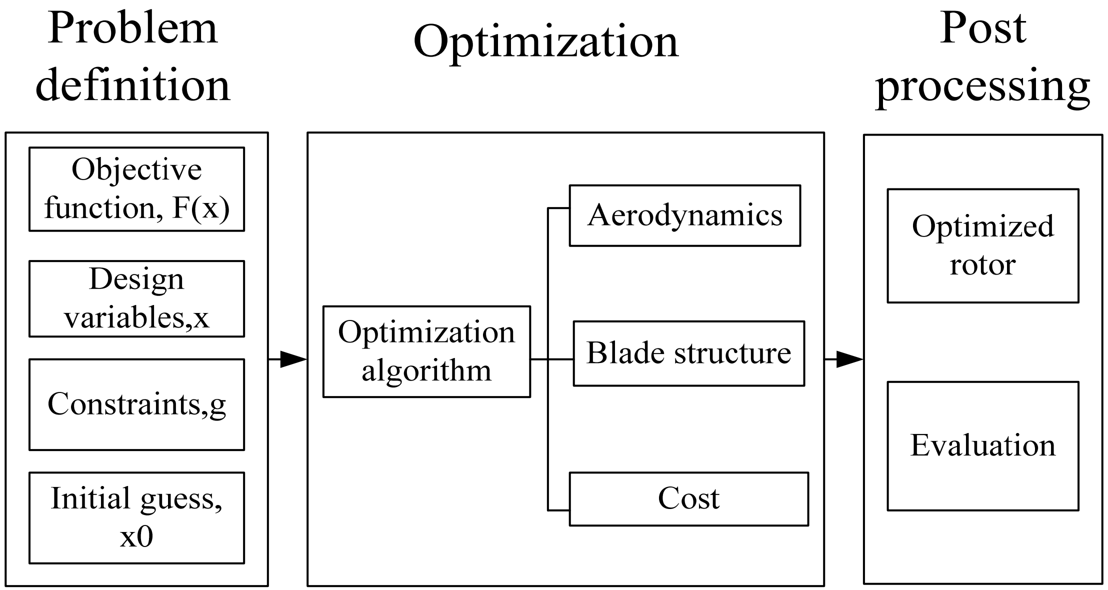
Optimization Model

Objective:

Min Cost: $f(x) = COE = \frac{C}{AEP}$

Design variables and constraints:

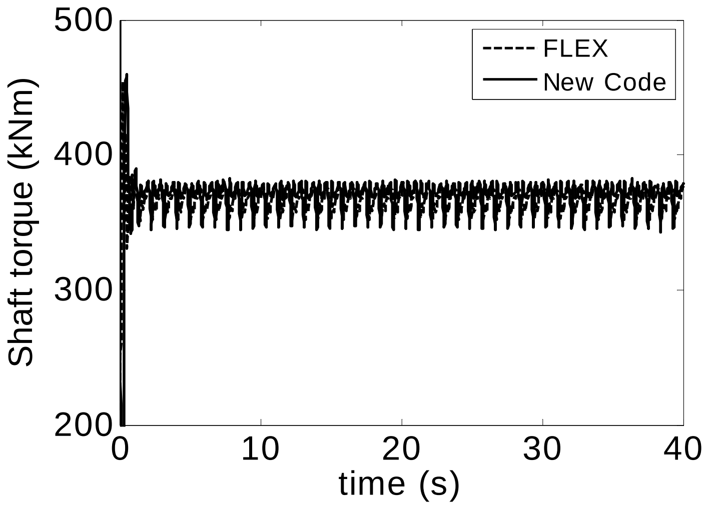
Chord;Twist angle;Relative thickness

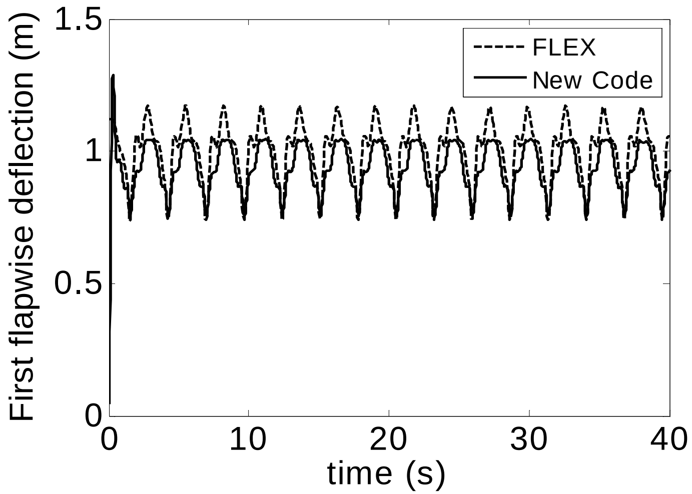


Results

Validation of the Aerodynamic/Aero-elastic Code

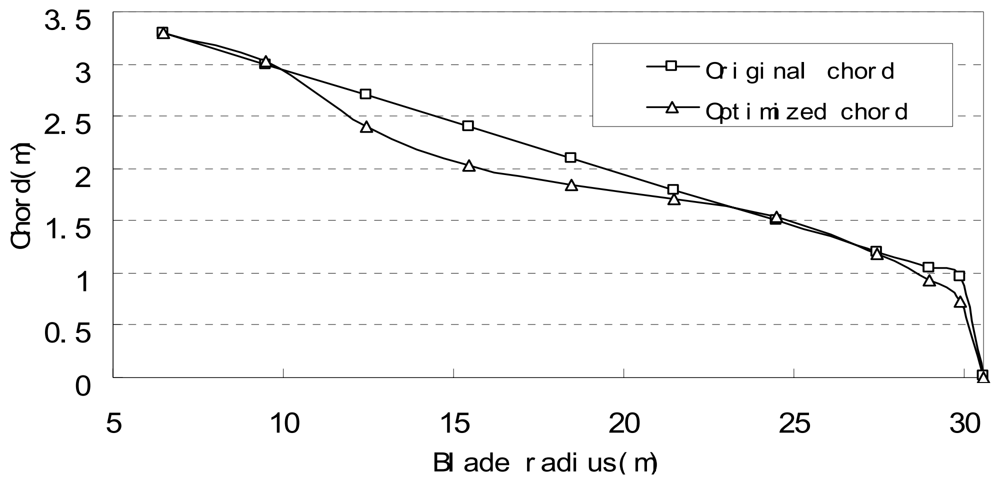
In order to validate the implementation of the structure model, the code is validated against the widely used aeroelastic code, FLEX.

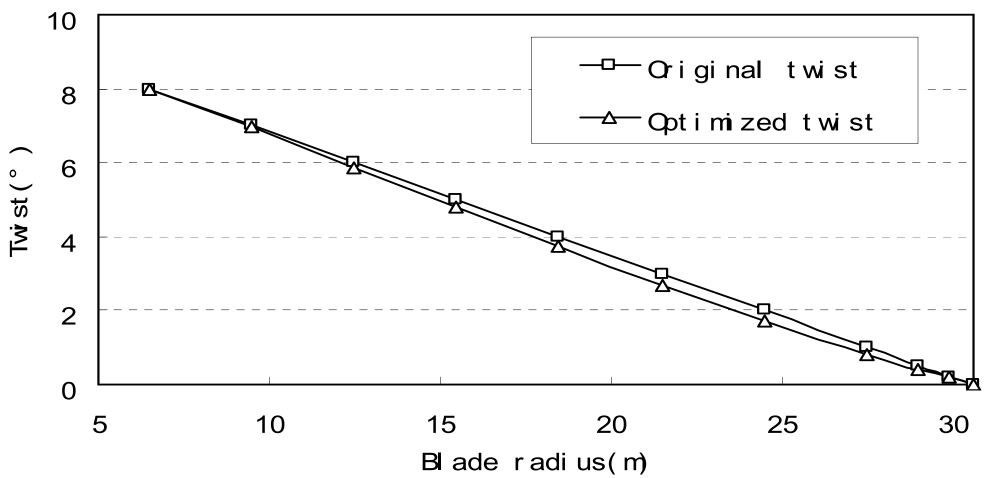


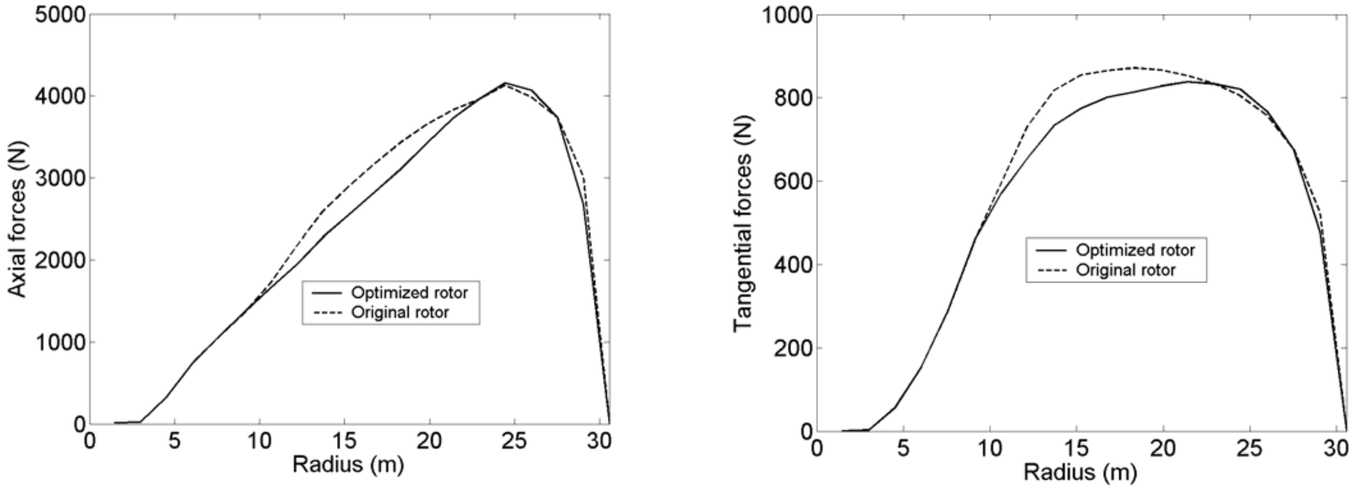


Comparisons between the new code and FLEX for torque and first flapwise deflection at the tip for flow past the Tjærgborg 2 MW wind turbine at a wind speed of 10 m/s.

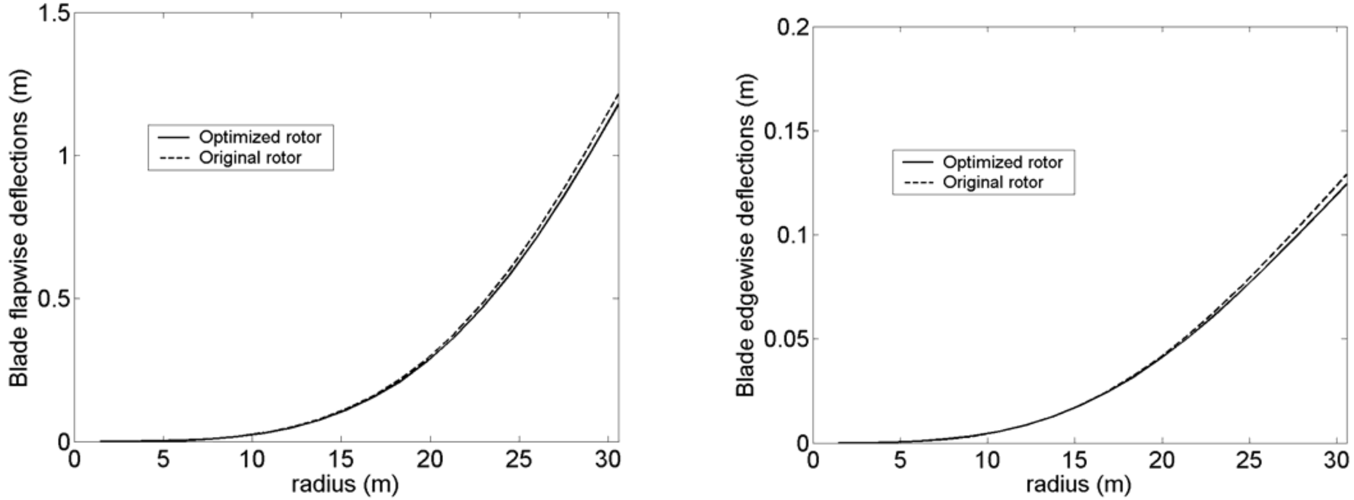
Optimization Results





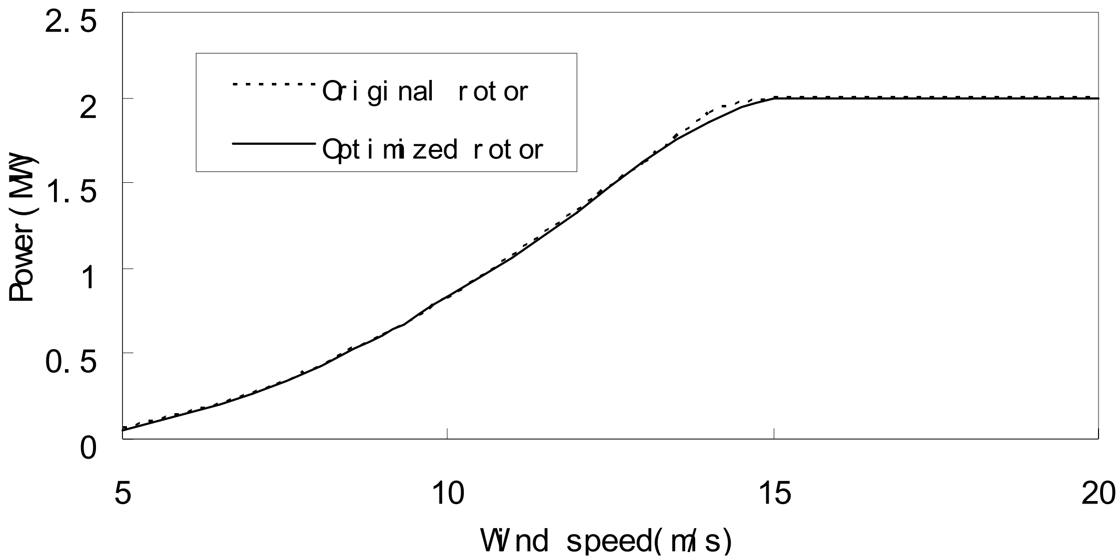


Axial forces and the tangential forces of the original and optimization Tjaereborg rotor



Flapwise and edgewise deflections of the original and optimization Tjaereborg rotor

DTU



Power performance of the original and optimization Tjaereborg rotor

Conclusions

Using the model, the Tjaereborg 2MW rotor has been optimized. Through the optimization, the cost of the optimization rotor has been reduced about 7.1% while the AEP of the optimized rotor has also been reduced about 4% compared with the original Tjaereborg rotor. So the overall cost of energy can be reduced about 3.4%.

THANKS!