Non-contact Vibration Measurements of a Wind Turbine Rotor Blade

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Technology and Safety Challenges

The importance of wind power as a source of energy is steadily on the rise. The German Federal government is currently planning on increasing the contribution of wind power to electricity generation by 25% by the year 2025. Wind turbines are subjected to strong vibrations and mechanical stress during operation. Therefore, they must be designed with high fatigue strength and their dynamic behavior must also be checked regularly

Fig. 1: Test station at the IMA in Dresden. The rotor blade is shown with additional mass loads.

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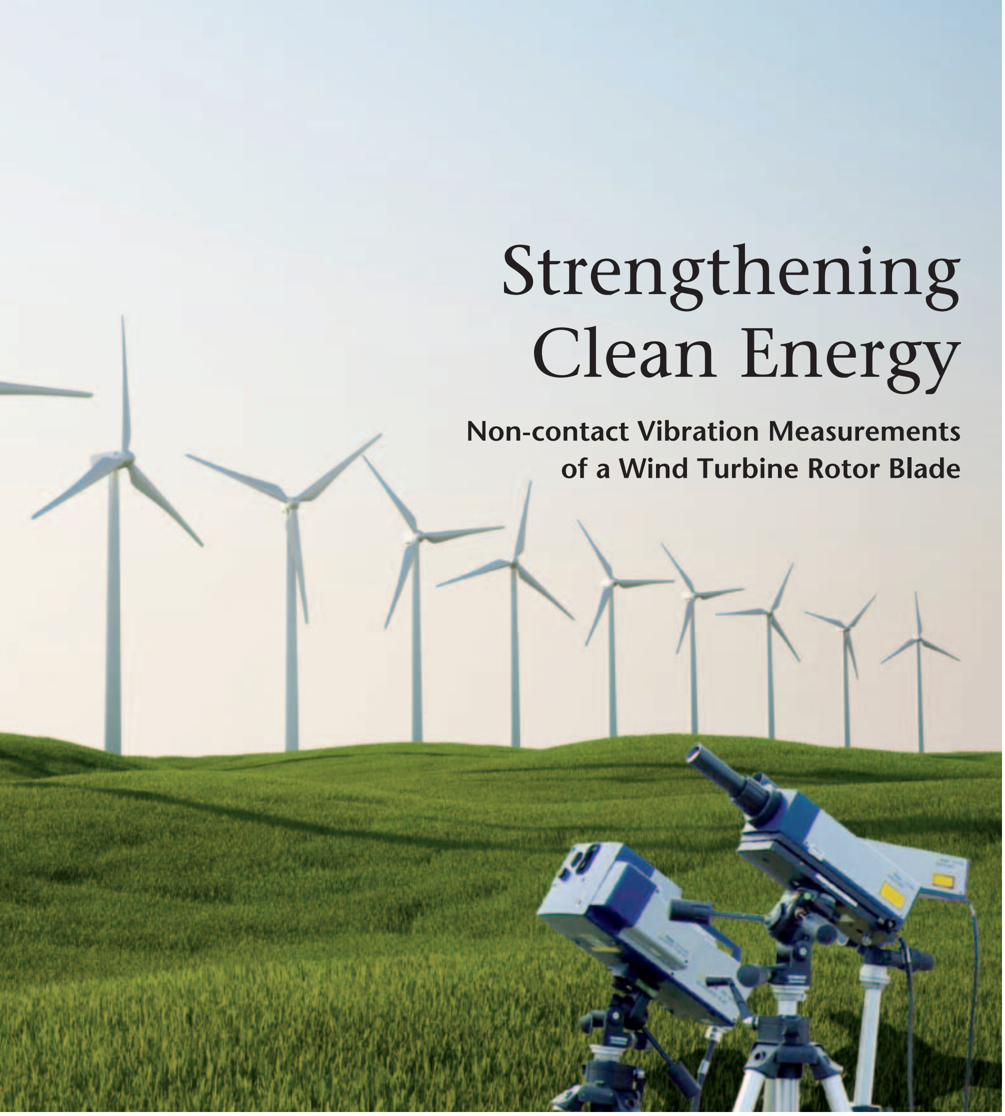


Strengthening Clean Energy

Non-contact Vibration Measurements of a Wind Turbine Rotor Blade

(condition monitoring). In this case, vibration testing using laser vibrometers can immediately provide several advantages. For example, the tests allow you to validate existing simulation models as well as inspect the quality of rotor blade construction and production. In addition, the measured vibrational behavior enables you to determine the ideal positions for installing fixed sensors to monitor the turbine's condition.

Fig. 2: An electromotive shaker made by Wölfel generated the excitations.

Preliminary Investigations were Very Promising

Measurements using laser vibrometers have already been conducted at the University of Applied Sciences in Flensburg, Germany, during a project aimed at researching sensor-supported condition monitoring systems [1]. The test measurements were made on a 300-kW plant with a hub height of 50 m and demonstrated that laser vibrometers are well-suited for non-contact remote diagnostics of vibrations on wind turbines.

Single-point vibrometers equipped with a telephoto lens, telescopic sight and autofocus are custom-designed for field use. In contrast, a scanning vibrometer is the ideal measuring device for determining the normal vibrational behavior (deflection shape) of rotor blades on the test bench with high local resolution and accuracy.

A Project with Many Partners

The measurements presented here are the result of a project geared toward diagnosing wind turbines. German project partners include the IMA Institute for Materials Research and Application Technology in Dresden, the Fraunhofer Institute for Non-Destructive Testing Procedures (IZFP) in Dresden and the engineering consulting company Wölfel-Beratende Ingenieure GmbH in Höchberg.

Fig. 3: Scanning Vibrometer measurement head is shown mounted on the hydraulic platform.

For the measurements, a 40-meter long rotor blade was horizontally fixed to a foundation at the IMA premises (Fig. 1) The upper surface (aerodynamic suction side) was subjected to horizontal vibrations approximately 10 meters from the center using an electrodynamic shaker developed by Wölfel (Fig. 2). A periodic chirp signal in a frequency range of 3 – 100 Hz with a resolution of 62.5 mHz was applied to excite the rotor blade. An acceleration sensor on top of the blade and 16 meters from the center served as a phase reference for animating the deflection shape. Since there was an emphasis on the upper side of the blade, the vibrometer's measuring head was mounted on a hydraulic platform (Fig. 3) and moved above the rotor blade as shown in Fig. 4.

The large clearance between the measuring head and the measurement object enabled researchers to capture a significantly larger surface area in one scan.
A total of 531 measurement points on the suction side (top) and 480 measuring points on the pressure side (bottom) were used to construct the deflection shape. The geometric coordinates and the FFT spectra of the vibrations were measured with high resolution. The PSV-400 equipped with the long range optics in conjunction with the VD-08 Velocity Decoder and a 5 KHz low-pass filter were used to record the measured data.

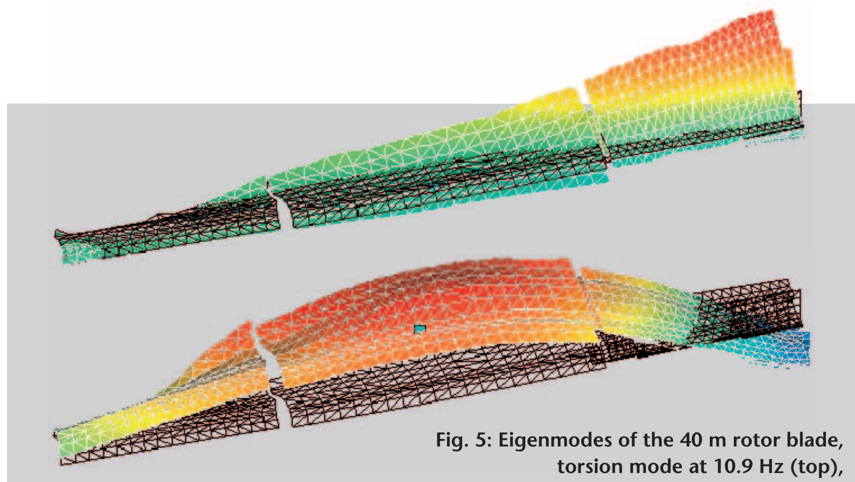


Fig. 5: Eigenmodes of the 40 m rotor blade, torsion mode at 10.9 Hz (top), contour mode at 12.44 Hz (bottom)

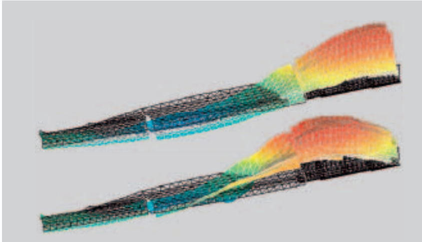


Fig. 6: Combined eigenmodes, at 17.63 Hz (top), at 21.81 Hz (bottom)

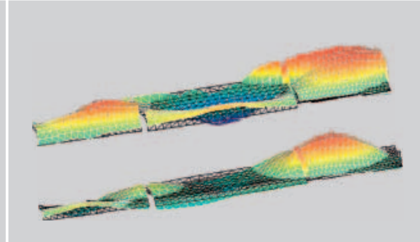


Fig. 7: Combined eigenmodes, top at 29.75 Hz, bottom at 36.13 Hz

Comparing Simulation and Measurements

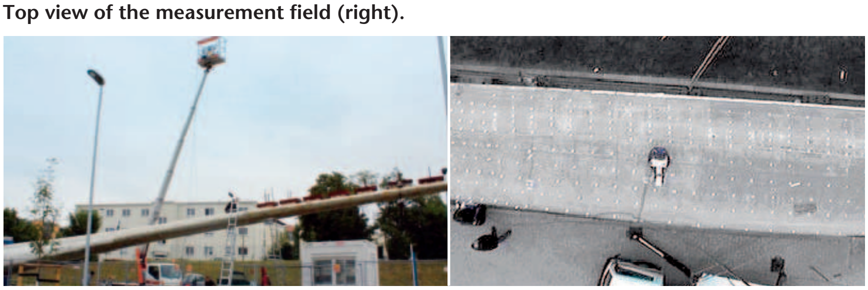
The rotor blade's eigenmodes were determined from the measurements. Due to the geometry of the test arrangement, the measurements were each taken in sections covering several meters. These were then stitched together in one complete image using the PSV software. The measured natural frequencies below 22 Hz provide a good match with the model calculations and the existing measurements taken by the Wölfel company [2] (Fig. 5 and 6). The shaker used could not excite natural frequencies below 3 Hz and, therefore, data at these frequencies was not taken.

Summary and Outlook

The measurement results provide the natural frequency vibration patterns of the entire rotor blade as well as the vibration amplitudes of each individual scanning point in conjunction with the current positions in the 3-D coordinate system. Calculated models are easily and quickly compared with the real dynamic behavior to make constructive adjustments where necessary. The measurement data also enable the engineer to quickly and efficiently determine the optimal measuring points for attaching contact sensors in order to construct condition monitoring systems.

While the natural vibration levels should only change slightly according to the model calculations, larger changes in the eigenmodes are to be expected if the model is incorrect. Scanning vibrometers are ideal measuring systems to record a for measuring and confirming the modal model of a structure's eigenmodes (deflection shapes) with high local resolution and accuracy. With contact sensors, a comparable measurement would be very complex and time-consuming. Scanning vibrometers on the other hand enable users to set up a straightforward testing facility and quickly take non-contact measurements. In this case, the whole measurement procedure including setup and mounting could be performed within 8 hours.

Fig. 4: Rotor blade is shown with the 20 m high hydraulic measurement platform (left); Top view of the measurement field (right).



Literature

[1] Laser Vibrometers Make Non-contact Vibration Measurements on Wind Power Plants, Polytec InFocus 2/2008, www.polytec.com/infocus

[2] Ebert, C.; Friedmann, H.; Henkel, F.-O.; Frankenstein, B.; Schubert, L., 3. VDI-Fachtagung Baudynamik, Kassel 2009, VDI reports 2063.

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