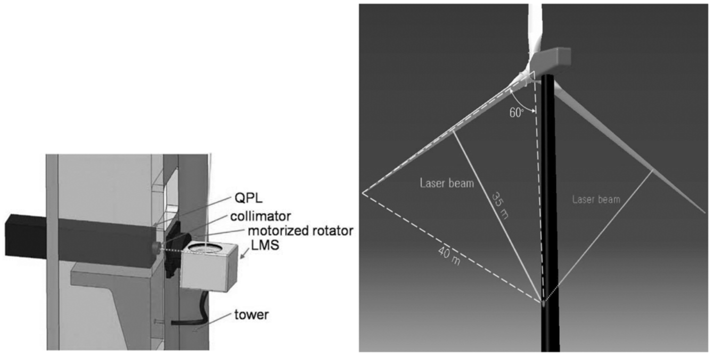
1.10.5. ULTRASONIC PROPAGATION IMAGING FOR IN-SITU WIND TURBINE BLADE DAMAGE VISUALIZATION

Hey-Jin Shin[1], Jung-Ryul Lee[1], Chen-Ciang Chia[1]
[1]DEPT. OF AEROSPACE ENG., CHONBUK NATIONAL UNIVERSITY, Jeonju, Chonbuk Korea.
Dong-Jin Yoon[2]
[2]SAFETY MEASUREMENT CENTER, KOREA RESEARCH INSTITUTE OF STANDARDS AND SCIENCE, Daejeon, Korea

Recently, wind power emerges as one of the most promising alternative energy sources to counter global energy crisis and the green house effect. As the wind power industry grows both in term of annual power output and turbine size, many operational problems have been encountered. Among them, damages related to turbine blade are the most reported and expensive to repair. Wind turbine blades are generally made of composite materials that are susceptible to damages. Those damages are usually difficult to be identified through naked eyes and hence suitable damage evaluation method is required. Many non-destructive test and evaluation (NDT&E) techniques as well as structural health monitoring (SHM) techniques could reveal those damages. However, considering the difficulties of performing NDT&E for large turbine blades mounted on high tower, and the great financial cost for bringing down a problematic blade for inspection in laboratory, *in-situ* SHM techniques utilizing embedded sensors that could perform structural integrity evaluation in the wind farm without needing the crane and abseiling personnel are significantly advantageous. Many NDT&E and SHM methods are potentially applicable as *in-situ* SHM system for wind turbine blades, such as acoustic emission (AE) sensing method, piezoelectric impedance method, shearography, thermography, and scanning laser Doppler vibrometry, but they are either lack of imaging ability or have limited inspection distance. Ultrasonic Propagation Imaging (UPI) method on the other hand is free from these limitations. It could generate ultrasonic signal in a turbine blade at great distance (tens of meters) using a Q-switched pulsed laser (QPL) and could adopt various ultrasonic sensors, such as piezoelectric sensor and fiber Bragg grating sensor for signal capturing. It generates Ultrasonic Wave Propagation Movie (UWPM) visible as a concentric ultrasonic wavefield emerging from the sensing location. Damages or anomalies could be quantitatively evaluated from area with wavefield phase discontinuity or scattered waves in UWPM or snapshots.

In this work, we propose a built-in UPI system suitable for pitch-controllable wind turbines both on-shore and off-shore. AE sensor embedded within the blade is adopted as ultrasonic sensor while other system components, including a QPL, laser optical pulse collimator, and laser mirror scanner (LMS), are placed within the tower, as shown in fig. 1. This configuration enables not only the scanning of all the blade surfaces in turn, but also potentially the scanning of blades for nearby turbines. During operation, AE event will activate the system to perform partial blade scanning near the AE source. Periodic blade inspection can also be scheduled if necessary. Complete system design, including the hardware composition and feasibility study will be given in the full paper.

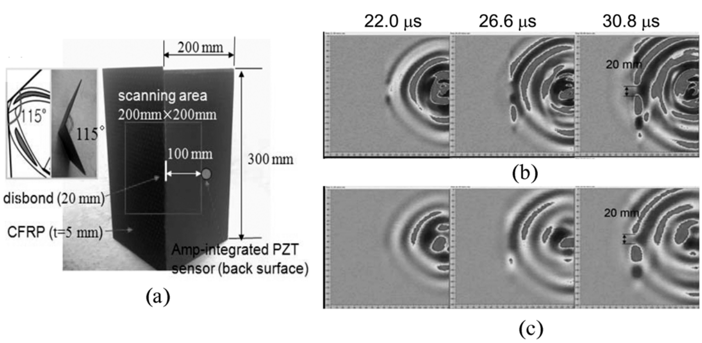


(a) (b)

Fig. 1. System conceptual design showing (a) built-in laser source and scanning module at the tower opening, where the laser is portable for another turbine, (b) scanning of all the blade surfaces in turn

For remote scanning capability verification, a mock-up blade leading edge with 20 mm disbond was inspected at 20 m and 40 m distances. The specimen was made of two pieces of 300×200×5 mm CFRP plates bonded together making an angle of 115 degree. UWPM snapshots at 22.0 μs, 26.6 μs and 30.8 μs for both cases were given in figs. 2b and c. Inspection of snapshots at 30.8 μs for both cases shows that the wavefield phase discontinuity is 20 mm long, which matches the disbond length. The amplitude difference between 20 m case and 40 m case was due to non-optimized laser optical pulse collimation. Optimization of laser optical pulse collimation is being carried out.

As conclusion, quantitative damage evaluation for on-shore and off-shore wind turbines at remote distance using UWPI system is possible. Detail design of the proposed built-in UPI system as well as additional function on aerodynamic surface management is being carried on. It is hope that this system will contribute to the cost reduction of green energy in the near future.



(a) (b) (c)

Fig. 2. Leading edge inspection (a) Experimental condition, UWPM snapshots for (b) 20 m case and (c) 40 m case