An experimental study on trailing edge crack detection for wind turbine blade using airfoil aerodynamic noise

Zhang, Y.; Avallone, F.; Watson, S.J.

Publication date
2021

Document Version
Final published version

Citation (APA)
Zhang, Y., Avallone, F., & Watson, S. J. (2021). *An experimental study on trailing edge crack detection for wind turbine blade using airfoil aerodynamic noise*. 7-123 / 7-124. Abstract from Wind Energy Science Conference (WESC) 2021, Hannover, Germany.

THEME 7

Realiability, Monitoring and Sensing Technology

WESC 2021
25 – 28 MAY
HANNOVER, GERMANY

An experimental study on trailing edge crack detection for wind turbine blade using airfoil aerodynamic noise

Yanan Zhang*, Francesco Avallone, and Simon Watson
Delft University of Technology
*Presenting author

Keywords: wind turbine blade | trailing edge crack | damage detection | aerodynamic noise

Recent decades have witnessed more and more wind turbines (WTs) being installed onshore and offshore. Health condition monitoring for WTs structures and components is increasingly becoming a compelling concern for stable power output and operational safety of a wind farm [1]. Blade damages seem to occur with a higher probability ahead of other components (e.g., gearbox and generator) damages [2]. After reviewing traditional damage detection approaches and their limitations [3], in this research a new non-contactable approach to detecting trailing edge (TE) damages is proposed based on airfoil aerodynamic noise measurements using a microphone array. In the experiment, four changeable TE parts with rectangular cracks (damaged width W of 0.2mm, 0.5mm, 1.0mm and 2.0mm) for a NACA0018 airfoil (chord C=200mm, span L=400mm) are designed and an example with W=0.2mm is shown in Fig.(a). The TEs with cracks have the same solid thickness as the baseline one (hsolid=0.76mm, standard NACA0018 airfoil TE thickness with chord of 200mm) but different dimensions of total TE thickness (h=W+hsolid). A phased microphone array with 64 microphones is used for acoustic measurement then beamforming is applied to extract TE noise and source power integration is performed within a 200×200mm2 region centred at TE midpoint [4][5].

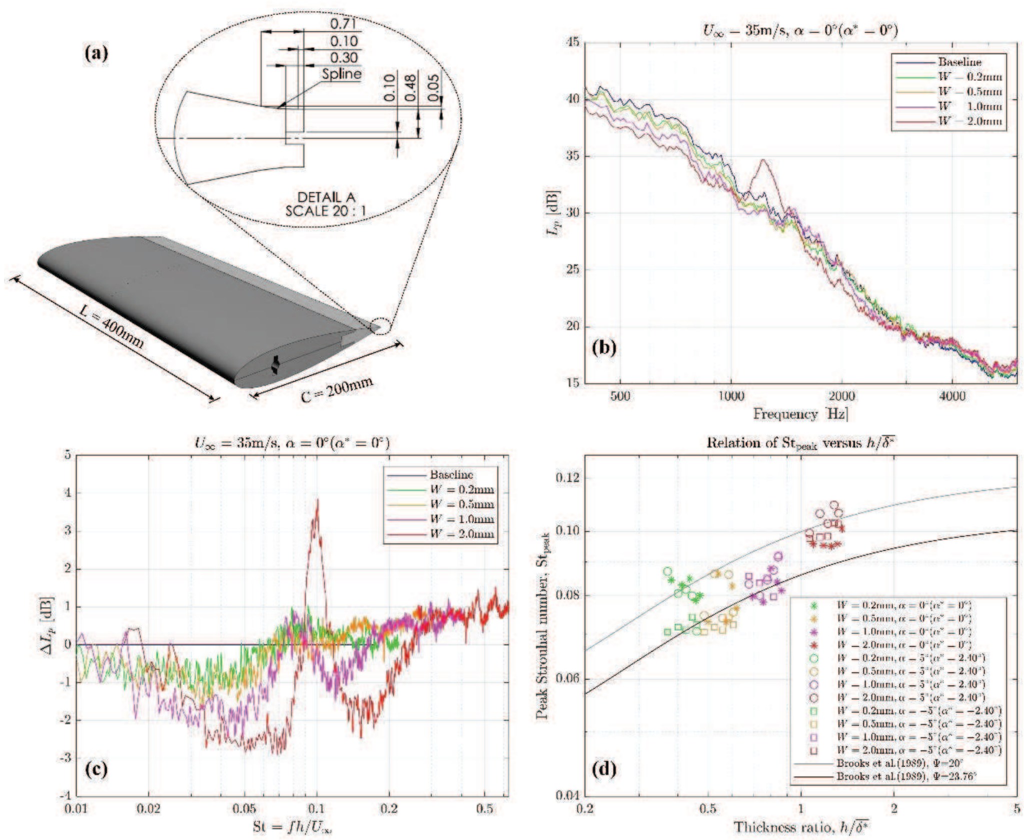

Figure: (a) An example of NACA0018 airfoil with a TE crack of 0.2mm. (b) SPLs with resolution of 10Hz (U=35m/s and alpha=0°). (c) Corresponding SPL differences compared with baseline case normalized as peak St. (d) Relations of peak St and thickness ratio: discrete points are the experimental date; grey and black curves are prediction models Brooks et al. proposed with solid angle of 20° and 23.76°.

Fig.(b) shows sound pressure levels (SPLs) Lp at the integrated region of four damaged cases as well as baseline with the frequency resolution of 10Hz under the free-stream velocity U of 35m/s and geometrical angle of attack (AoA) alpha of 0°. The cases with smaller cracks show less remarkable tonal peaks compared with the one of W=2.0mm (~4dB); when the crack size is smaller the spectral peak broadens. These peaks or humps are attributed to the periodic vortex shedding from blunt TEs. Fig.(c) shows the SPL differences Delta Lp between the damaged cases and baseline; frequency is normalized as TE-thickness-based Strouhal number St. Local maxima of Lp are present at approximately St = 0.1 [6]. In the experiment, it is difficult to extract the spectral peaks or humps if the effective AoA (alpha *) [6] is more than 2.40° because the boundary layer on suction side becomes thicker and the asymmetry of boundary layers prevents coherent and periodic vortex shedding [7]. In Fig.(d), the discrete points are the St at peak Lp (Stpeak) versus the ratio of TE thickness and averaged displacement thickness of pressure and suction sides (overline delta *) extracted from available cases (U=15m/s, 20m/s, 25m/s, 30m/s and 35m/s); the grey and blue curves are obtained from models reported in [6] with solid angle (Psi) of 20° and 23.76° (baseline solid angle), respectively. The points of Stpeak versus thickness ratio show a good agreement with the prediction model [6]. This means that particularly for smaller cracks at the first stage of damaged process, the effect of solid angle can be neglected and considered as a minor and adjunctive factor. The TE thickness retrieved through the application of the model can be used as a prediction of the damage level. Additional data obtained from experiments with turbulent inflow will be presented to assess if the approach proposed is still feasible in more realistic turbulent inflow conditions.

References:

[1] Tautz-Weinert, J. and Watson, S.J., 2016. Using SCADA data for wind turbine condition monitoring–a review. IET Renewable Power Generation, 11(4), pp.382-394.

[2] Yang, W., Peng, Z., Wei, K. and Tian, W., 2016. Structural health monitoring of composite wind turbine blades: challenges, issues and potential solutions. IET Renewable Power Generation, 11(4), pp.411-416.

[3] Du, Y., Zhou, S., Jing, X., Peng, Y., Wu, H. and Kwok, N., 2020. Damage detection techniques for wind turbine blades: A review. Mechanical Systems and Signal Processing, 141, p.106445.

[4] Merino-Martínez, R., Carpio, A.R., Pereira, L.T.L., van Herk, S., Avallone, F., Ragni, D. and Kotsonis, M., 2020. Aeroacoustic design and characterization of the 3D-printed, open-jet, anechoic wind tunnel of Delft University of Technology. Applied Acoustics, 170, p.107504.

[5] Carpio, A.R., Avallone, F., Ragni, D., Snellen, M. and van der Zwaag, S., 2020. Quantitative criteria to design optimal permeable trailing edges for noise abatement. Journal of Sound and Vibration, 485, p.115596.

[6] Brooks, T.F., Pope, D.S. and Marcolini, M.A., 1989. Airfoil self-noise and prediction.

[7] Moreau, D.J. and Doolan, C.J., 2016. Tonal noise production from a wall-mounted finite airfoil. Journal of Sound and Vibration, 363, pp.199-224.