PO.ID 041

Research on A New Technique Dedicated to Monitoring Long Wind Turbine Blades

Sunny W. Tian[1], W. Yang[1], Z. Lang[2], L. Tao[1], C. Ng[3], P. Mckeever[3]

[1] Newcastle University, [2] University of Sheffield, [3] Offshore Renewable Energy Catapult Centre

Newcastle University

Abstract

Being expensive in capital cost, difficult to repair and replace, and significant in fault-induced revenue loss, the safe operation of wind turbine (WT) blades via condition monitoring (CM) has been regarded as one of the most effective approaches to lowering the energy cost of wind power. However, the continual scaling up of the size of WT blade is making blade CM more difficult than ever before. The research reported in this paper is just in order to tackle this issue by developing a more reliable blade CM technique with the aid of Finite Element (FE) calculations. To facilitate research, a finite element model of a long WT blade is developed in SolidWorks in order to simulate the dynamic responses of healthy and unhealthy long blades under various wind loading conditions. The corresponding strains distributed on blade surface, bending deflection of the blade, and the bending moment at the root section of the blade under each wind loading condition are calculated and compared, so that a better blade defect indicator can be identified from them. Based on this, an effective blade CM technique is proposed and furthermore, verified by using the calculated blade CM data. It has been proved that the proposed technique is effective not only in detecting the presence of the blade defect but also in defect location and severity assessment despite the variation of external load.

Objectives

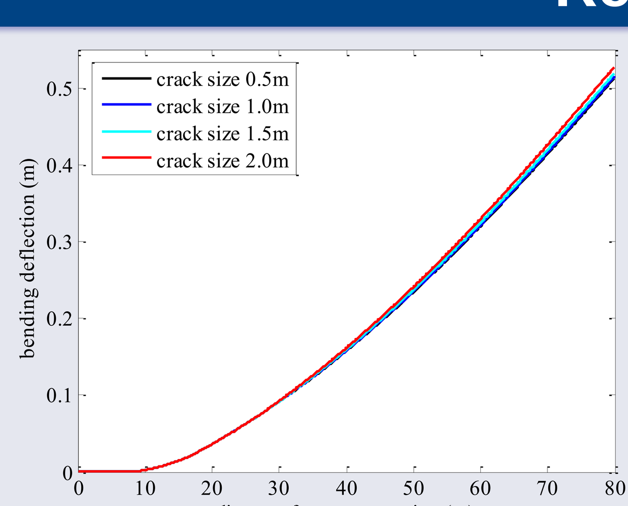
External loads, coupled together with structural defects, have significant influence on the dynamic response of WT blades. Accordingly, a reliable blade CM technique should be in/less-dependent of external load. The existing blade CM techniques based on the analysis of individual CM signals have not met such a requirement thus are not ideal for blade CM. To fill the gap of technology, this research will reach the following objectives:

- The limitations of the existing technique in WT blade CM are proved by the approach of numerical analysis;
- Identify critical information for WT blade CM from numerical analysis results;
- Develop a reliable and efficient WT blade CM and fault location technique.

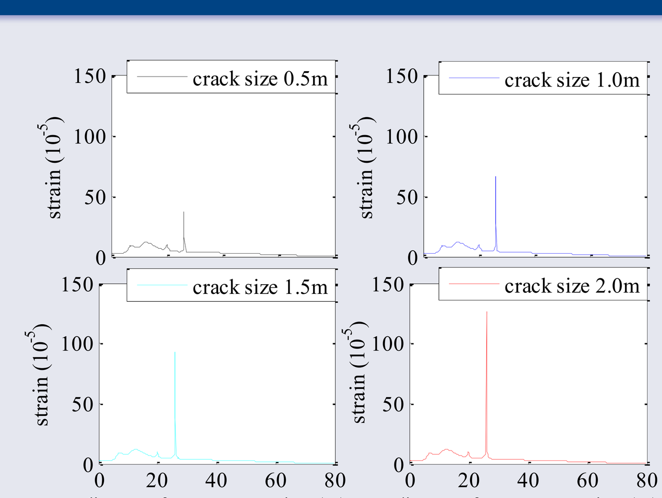
Methods

1. Firstly, a Finite Element model of a large WT blade is developed with the aid of software SolidWorks. The size of the blade is defined by referring to the dimension of the blade used by Vestas' 8MW V164-8.0.
2. Mesh the blade and make artificial crack on blade surface. The size of lateral crack is 0.5 m, 1.0 m, 1.5 m and 2.0 m, respectively.
3. Apply different wind speeds, i.e. 5 m/s, 10 m/s and 15 m/s, to the blade with and without crack, and calculate the corresponding bending deflection, strain on blade surface, and bending moment at the root section of the blade.

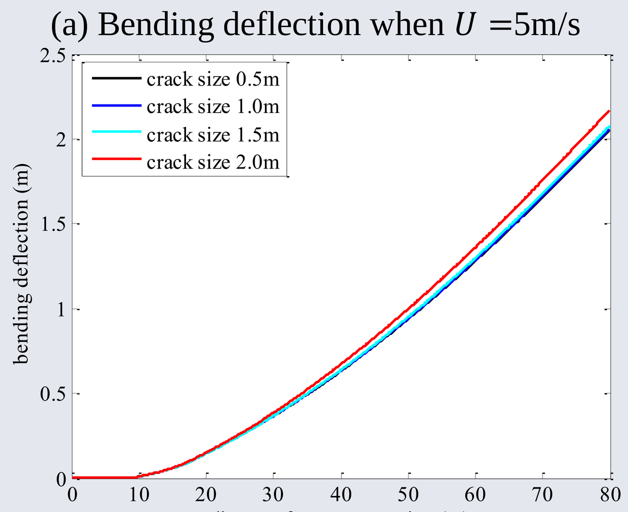
Results



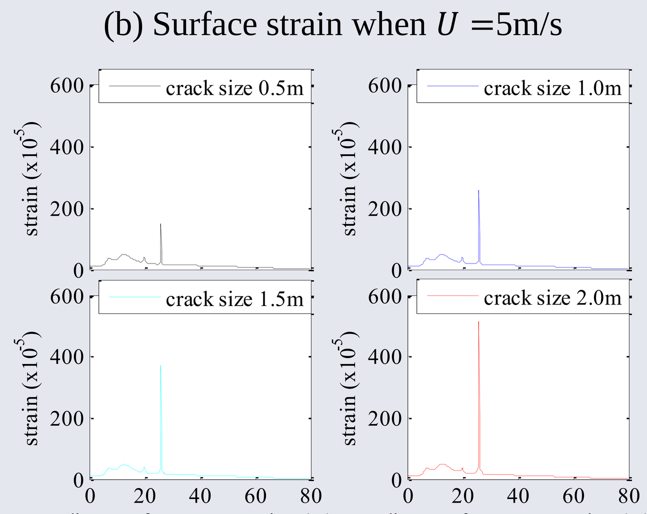
(a) Bending deflection when U =5m/s



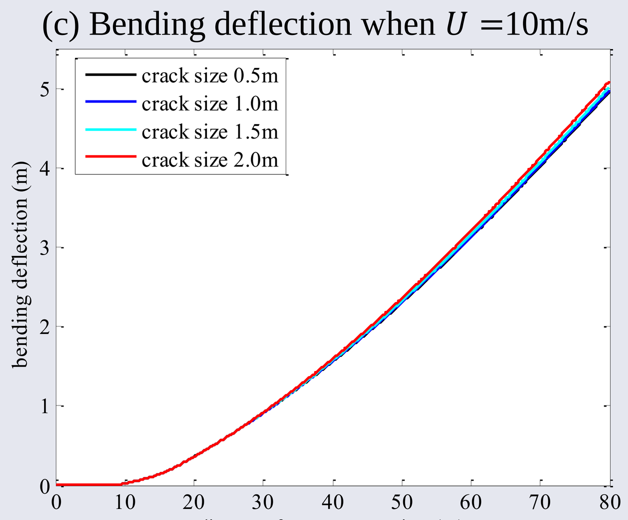
(b) Surface strain when U =5m/s



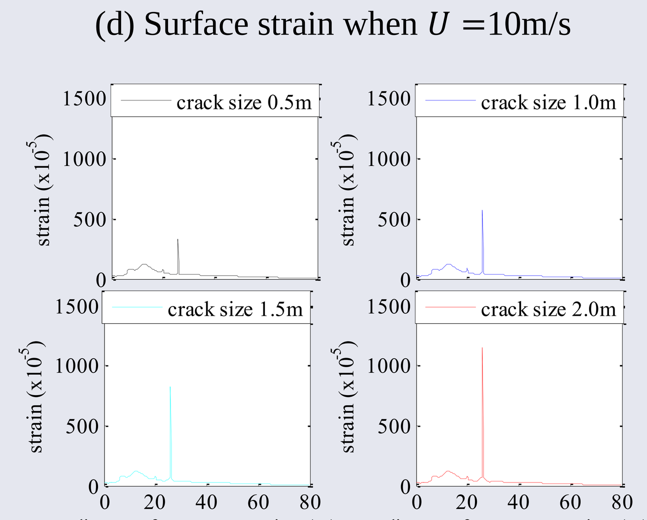
(c) Bending deflection when U =10m/s



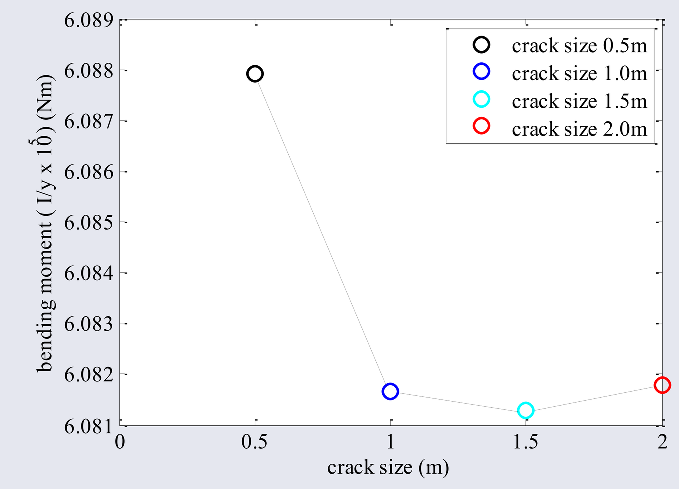
(d) Surface strain when U =10m/s



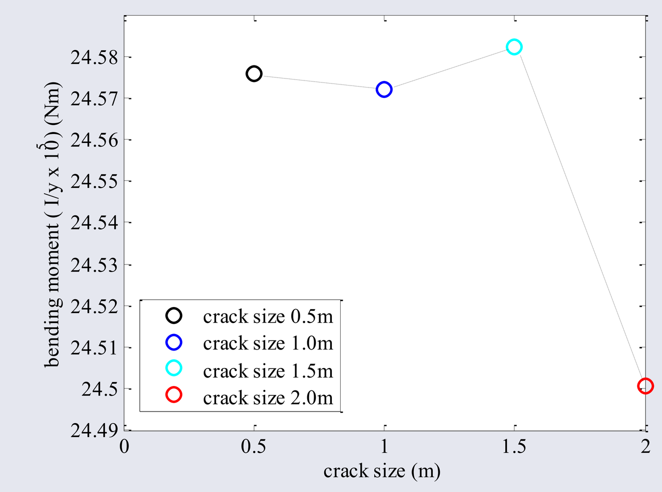
(e) Bending deflection when U =15m/s



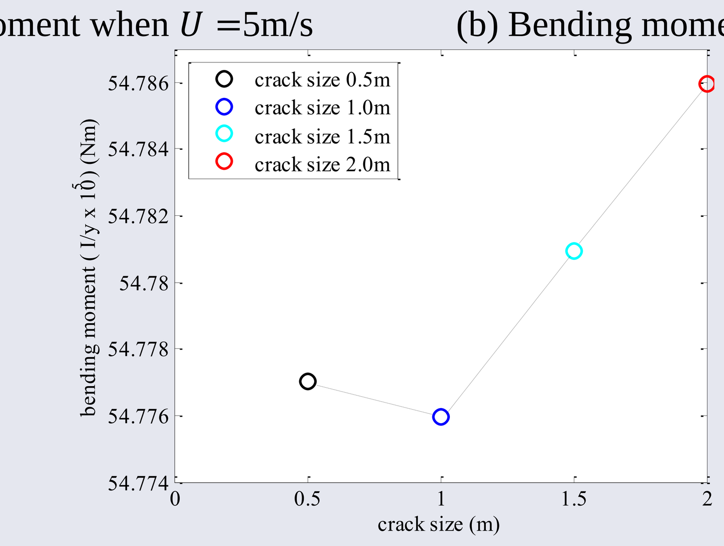
(f) Surface strain when U =15m/s



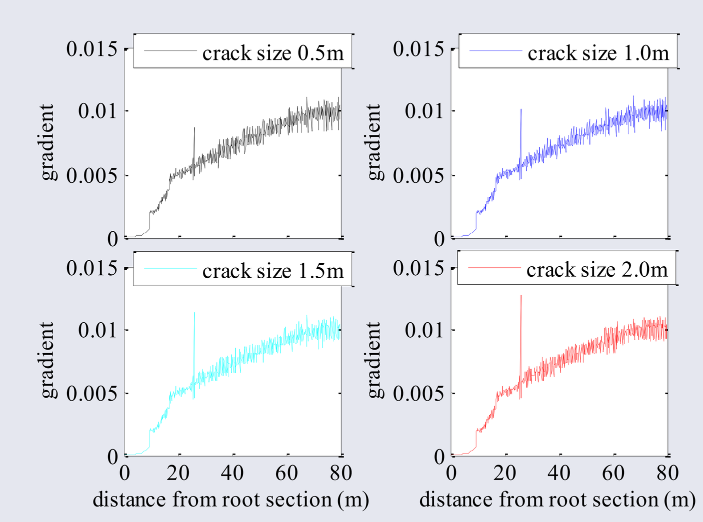
(a) Bending moment when U =5m/s



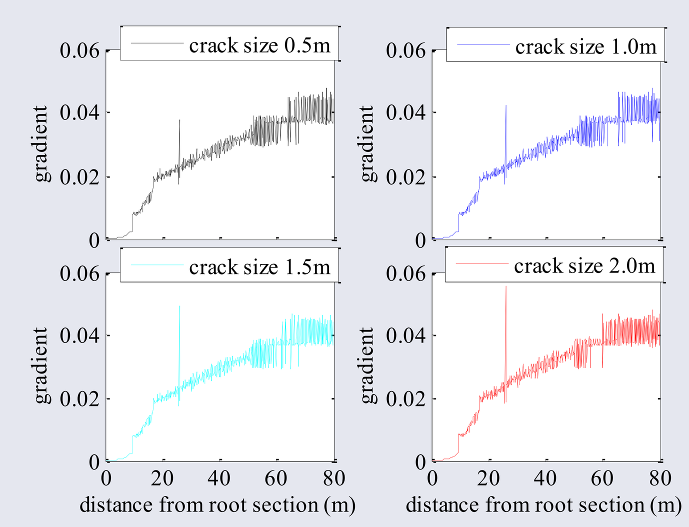
(b) Bending moment when U =10m/s



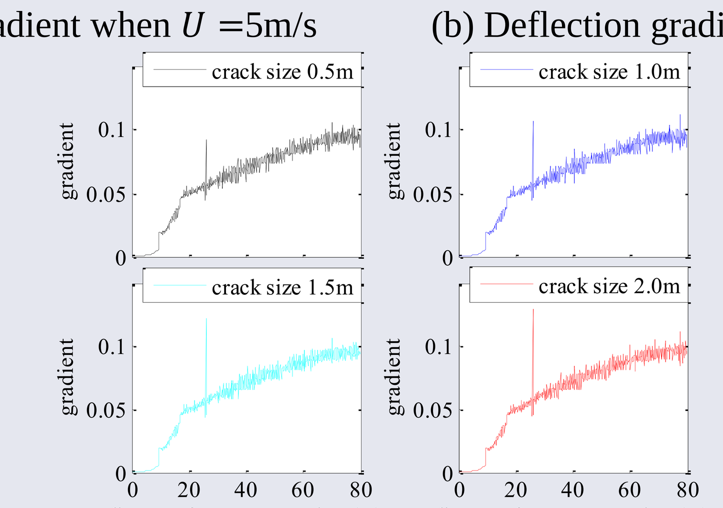
(c) Bending moment when U =15m/s



(a) Deflection gradient when U =5m/s



(b) Deflection gradient when U =10m/s



(c) Deflection gradient when U =15m/s

Conclusions

1. The bending moment measured at the root section of WT blade does respond very well to the variation of wind load. Thus, it is indeed an excellent indicator of the wind load applied to the WT. So, apply bending moment to WT control is a successful strategy for WT operation and safety protection. However, the FE calculation results presented in this paper disclose that the bending moment is not a good indicator of the structural integrity condition of the blade, because its response to the gradual increase of crack size does not show a consistent variation tendency;
2. In contrast to bending deflection and bending moment, the strain measured from blade surface is the best indicator of blade's structural health condition. Moreover, both the location of the defect occurring in blade and its severity can be clearly indicated by the strain. However, at the moment the application of strain gauges is limited only in the laboratory tests of WT blade. They are difficult to be applied to monitoring WT blade in operation due to reliability and durability issues and relevant challenges in transducer installation and data management;
3. The structural health condition of a long WT blade is not easy to be properly assessed through direct observation of the bending deflection of the blade. However, the deflection gradient proposed in this paper based on bending deflection has been proved a successful CM criterion for blade defect detection, location and assessment.

References

1. W. Yang, "Testing and condition monitoring of composite wind turbine blades," in *Recent Advances in Composite Materials for Wind Turbines Blades*, Dr. Brahim Attaf (Ed.), ISBN 978-0-9889190-0-6, The World Academic Publishing Co. Ltd, December 2013.
2. P. Tavner, Offshore Wind Turbine: Reliability, Availability & Maintenance. IET Press, ISBN: 978-1-84919-229-3, 2012.
3. K. Fischer, F. Besnard, and L. Bertling, "Reliability-centered maintenance for wind turbines based on statistical analysis and practical experience," *IEEE Transactions on Energy Conversion*, vol. 27, no. 1, pp 184-195, 2012.
4. P. Caselitz and J. Giebhardt, "Rotor condition monitoring for improved operational safety of offshore wind energy converters," *ASME Journal of Solar Energy Engineering*, vol.127, pp 253-261, 2005.
5. C.S. Shin, B.L. Chen, and S.K. Liaw, "Foreign object impact monitoring on wind turbine blade using FBGs," in *Proceedings of IEEE Conference of Sensors*, Limerick, October 2011.
6. W. Yang, P. Tavner, C. Crabtree, Y. Feng, Y. Qiu, "Wind turbine condition monitoring: technical and commercial challenges," *Wind Energy*, vol.17, no.5, pp 673-693, 2014.
7. C.C. Ciang, J.R. Lee, and H.J. Bang, "Structural health monitoring for a wind turbine system: a review of damage detection methods," *Measurement Science and Technology*, vol.19, pp 1–20, 2008.