Reliability & Risk Division
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Active Condition Monitoring of Wind Turbines

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RELIABILITY MAINTENANCE & MANAGING RISK CONFERENCE

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Objective

- To Assess the feasibility of crack detection on micro wind turbine blades using low cost piezoelectric transducers in the excitation frequency range of 1-40 kHz.

- Development of a novel wind turbine condition monitoring system using low cost piezoelectric transducers and investigation of a crack detection and propagation methodology.

- Construction and testing of a replica Marlec 913 Windcharger Turbine blade in a lab environment.

Outline

- Literature review of wind turbine blade fatigue mechanisms and fatigue propagation.
- Literature review of wind turbine blade failure mechanisms.
- Replica blades of Marlec 913 with simulated cracks measured with a network of a piezoelectric transducers.
- Proof of concept for an ultrasonic NDT crack detection and monitoring system.
- Conclusions and suggestions for further work.

Introduction

- Wind turbine blades are made of a composite material and are subject to cyclical fatigue cycles, this will eventually lead to catastrophic failure and this can be very costly to the operator.

- Literature has an emphasis on large industrial sized turbines and various blade failure mechanisms that occur within them.

- It is difficult to predict the exact fatigue life of a blade and often difficult to tell the extent of the fatigue damage so an efficient predictive condition monitoring system would play an essential role in mitigating against catastrophic failure.

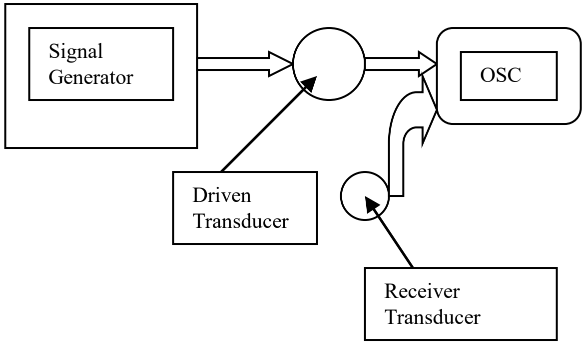
Introduction

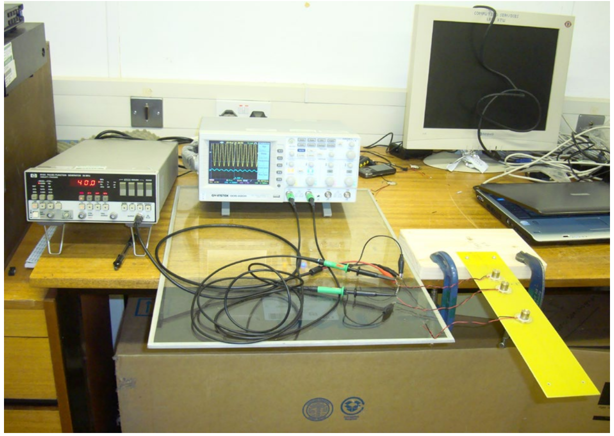
- NDE methods for blade evaluation such as oil analysis, Acoustic Monitoring, Infrared Thermography and resonant comparison method were investigated.
- As a low cost method a transfer function was used to compare the signal between piezoelectric transducers in different locations in order to detect changes in the vibrational pattern of the wind turbine blade if a crack was present.
- A signal generator was connected to a set of piezoelectric transducers in order to vibrate the structure and another set of piezoelectric transducers were acting as vibration sensors.

Methodology

- Transducers placed in a non-linear arrangement based on geometric progression to prevent the transducer being placed at the node position as this would mean that model vibration patterns would not be detected.
- Three FR4 board 385mm x 75mm copper was etched away using a chemical process
- Test Area 335 x 75 mm
- 50 mm for mounting a piece of wood.
- Experimental setup shown opposite.

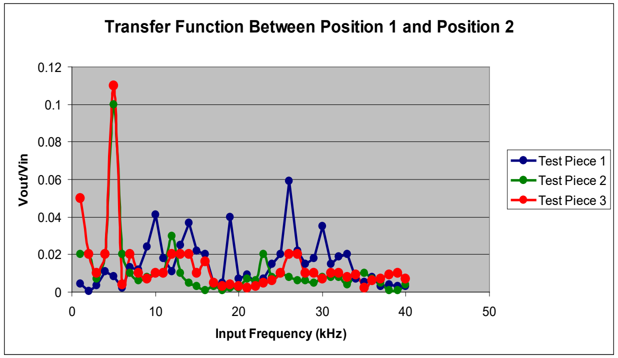
- Driven and Receiver transducer arrangement





Methodology

- Transducer 1 closest to the piece of wood
- Transducer 2 Roughly middle of the blade
- Transducer 3 End of the blade
- Natural Frequency calculated and resonant peaks identified optimum frequency range identified.



- Series of cracks were created in the root region
- Crack development and propagation were measured.
- Comparison of cracked and uncracked waveforms
- dB difference graph used to model the differences between the uncracked and cracked blades.

$$= 20\log\left|\frac{C(f)}{G(f)}\right|$$

- C(f) = Vout/Vin reading after the crack
- G(f) = Vout/Vin reading before the crack was induced into the material.

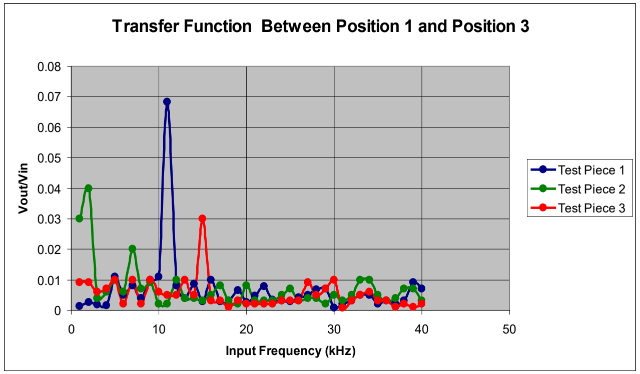
Data Collection

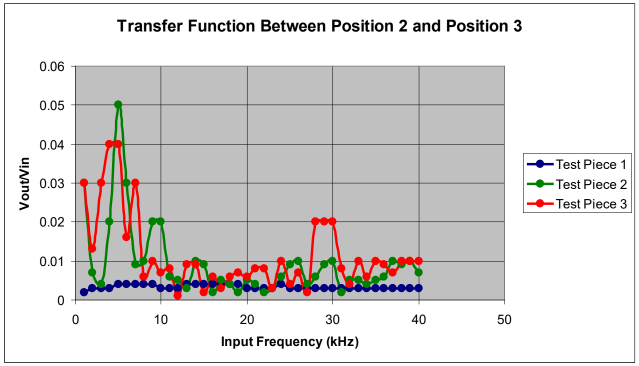
Vpp	Frequency

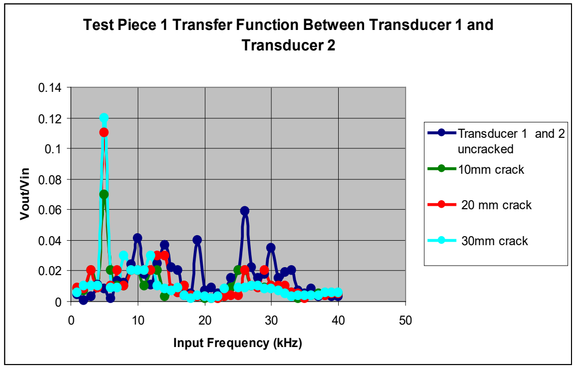
- AC voltage measured peak to peak for driven and graphs prepared in excel. Peak to peak voltage. Data obtained from GW Instek GDS-2204 Output Impedance 1 MegaOhm.

Analysis

- Determination of optimum transducer position for crack detection







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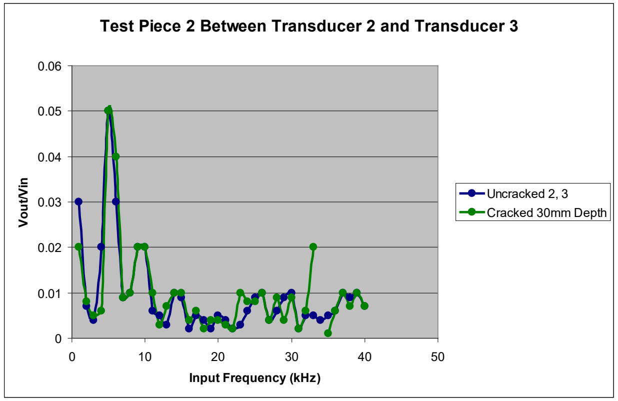

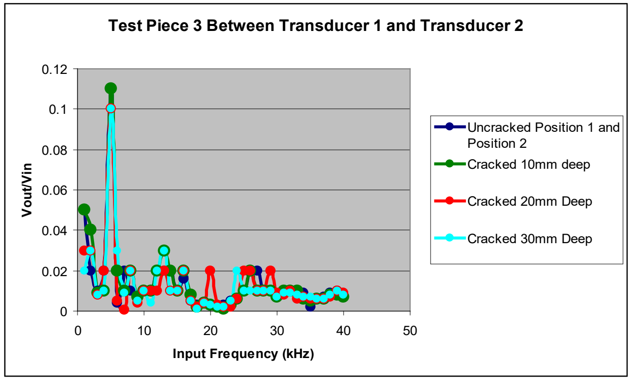

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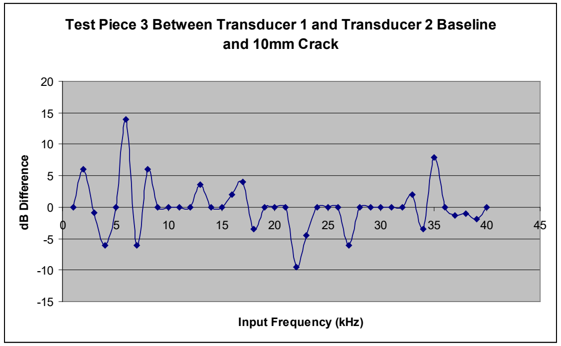

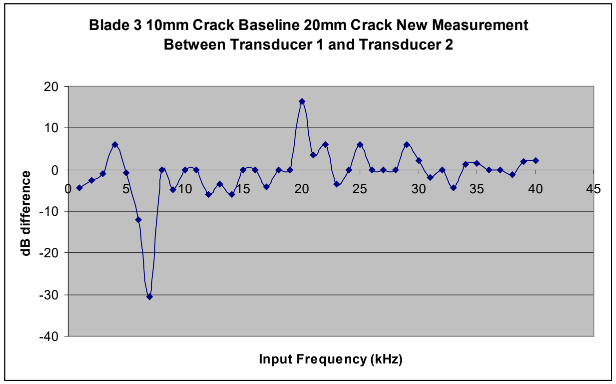

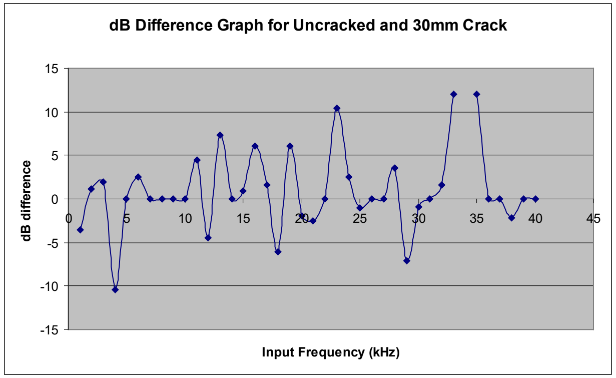

Conclusions

- Transfer Function is a good way of detecting the onset of cracks in a wind turbine blade and can also be used to track crack propagation.

- Changes in transfer function graph between Vout/Vin are very small but a dB difference graph can be used in order to exaggerate the differences.

- Further work needed to understand and categorize crack types and develop a fatigue model.

Further Work

- Adding control limits to the dB difference graph to create a visual threshold for crack initiation and propagation.
- Fatigue Testing to develop a fatigue model for wind turbine crack propagation
- Application to track the remaining life on a bathtub curve based on failure probability.
- Investigation of the possibility of miniaturization of signal generation and oscillocope instruments for active condition monitoring of wind turbine blades.

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