Damage severity assessment of wind turbine blades

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ENGINEERING POSTGRADUATE RESEARCH SYMPOSIUM

1. Introduction

Significant growth in the wind industry has been noted and predictions expect this to continue (Figure 2).

Wind turbines are being located in harsh, remote areas causing challenges to current visual inspection methods. Operational and maintenance costs must be reduced whilst maintaining reliability.

This research aims at developing a physics based structural health monitoring methodology to continuously monitor the health of wind turbine blades as opposed to scheduling maintenance at predefined intervals.

Damage severity assessment of blades using fuzzy finite element model upgrading (FFEMU) techniques will be the main focus of this research, with the overall objective of damage location and severity assessment of a small scale wind turbine blade.

Figure 1 – Harsh and often remote operational environments of wind turbines - Siemens Press Picture [1]

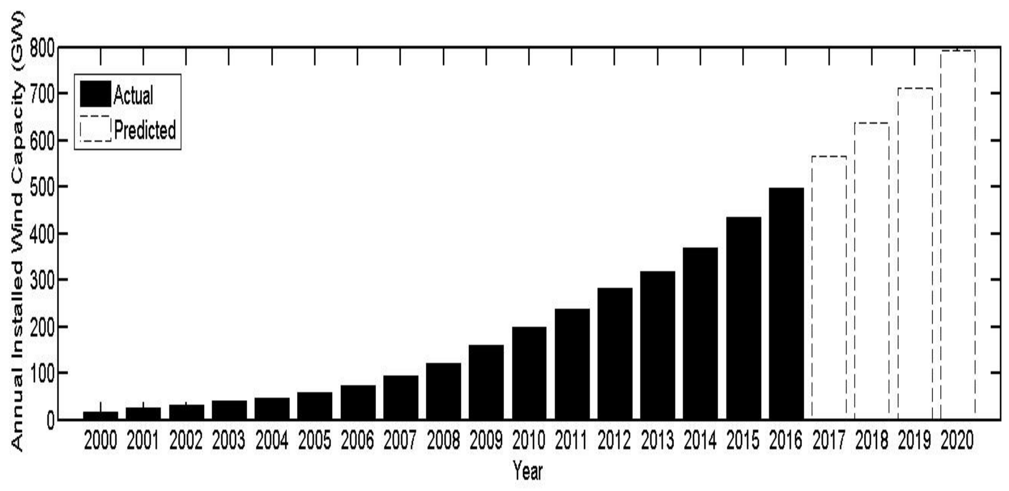

Figure 2 - Global annual installed wind capacity 2000-2020 [2]

2. Methodology

Damage simulated as structural alteration through addition of mass to trailing edge of the blade.

Experimental Modal analysis conducted on small scale blade (Figure 3) in two states, baseline and altered. Modal parameters of the blade measured.

Numerical model created and upgraded using experimental results to obtain calibrated FEM.

Calibrated FEM used to determine magnitude and confirm location of structural alteration. FFEMU implemented to account for uncertainty within updating.

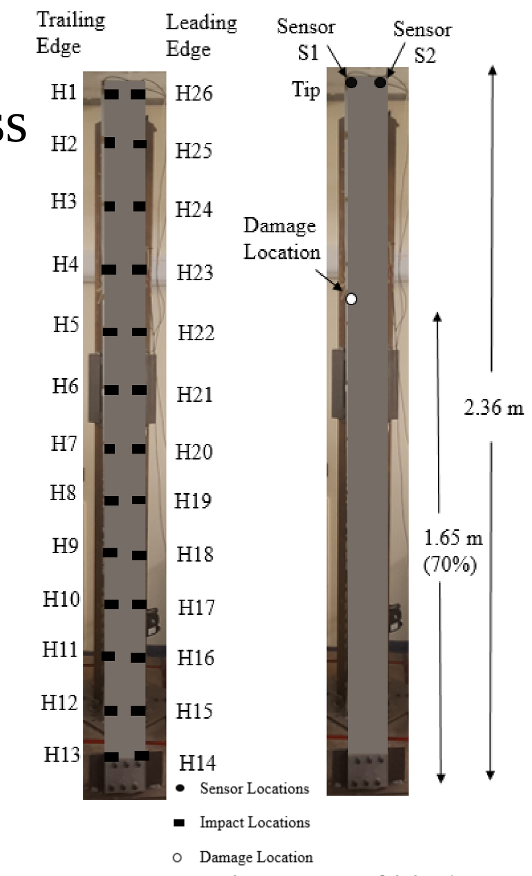

Figure 3 – Schematic of blade with impact, sensor and damage locations

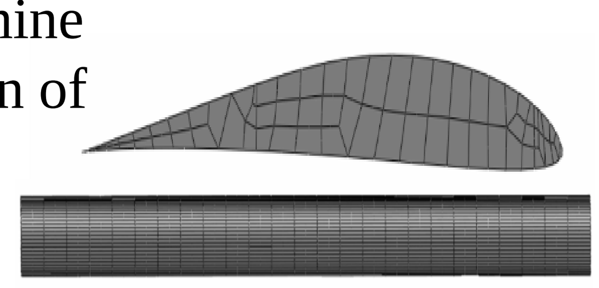

Figure 4 – Numerical model of test specimen

3. FFEMU Baseline Updating

An objective function, which is a function of updating parameters E_1 and G_{12} was created containing difference between experimental and analytical frequencies at each α-level.

The objective function was minimised using two optimisation algorithms particle swarm optimisation (PSO) and firefly algorithm (FA) to produce frequencies shown in Figure 5.

Fuzzy updated parameters shown in Figure 6 were constructed to provide baseline values whilst accounting for material variability.

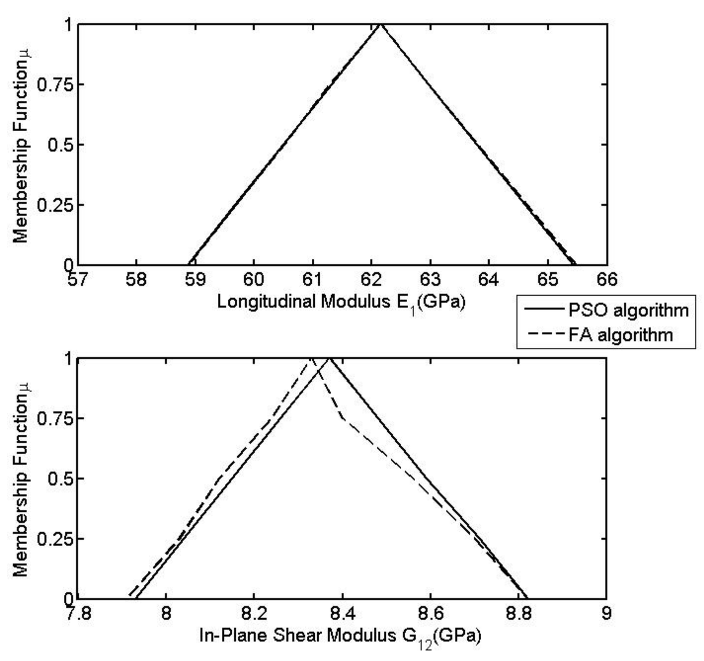

Figure 6 – Fuzzy updated parameters E1 and G12 obtained via PSO and FA

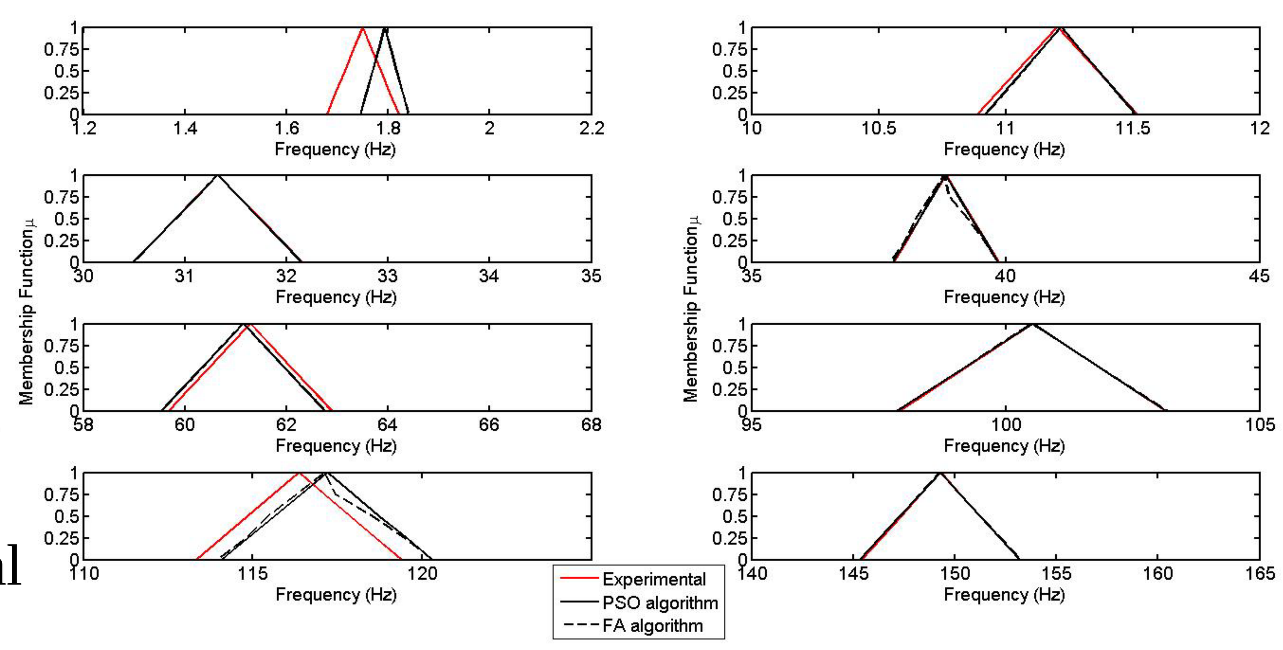

Figure 5 – Fuzzy updated frequency values showing comparison between experimental campaign (red) and PSO (black) and FA (dashed) models.

4. FFEMU Damage Updating

Four masses were simulated on blade FEM with added mass of each used as updating parameter

Two metaheuristic optimisation algorithms used PSO (Figure 7) and FA (Figure 8).

Fuzzy updated mass parameters shown Figure 7 highlight large magnitude of mass detected in region of experimental mass.

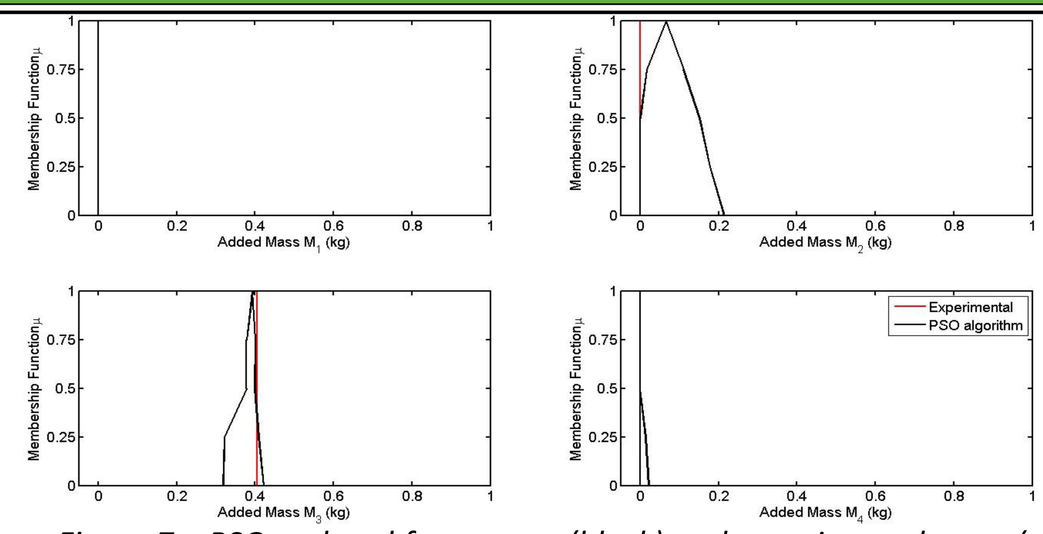

Figure 7 – PSO updated fuzzy mass (black) and experimental mass (red)

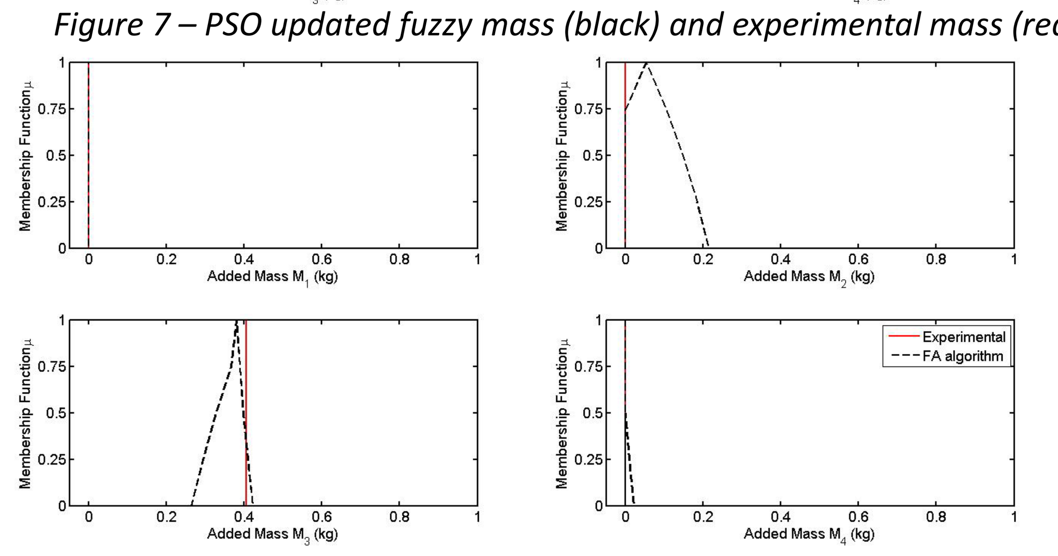

Figure 8 – FA updated fuzzy mass (black) and experimental mass (red)

Table 1 highlights accuracy between experimental (0.405 kg) and predicted (0.409 kg).

Table 1– Deterministic damage identification comparison between PSO and FA results

Added mass	M_1	M_2	M_3	M_4
Experimental (kg)	0.000	0.000	0.405	0.000
PSO-updated (kg)	0.000	0.066	0.393	0.000
FA-updated (kg)	0.000	0.053	0.380	0.000

5. Conclusions

This work demonstrates the preliminary stages of the research, proving the concept of structural modification detection and quantification on a small scale blade. Future work will involve upgrading the current FEM to model inaccuracies associated with boundary conditions. In addition to this, detection and quantification of unknown damage extents will be developed and applied to the blade whilst accounting for uncertainties within the experimental setup.

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References

[1] Siemens 2.3 MW Offshore Wind Turbines (NREL 27851)
[2] Global Wind Energy Council (GWEC), (2016). Global wind report annual market update 2015

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