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Damages of wind turbine blade trailing edge: Forms, location, and root causes

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ABSTRACT

The geometrical form and the manufacturing technique make the trailing edge of the wind turbine blade more susceptible to damage. In this study the trailing edge in a number of 81 blades of 100 kW wind turbines and 18 blades of 300 kW wind turbines of working life ranging between 6.5×10^7 and 1.1×10^8 cycles were completely visually scanned. The different damages were classified and allocated in their exact position relative to the blade length. Cracks in different orientations with the blade length were the frequent types of damages which found on the trailing edge. First, longitudinal cracks (LCs) that found along the blade trailing edge from the blade root to the tip were in lengths that varied from a few centimeters up to around 1.35 m. Second, transverse cracks (TCs) were found in either simple TCs which growing on one shell at the trailing edge or round TCs which growing across the two shells. TCs lengths were ranging from 20 to 50 mm. Third, edge damages were detected in the form of edge cuts or crushing. The possible root causes of the different types of cracks have been discussed.

1. Introduction

Trailing edge of the wind turbine blade is the region of the two half shell bonding which include a long line of adhesive joints. The trailing edge is subjected to changeable complex state of stress through the cycle, while the adhesive joining material at this edge can be subjected to shear stresses. Although, the designed fatigue life of the wind turbine blade should be 20 years [1]. Failure of wind turbines due to failure of the blades represents 19.4% of a total of 1028 wind turbine failure cases [2] and the main failure root cause are mostly due to the operation and environmental conditions.

There are no available much data about the various forms of damages in the trailing edge of the wind turbine blades. Thus the aim of the current work was to present the most frequent forms of damages of the wind turbine blade trailing edge and the locations of their occurrence. This has been carried out through the full visual scanning inspection of a considerable number of wind turbine blades, those were working at the boundaries of their proposed life.

2. Inspection procedure

In this study 18 blades of 300 KW wind turbines and 81 blades of 100 KW wind turbines were full visually inspected (VT). The blade lengths are 9.5 m and 14.2 m for the 100 KW and 300 KW power, respectively. Before the visual inspection of the wind turbine blades, the blades have been washed and cleaned thoroughly. The VT inspection is started by giving a designation name for the blade under investigation followed by attaching a scale tape to the blade side under inspection

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to determine the location of any discontinuity or damage. The inspection was carried out thoroughly from the tip up to the root hub on the trailing edge of the blade. The different discontinuities on the blade were documented using a high resolution digital camera.

3. Results and discussion

3.1. Estimation of the actual working life

The inspected wind turbines were installed in different dates, so that their lives were ranging between 17 and 22 years. The actual working life (in cycles) of each wind turbine was calculated based on the operational data using Eq. (1):

$$\text{Actual working life} = \text{RPM} \times \text{Age (Minutes)} \times \text{Capacity factor} \tag{1}$$

where, RPM is the average number of cycles per minutes of each turbine model, the age is based on the date of start working date after installation of each turbine and the capacity factor describes the net time fraction of working excluding the times when the wind speed is under the cut-in speed. The availability factor of these turbines is ranging between 0.95 and 0.98. The capacity factor is 0.22 and 0.25 and the RPM is 33 and 38 for the 100 kW and 300 kW turbines, respectively. The actual turbines working lives were calculated in number of cycles till the time of inspection and found between 6.5×10^7 and 1.1×10^8 cycles which are illustrated against the different turbines in Fig. 1. The calculated working number of cycles was consistent with published information [3] which confirmed that the working life of 20 years delivered a number of cycles in the order of 10^8 cycles.

3.2. Trailing edge damage forms

Extensive analysis of the documented pictures has been carried out to determine the type, size and location of the different forms of damages. It should be mentioned here that a number of other damage forms exist in the blade shells were not included in this context. The trailing edge damages were categorized as follows:-

(1) Longitudinal cracks along the trailing edge through the bonding materials.
(2) Transverse cracks.
(3) Edge cuts or crushing.

Table 1 indicates the number of each type of damages in the inspected wind turbine blades. Because the inspected wind turbines were of different types (100 kW and 300 kW) some normalization was made to relate the location of the damage to the blade length. For the wind turbines 100 kW and 300 kW power, the number of inspected blades B was 81 and18 and the blade lengths R_0 were 9.5 m and 14.2 m respectively. The number of discontinuities (N) is normalized and expressed in term of number per blade unit length (n) using Eq. (2).

$$n = \frac{N}{B \cdot R_0} \tag{2}$$

Fig. 2 illustrates the number of damage per blade unit length for each type of damages for both 100 kW and 100 kW power wind turbine blades. Clearly, it can be observed that the number of damages per blade length is higher in the 300 KW wind turbine blades than in the 100 kW wind turbine blade in case of the longitudinal crack and edge cuts, while transverse cracks are higher in 100 KW wind turbines than 300 KW wind turbines.

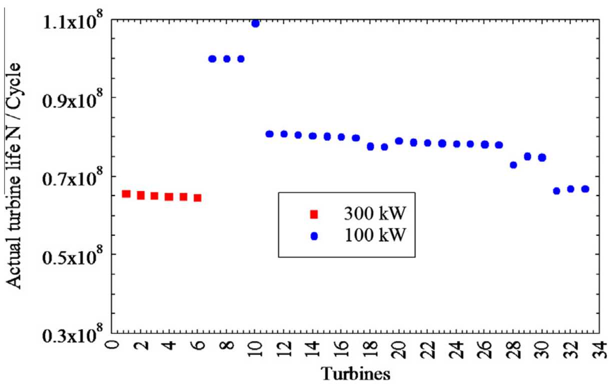

Fig. 1. Actual working lives (in cycles) against the turbine number.