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INVESTIGATIONS ON WIND TURBINE BLADES DEGRADATION

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ABSTRACT

In the frame of increasing need for renewable energy harvesting, the wind turbines stand as one of the most promising solutions. Taking into account that one of the most exposed parts of a wind turbine is the propeller, since the blades are subjected to an intensive abrasive wearing processes, an analysis of the consequent degradations will be valuable in order to establish the ways to prolong the turbine's working life.

Starting from a structural analysis of an industrial blade and several wear tests performed in abrasive environment conditions, the present paper try to identify the most exposed parts of the blade and the degradation evolution during the wearing process. The obtained results allow the establishing of a maintenance strategy leading to a prolonged working life of the blade.

Keywords: *wind turbine blade; abrasive wear; degradation evolution*

1. INTRODUCTION

In the area of green energy harvesting devices, the wind turbines are valuable solutions, capable to extract general available renewable energy - the wind energy. The technology achievements allowed the increasing of usage of wind turbines both in onshore and offshore areas. This way, the role of wind energy in achieving the goal of 1.5 ºC global warming until 2100 [1] become more and more important. Taking into account that the price of using a wind turbine is composed of several categories, like the turbine itself, assembly, installation, maintenance etc., the final value is not low. Looking only to the turbine price, one can find that 16.5% goes for the tower, 35.9% for the nacelle and 19.2% for the rotor [2]. Taking into account that the most exposed components to the environmental wearing factors are the rotor's blades, being in direct contact with dust, rain drops, hail etc. From these components, the most exposed are the rotor's blades, which are in direct contact with several environmental wearing factors, like dust, rain drops, hail etc. Following the blade length and the wind speed value, the rotating speed can reach high values, like 100 m/s [3]. As a consequence, the blade material must comply with several requirements like mechanical and fatigue strength, low density, wear resistance etc. [4]. Nowadays, the composite materials are chosen since these can satisfy most of needed requirements [5]. Among these, the glass fibers reinforced in thermoset epoxy matrix based seems to be the most popular [6]. The assessment of wear resistance of blades is an important step in the improvement of the turbine performance, which may prolong its working life. Following the placement areas, some environmental factors can overcome others, for example in offshore areas the rain and hail can be more present, while in on-shore areas the most encountered are the dust and sand particles.

The aim of the present paper is to evaluate the blade abrasive wear resistance in the presence of sand particles of an onshore industrial turbine blade material

2. TESTING METHODOLOGY

In order to assess the wear resistance of blade material, some samples extracted from an industrial wind turbine propeller were used. As can be seen in Fig. 1, the blade is composed by several layers.

As testing methodology, the erosion with abrasive particles flowing in air stream method was chosen [7]. In figure 2a is presented the experimental setup.

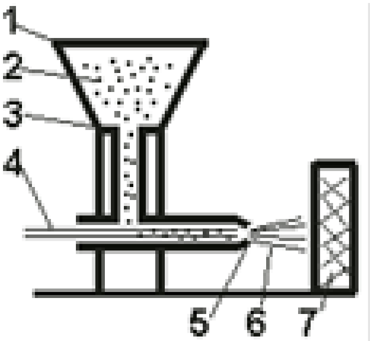
The abrasive material used for testing was dust collected from the area where the turbine is placed, figure 2b. In table 1 are presented the statistical values for particles' dimensions.

Following the tests, several samples, with different stages of degradation obtained after different testing time periods, were analyzed.

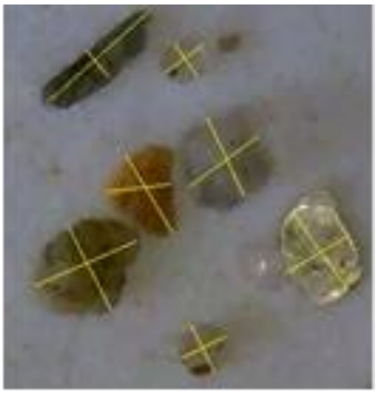
3. RESULTS AND DISCUSSION

Analyzing the surface's damage evolution of the industrial blade composite material, some observations can be made. Figure 3 shows the image of damaged areas obtained with the exposing time increasing from 15 s to 180 s.

As one can see, there are several stages of degradation, following the exposure time to the abrasive agent. Figure 4a presents the damaged area obtained after 15 s testing time, while Figure 4b shows the corresponding cross-section of the area. In this case, the top layer of the blade is damaged, but not penetrated, the maximum depth of the scars being 0.35 mm.



a)

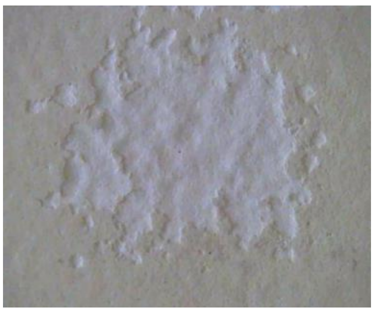


b)

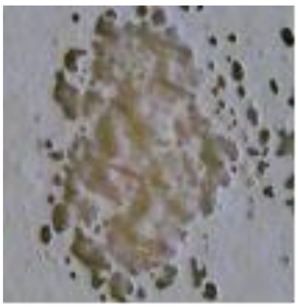
Fig. 2. Experimental setup
a) testing rig (1- reservoir, 2 - abrasive particles, 3 - calibrated orifice, 4 - high pressure air stream, 5 - ejecting nozzle, 6 - abrasive compound, 7 - tested sample); b) abrasive particles

Table 1. Experimental test parameters

Air speed [m/s]	Impact angle [º]	Particle dimensions [mm]	Nozzle-sample distance [mm]	Testing time [s]	Abrasive/air ratio [g/s]
30	90	min. 0.407 max. 1.509 mean 0.847 SD 0.322	180	15…180	10



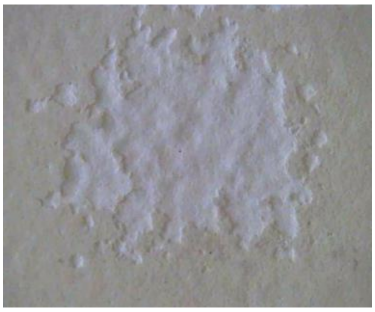
a)

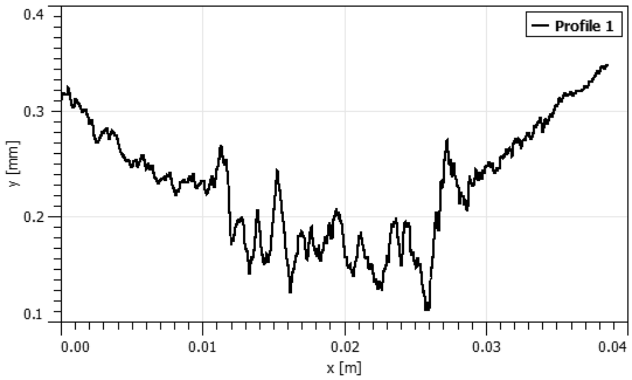


b)

c)

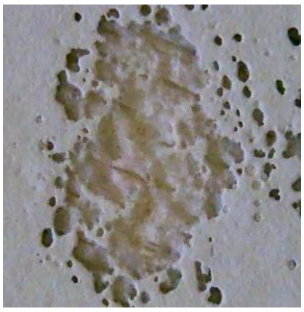
Fig. 3. Samples' degradation
a) initial degradation (15 s); b) medium degradation (160 s); c) advanced degradation (180 s)

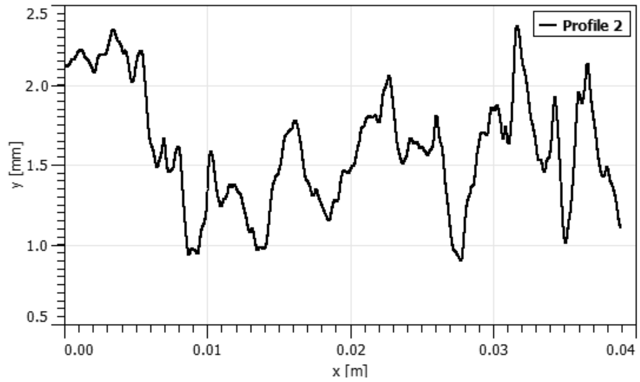




a) b)

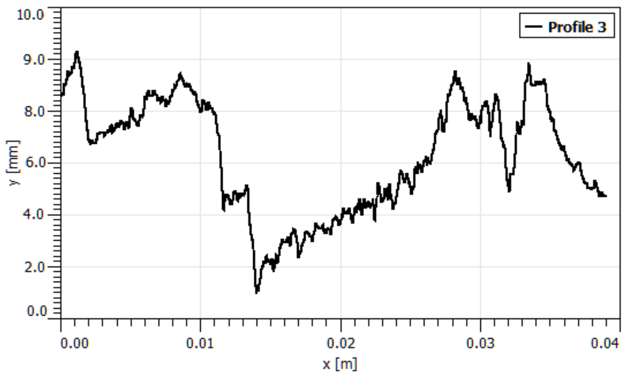
Fig. 4. Image of damaged area of the blade material tested for 15 s testing time
a) top view; b) cross-section of the damaged surface





a) b)

Fig. 5. Image of damaged area of the blade material for 160 s testing time
a) top view; b) cross-section of the damaged surface



a) b)

Fig. 6. Image of damaged area of the blade material for 180 s testing time
a) top view; b) cross-section view

Increasing the exposure time to 160 s, the maximum depth of the damaged area is increased (Fig. 5a) and, also, the depth showing a maximum value of 1.6 mm. In this case the top layer is penetrated (Fig. 5b) and, in some areas, the glass fiber fabric is also damaged.

If the top and glass fibers layers are penetrated, the internal layer is exposed to the direct action of the abrasive agent, leading to a rapid increase of the degradation. If the time necessary to penetrate the first two layers is approximatively 160 s, the internal layer is destroyed in approximately 20 s, the degradation depth reaching 8.6 mm (Fig. 6).

In Figure 6a, it can also be observed the pattern of the degradation. Taking into account that the abrasive particles have different weights and the air stream have a conical shape, the corresponding impact energies are different, leading to uneven damaged area. In the middle, all layers are penetrated, meanwhile near the borders, only the first two layers are damaged, as it can be observed in figure 6a.

The tests' results shown that the most resistant to the abrasive agents is the top layer, the next two layers being more sensitive to the erosive action. If the top layer is penetrated, the degradation become rapidly catastrophic, leading to the removal of an important quantity of material from the blade.

CONCLUSION

The propellers used in wind turbines construction works at high rotational speeds, and can be subjected to several types of deteriorations. Among these, the abrasive wear, due to the impact of the hard particles to the blade surface can lead to important damages. The investigation of the blade resistance in abrasive conditions, performing abrasive wear tests on composite material samples from an industrial wind turbine blade, can provide valuable information on degradation evolution, leading to a better materials structure designing.

Within the limitations of this study, the following conclusions may be drawn:

- The most important part of the blade material, from the abrasive resistance point of view, is the top layer.
- It was found that the air speed has significant influence on the abrasive wear resistance of the blade material. At low air speeds (14m/s), the cover layer succeeds to avoid the penetration, protecting the inner layers. By increasing the exposure time, the top layer was penetrated and the subsequent layers were quickly destroyed, leading to serious damage of the blade.
- As consequence, in order to increase the blade resistance to abrasive wear, is needed to increase design top layers with higher resistance in abrasive environments. Other possibility is to increase the top layer thickness, in order to delay as much as possible the penetration and the contact of the abrasive agents to the inner layers.

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