DEVELOPMENT OF AN ON-SITE DEVICE TO MEASURE CORROSION LOAD AND IMPACT TO ROTOR BLADES OF A WIND TURBINE

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Summary

To acquire the different wear and tear conditions on a rotor blade of a wind turbine a device will be designed to be installed on top of a nacelle roof. Thereby particle, precipitation, UV radiation and other environmental parameters will be measured in a time frame of 12 month or more. With this information it will be possible to analyze and estimate the erosion load based on improved erosion models. This knowledge provides the basis for a clearer understanding of the mechanisms of erosion and develops better test scenarios which will be implemented in an already existing erosion test facility.

1. Introduction

The normal design lifetime of a wind turbine is 20 years. During these years the machine is exposed to different environmental influences. Especially at rotor blades, this leads to abrasion at the blade surface. The main influences are precipitation, dust particle and UV-light exposure.

These influences result in leading edge erosion on the outer diameter as the main affected area caused by the higher differential velocity between particle and rotor surface (Fig.1). The degradation rate is increased by defects in the resin through UV-Light exposure of the damaged area [1].

Fig. 1 worst case example of leading edge erosion

This has a serious effect on the aerodynamic parameters of the rotor blade and deteriorates efficiency of the turbine (Fig. 2). The end results are higher maintenance costs and in long term reduced annual yield of a machine.

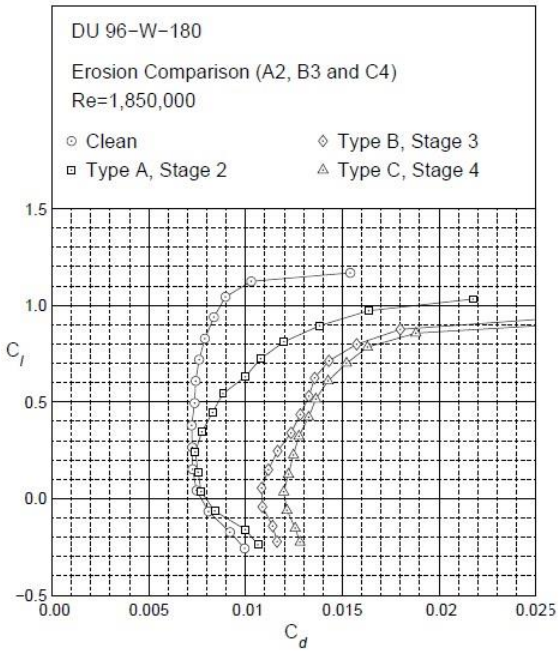

Fig. 2 Example of the influence of erosion damage

2. Erosion damage mechanisms

The main abrasive factor is precipitation and particle impact. For these two factors the main damage mechanism of erosion following the theory of Preece and Macmillan [2] is described as an erosion rate *W* and is driven by the following parameters:

Diameter	***d***
Relative impact velocity	***v***
Angle of incidence	***α***

Particle diameter and relative impact velocity are weighted by empirical gained material parameters x and y, see formula (1). The material parameters vary in a range of 0.9 to 3.0 for parameter x and 2.0 to 6.5 for parameter y.
These values influence the erosion rate in a significant way which leads to the insight that there have to be a variety of test scenarios to reproduce the whole spectrum of erosion damages on rotor blades. As a consequence, the test facility needs to be very customizable to cover all relevant scenarios.

$$W \approx d^x \cdot v^y \cdot f(\alpha) \quad (1)$$

The erosion rate *W* is influenced by f(α), which is a function of material properties of the impacted surface, e.g. the rotor blade's painting and sub-layers.
For low incident angles α, small particles furrow the material. For *higher* α, small particles cause material fatigue (Fig. 3)

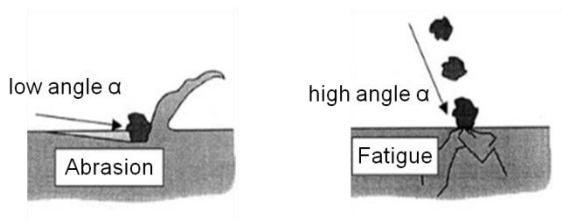

Fig. 3 Different damage effects for small (left) and high angles of incident (right) [3]

Since bigger diameters of droplets and particles increase the erosion rate, only particles bigger than 20 µm are considered during the tests. Thus fine dust will not be tested in the test scenarios.

Droplet as well as particle erosion show specific propagation patterns. When droplets hit the surface material, an impulse is induced. Additionally a strong shear strain along the plane of the surface occurs.

The velocity of falling droplets depends on their size but is usually lower than 10 m/s. Furthermore there is a correlation between droplet size and rain rate. For higher rain rate the number of large raindrops increases (see Fig. 4). The relative impact velocity depends on wind speed and is often higher than the velocity of free falling droplets. Fig. 4 shows typical distributions of raindrop diameters for different rain intensities.

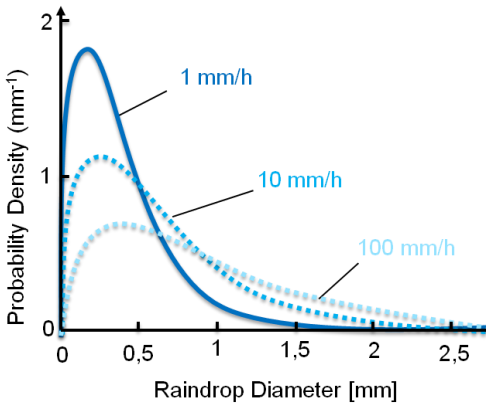

Fig. 4 Distribution of probability density and rain drop diameter for different rain intensities [4].

In addition to the mechanical damage there is also chemical and physical related damage.
Additionally to the mechanical damage there is also chemical and physical related damage such as the day and night cycle leads in a temperature and other environmental related load. Furthermore the UV radiation of the sun alters the epoxy matrix of the carbon or glass fiber reinforced material.

3. Test Scenarios for Rotor Blades

To develop test scenarios for the erosion test facility (MET – mobile erosion test facility [6]) the erosion milieu of the specific site is needed.
Regular weather monitoring services do not take into account rain or particle size distribution which would help to predict the impact energy. Also the normal measuring height is around 2 m. To get the real environmental load of the rotor blades an environmental DAQ System has to be installed at the height of the occurring load. That system needs to be also compact to not affect the normal operation of the wind turbine.

4. On-site data acquisition

To get the exact abrasive milieu around a turbine we develop an instrument for acquisitioning the different erosion loads on site of a wind turbine directly. The kind of precipitation, the size and velocity, as well as the dust particles size will be measured with the erosion milieu detector (EMD) (Fig. 5).

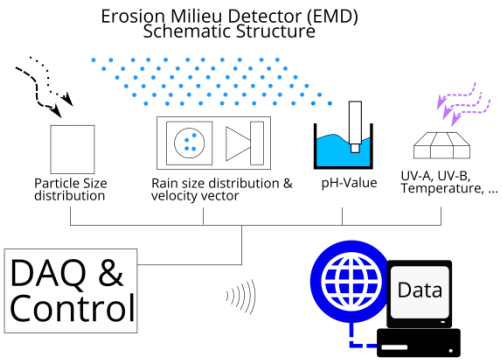

Fig. 5 schematic diagram of the EMD

The measuring site is located on top of the nacelle of the wind turbine, inside the EMD or in an equivalent place (Fig. 6). This information provides the basis for comparable conditions in an erosion test chamber to provide a prediction test for turbine operators to test different protection coatings [6]. Later resulting knowledge can be used for condition based maintenance and reduced blade inspection and repairs. Additionally it is able to help to choose the right coating system for rotor blades according to the site.

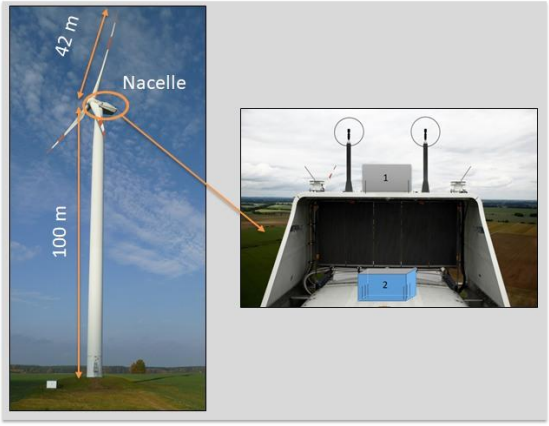

Fig. 6 Example of EMD placement (1), (2)

5. Conclusion & Outlook

For better understanding of the erosion milieu around a turbine it is necessary to acquire the exact environmental parameters which lead to rotor blade erosion.
These parameters have to be measured at the operating height of a turbine.
This improves existing erosion test and help developing better models with more realistic parameters. This leads to optimized blade production and/or operational management. As an additional

6. Final Remarks

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References

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