

IEA Wind Task 46

Erosion of wind turbine blades

**Microstructure and macrostructure
material analysis for the erosion
damage progression development
based on different accelerated rain
erosion testing rigs**

Technical report

Edited by Fernando Sánchez



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Microstructure and macrostructure material analysis for the erosion damage progression development based on different accelerated rain erosion testing rigs

**Prepared for the
International Energy Agency Wind Implementing Agreement**

**Prepared by
Fernando Sánchez, Asta Sakályte, Mohamed Anshari, Chun-Yen Wu, Julie Teuven, Trevor Young, Aurelio Olivares, Luis Domenech**

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Purpose

Leading edge erosion (LEE) of wind turbine blades has been identified as a major factor in decreased wind turbine blade lifetimes and energy output over time. Accordingly, the International Energy Agency Wind Technology Collaboration Programme (IEA Wind TCP) has created the Task 46 to undertake cooperative research in the key topic of blade erosion. Participants in the task are given in Table 1.

The Task 46 under IEA Wind TCP is designed to improve understanding of the drivers of LEE, the geospatial and temporal variability in erosive events; the impact of LEE on the performance of wind plants and the cost/benefit of proposed mitigation strategies. Furthermore Task 46 seeks to increase the knowledge about erosion mechanics and the material properties at different scales, which drive the observable erosion resistance. Finally, the Task aims to identify the laboratory test setups which reproduce faithfully the failure modes observed in the field in the different protective solutions.

This report is a product of Work Package 5 Damage models based on fundamental material properties.

This report analyses aims connecting the observed macroscopic mechanical behavior with the polymer composition and microstructure of leading edge protection systems investigating the effect of polymer chemistry on erosion mechanics and accumulation damage. Moreover, it also pretends to investigate a comparison of different accelerated rain erosion testing techniques for polymer system analysis linked with the erosion damage progression in order to extract material/interfacial modelling input data.

Table 1 IEA Wind Task 46 Participants.

Country	Contracting Party	Active Organizations
Belgium	The Federal Public Service of Economy, SMEs, Self-Employed and Energy	Engie
Canada	Natural Resources Canada	WEICan
Denmark	Danish Energy Agency	DTU (OA), Hempel, Ørsted A/S, PowerCurve, Siemens Gamesa Renewable Energy
Finland	Business Finland	VTT
Germany	Federal Ministry for Economic Affairs and Energy	Fraunhofer IWES, Covestro, Emil Frei (Freilacke), Nordex Energy SE, RWE, DNV, Mankiewicz, Henkel
Ireland	Sustainable Energy Authority of Ireland	South East Technology University, University of Galway, University of Limerick
Japan	New Energy and Industrial Technology Development Organization	AIST, Asahi Rubber Inc., Osaka University, Tokyo Gas Co.
Netherlands	Netherlands Enterprise Agency	TU Delft, TNO
Norway	Norwegian Water Resources and Energy Directorate	Equinor, University of Bergen, Statkraft
Spain	CIEMAT	CENER, Aerox, CEU Cardenal Herrera University, Nordex Energy Spain
United Kingdom	Offshore Renewable Energy Catapult	ORE Catapult, University of Bristol, Lancaster University, Imperial College London, Ilosta, Vestas
United States	U. S. Department of Energy	Cornell University, Sandia National Laboratories, 3M

Executive Summary

The aim and scope of the *Working Package 5 Damage models based on fundamental material properties* considers to review and apply appropriate modelling techniques and material properties characterization methods to be defined and used to understand erosion mechanics for LEP system technologies and to quantify the influence on the erosion performance. Its activity includes literature reviews and alternative or complementary studies including partner's experiences.

The report is focused on the erosion progression analysis to connect the observed macroscopic mechanical behavior with the polymer composition and microstructure of leading edge protection systems. Furthermore, it seeks to compare different accelerated rain erosion testing techniques for analyzing polymer systems in relation to erosion damage progression, with the objective of extracting valuable material and interfacial modeling input data.

LEP performance modelling is mainly based on in-lab testing data. Rain erosion progression can be measured experimentally in lab in various ways. One approach is to assess average erosion depth over time or mass loss over time (directly linked to the number of impacts). Initially, there is an incubation period during which damage progresses without noticeable material weight loss. Once a sufficient degree of fatigue degradation has accumulated, the material begins to lose mass at a constant erosion rate, indicating the end of the incubation period and the commencement of a steady mass loss period where weight loss progresses almost linearly with time until complete breakthrough. The quantification of the severity of erosion in wind turbine blades is challenging due to the many aspects involved, including meteorology, aerodynamics, materials science and wind turbine dynamics. All these studies are based on the required material characterization data that depends on its lab testing conditions. This initial in-lab data performance can then be extrapolated to its in-field installation configuration for lifetime modelling evaluations. This work analyses different application cases of rain erosion testing, considering a comparison of the current testing standards in order to assess in-lab material performance for different chemistries.

The work is compiled as a research journal paper than can be found for public dissemination in next reference:

Sánchez, Fernando and Sakalyte, Asta and Ansari, Mohammad Quaiyum and Wu, Chun-Yen and Teuven, Julie and Young, Trevor M. and Olivares, Aurelio and Domenech, Luis, Erosion damage progression analysis for wind turbine blade material coatings based on comparison of accelerated rain erosion testing methods and polymer properties (March 10, 2025). Available at SSRN: <https://ssrn.com/abstract=5172335>