IEA Wind Task 46

Erosion of wind turbine blades

Use of in-field turbine blades inspection data for the modelling of the rain erosion damage initiation

Technical report

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Use of in-field turbine blades inspection data for the modelling of the rain erosion damage initiation

Prepared for the

International Energy Agency Wind Implementing Agreement

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Acknowledgments

The participation of Siemens Gamesa Renewable Energy (SGRE) is acknowledged for providing all measured wind and rain data of the wind farm site, the rotor blade damage inspection data and also the corresponding in-field SGRE material characterization data.

March 2025

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 proposes alternative modelling methodology based uniquely on field data instead of fundamental properties or in-lab testing data. It pretends to be considered as an appropiate damage model for accumulative droplet impact erosion attending initiation of the wear damage. The report also considers its validation with observed in-field blade inspections.

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 better understanding of lifetime performance analysis without predetermined material input data information based on lab testing.

Leading-edge erosion from raindrop impacts affects wind turbine blades in onshore and offshore farms, causing surface damage that reduces energy production. A numerical tool to predict blade's erosion incubation lifetime under specific operating conditions is crucial for inspection and maintenance. This report introduces a new model developped within the Task activities for predicting rotor blade erosion. It considers material properties, rain, and wind loads. It has been validated against industrial approaches and wind farm observations, showing reliable forecasts. The model is designed for field application, helping wind farm owners assess blade erosion without needing detailed manufacturing data.

Recent meteorological observations reveal several key findings: i) the risk of erosion is highly site-specific and varies according to the environmental conditions in which the turbine rotor operates post-installation, ii) material characterization data requirements are influenced by initial laboratory testing conditions and installation configuration.

The objective of this study is to propose an erosion damage prediction model to evaluate and quantify its progression over the lifespan and operational period of wind turbine rotor blades. Current lifetime prediction models use input data based on the material configuration during manufacturing, assuming performance characteristics defined under initial laboratory conditions. However, for older turbine fleets or those that have undergone repairs, the blade leading edge protection system characterization may vary or be unavailable.

This study presents an alternative model that can provide predictions incorporating observed damage data from inspections of blade surfaces throughout their operational lifecycle, rather than relying solely on initial manufacturing test data. Additionally, given that wind farms typically employ similar commercial models of rotor blades, an additional aim of this research is to develop a computational tool, utilizing inspection data, to analyze and compare the erosion performance of a particular turbine model (with a consistent leading-edge protection system) under varying operational and meteorological conditions.

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

Hao, Hao and Domenech, Luis and Sánchez, Fernando, Modeling Rain Erosion Surface Damage Initiation in Turbine Blades Based on Inspection Data at Wind Farms (December 18, 2024). Available at SSRN: https://ssrn.com/abstract=5062754 or http://dx.doi.org/10.2139/ssrn.5062754