Report 2023
Task 46

Photo: @russellillig / Getty Images-Canva Pro.

Erosion of Wind Turbine Blades

Author *Charlotte Bay Hasager, Technical University of Denmark (DTU), Wind and Energy Systems, Denmark.*

Task 46 aims to improve the understanding of factors driving erosion, develop datasets and modelling tools to enhance the prediction of leading-edge erosion, identify damage at the earliest possible stage, and advance potential solutions.

The scope of work is divided into four technical Work Packages:

- WP 2: Climatic conditions driving erosion.
- WP 3: Wind turbine operations with erosion.
- WP 4: Laboratory testing.
- WP 5: Erosion mechanics and material properties.

The key results of 2023 include five main deliverables (two technical reports, two peer-reviewed articles, and one software code), a dissemination in the second outreach webinar and the fourth International Symposium on Erosion of wind turbine blades.

Introduction

The purpose of IEA Wind Task 46 is to attain more knowledge about factors causing erosion of wind turbine blades, promote the creation of data-sets, methods, and tools quantifying the occurrence of erosion and its financial impact, and to advance the development of solutions. The scope of work covers the following related topics:

- Climatic conditions driving erosion.
- Wind turbine operations with erosion.
- Laboratory testing.
- Erosion mechanics and material properties.

There are 41 participants from 12 countries active in Task 46. Of these participants, half are from industries in the wind energy sector, including OEMs, wind farm developers and operators, as well as coating companies delivering coating systems for wind turbine blades. The other half of participants are from academia.

Table 1. Countries Participating in Task 46.

COUNTRY/SPONSOR	INSTITUTION(S)
Belgium	Engie
Canada	WEICan
Denmark	DTU; Hempel; Power Curve; Ørsted A/S
Finland	VTT
Germany	Covestro; DNV; Emil Frei (Freilacke); Fraunhofer IWES; Henkel; Mankiewicz; Nordex Energy; RWE Renewables
Ireland	IT Carlow; University of Galway; University of Limerick
Japan	AIST; Asahi Rubber Inc.; Osaka University; Tokyo Gas Co.
The Netherlands	TNO; TU Delft; Equinor
Norway	Statkraft; University of Bergen
Spain	Aerox; CENER; Nordex Energy Spain ; Siemens Gamesa Renewable Energy; Universidad Cardenal Herrera – CEU
The United Kingdom	Imperial College London; Ilosta; Lancaster University; ORE Catapult; University of Bristol; Vestas Technology UK
The United States	Cornell University; Sandia National Laboratories; 3M

Progress and Achievements

Recent progress outlining the climatic causes of erosion, on the topic of hydrometeor size distribution measurements to projections of wind turbine blade leading-edge erosion, is presented in the peer-reviewed article [1] based on rain data observed by a disdrometer. The work is founded on research from WP 2, which considers the atmospheric meteorological drivers of erosion of wind turbine blade leading-edge erosion [2], in combination with findings from a technical report detailing ancillary variables on atmospheric drivers of wind turbine blade leading-edge erosion [3]. Furthermore, the research in WP 2 is closely connected to WP 5 in terms of modelling techniques used to predict erosion [4]. Here, the damage model (Springer model) is used.

The projection of erosion risk to a larger area has been upscaled based on rain and wind speed data from numerical modelling. This was presented in a peer-reviewed article based on the ERA5 and NORA3 datasets from Scandinavia. A key outcome is a rain erosion atlas [5]. In this work, the damage model used, the so-called spray mode, has been published for open-access on GitLab [6]. The blade damage model is based on a rain erosion test using various droplet sizes and testing speeds. The tests resulted in VH (velocity impingement)

curves, among those the so-called spray mode [7]. The results from the rain erosion test became the foundation for the VH-curve spray mode damage model.
Erosion effects wind turbine operation resulting in aerodynamic loss. WP 3 presented a technical report with a new classification system for leading edge erosion [8]. Inspired by this classification system, a similar system for laboratory testing was developed in WP 4 and published in the technical report with focus on erosion failure modes in leading-edge protection systems [9].

The characterisation of erosion which is relevant for estimating aerodynamic loss differs from the erosion categories used to decide for repair, which differs from the incubation used in recommended practice for coatings testing. The relationship between aerodynamic loss and erosion is provided through the software, Simplified Aerodynamic Loss Tool (SALT) [10]. Further work to measure the performance impact of erosion was presented at the fifth Symposium on Erosion.

The work in WP 5 supports the projection of erosion (in WP2). It focuses on erosion mechanics and damage progression analysis based on accelerated weathering considerations. It also focuses on developing physics-based and experimental data-driven modelling to estimate the progression of wind turbine blade damage. The results were also presented at the fifth Symposium on Erosion.

In February, the fourth International Symposium on Erosion of Wind Turbine Blades was held with a focus on communication with key clients and stakeholders. Additionally, Task 46 organised a mini-symposium on atmospheric drivers of blade leading edge erosion at the Wind Energy Science conference in Glasgow, Scotland in May 2023. Moreover, Task 46 participants have presented at various conferences, among those, AFORE in South Korea in November, 2023 [11]. A public outreach webinar was held in December.

Highlight(s)

Task 46 has achieved the completion of a new technical report about erosion failure mode classification in leading-edge protection systems [9]. Figure 1 shows the damage class system and two specimens with damages. A survey showed that the damages post-incubation with erosion to the substrate were well aligned between the peers. In contrast, less severe damages caused a large spread in the classification. This important finding highlights the need for detection methods in addition to visual methods.

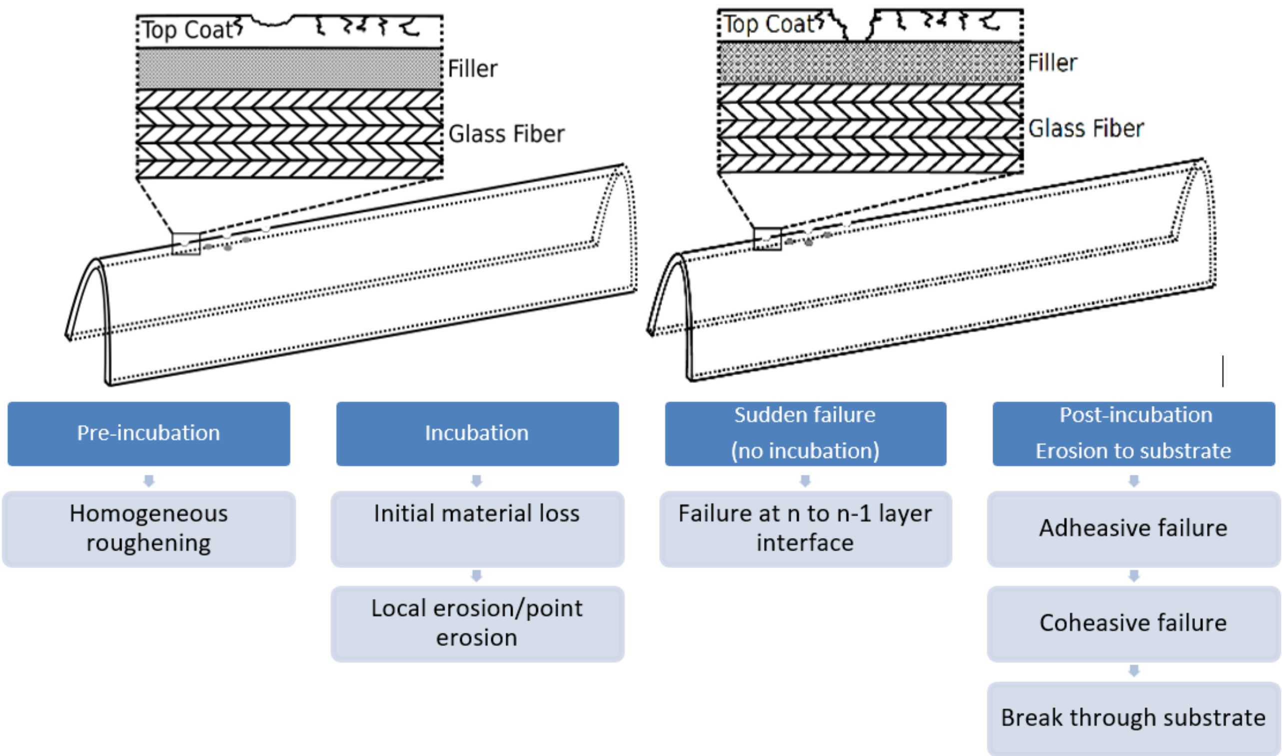

Figure 1: Sketches of rain erosion test specimen with damage and overview of damage classes. Note the n-layers are counted from the substrate (glass fibre) and up towards the top coating. From Johansen, 2023 [9].

The Task attracted new participants during the year and network activities highlighted new relevant topics surrounding blade erosion. During the two-day plenary meeting in Valencia (Figure 2), new activities were proposed within the ongoing work. Thus, ambitions grow steadily with the many active participants in the Task.

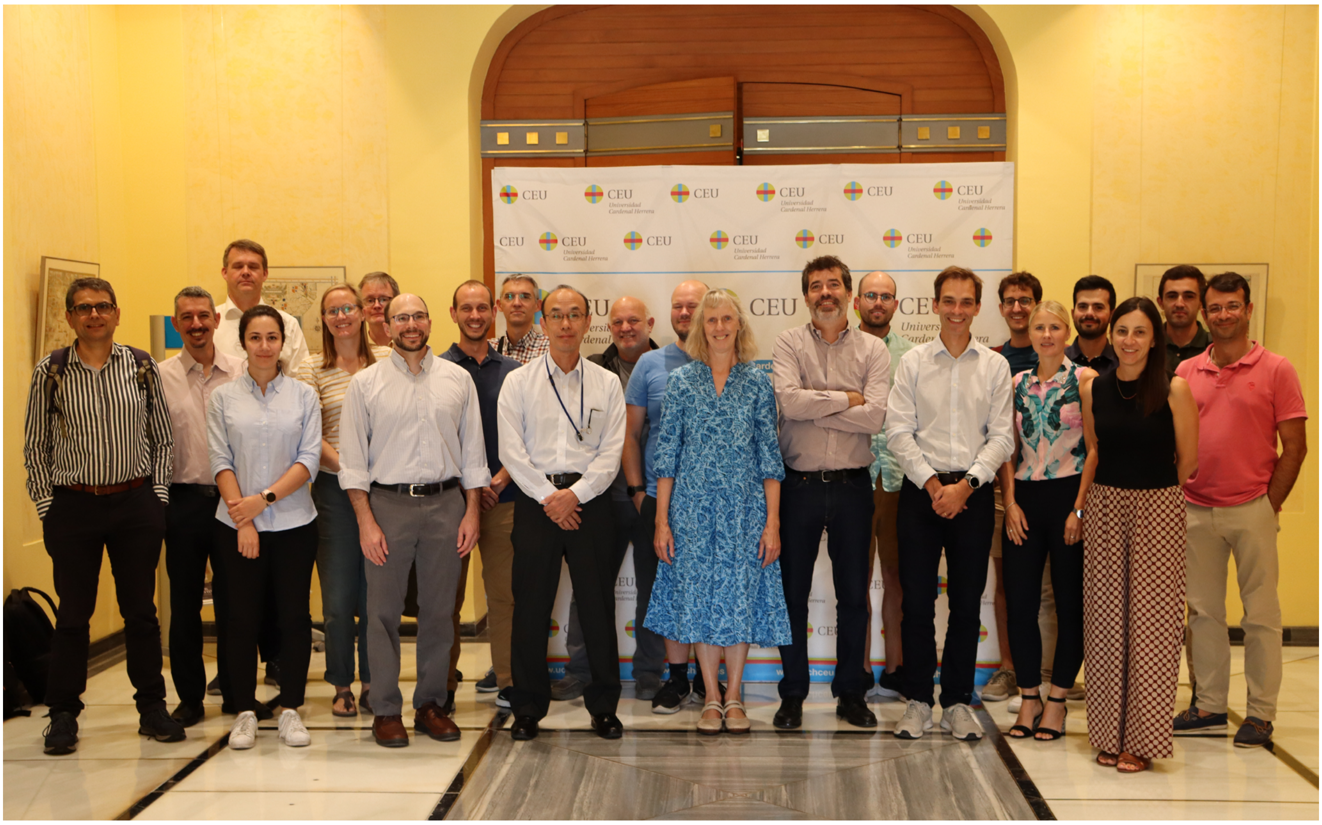

Figure 2: Plenary meeting participants at CEU in Valencia, Spain, September 2023.

Outcomes and Significance

The Task has allowed the wind energy community to work together on the complex and multidisciplinary topic of blade erosion. The forum, formed by 129 colleagues from 41 organisations, engages in technical discussions in the periodic meetings of topical work packages and plenary sessions.

The key outcomes of the Task are 1) deeper knowledge of the topic of erosion in the community, which benefits the wider wind energy sector, 2) establishment of an ambitious research portfolio on the topic of erosion through communication and alignment between the organisations involved, which aims to solve the challenges of blade erosion.

Next Steps

The Task will continue its planned activities within the four technical work packages including the following projects. A roadmap is under development to make an atlas for erosion risk based on observations and numerical modelling. However, the project will take more time to complete than expected. Recommended practices for rain-erosion test data analysis are being developed with the goal of assessing the expected lifetime of blade coatings. Furthermore, a benchmark study of aerodynamic loss is on the timeline, as modelling studies which further the understanding of damage processes will be continued. Task 46 participants are preparing to extend the Task with the goal of expanding knowledge on erosion.

References

[1] Letson F. and Pryor S.C. (2023) From Hydrometeor Size Distribution Measurements to Projections of Wind Turbine Blade Leading Edge Erosion. *Energies*, 16, 3906. https://doi.org/10.3390/en16093906

[2] Pryor, S.C., Barthelmie, R.J., Cadence, J., Dellwik, E., Hasager, C.B., Kral, S.T., Reuder, J., Rodgers, M., Veraart, M. (2022) Atmospheric Drivers of Wind Turbine Blade Leading Edge Erosion: Review and Recommendations for Future Research. *Energies*, 15, 8553. https://doi.org/10.3390/en15228553

[3] Pryor S.C., Barthelmie R.J., Dellwik E., Hasager C., Kral S.T., Prieto R., Reuder J., Rodgers M., Veraart M. (2023) IEA Wind task 46 Technical Report: Atmospheric drivers of wind turbine blade leading edge erosion: Ancillary Variables. 20 pp. https://iea-wind.org/wp-content/uploads/2023/04/D2-3-Ancillary-variables-data.pdf

[4] Antoniou, A., Dyer, K., Finnegan, W., Herring, R., Holst, B., Bech, J. I., Katsivalis, I., Kutlualp, T., Mishnaevsky, L., Šakalyte, A., Sánchez, F., Teuwen, J., & Young, T. (2022). Multilayer leading edge protection systems of wind turbine blades: A review of material technology and damage modelling. In ECCM 2022 - Proceedings of the 20th European Conference on Composite Materials: Composites Meet Sustainability (Vol. 5, pp. 97-104). École Polytechnique Fédérale de Lausanne. https://orbit.dtu.dk/en/publications/multilayer-leading-edge-protection-systems-of-wind-turbine-blades

[5] Hannesdóttir, Á., Kral, S. T., Reuder, J., Hasager, C.B. (2024) Rain erosion atlas for wind turbine blades based on ERA5 and NORA3 for Scandinavia, *Results in Engineering*, Volume 22, 2024. https://doi.org/10.1016/j.rineng.2024.102010

[6] Software code at gitlab, Ásta Hannesdóttir (2024). https://gitlab.windenergy.dtu.dk/astah/era5_erosion_atlas

[7] Bech, J.I., Johansen, N. F.-J., Madsen, M.B. Hannesdóttir, Á., and Hasager, C. B. (2022) Experimental study on the effect of drop size in rain erosion test and on lifetime prediction of wind turbine blades. *Renewable Energy*, 197, 776-789. https://doi.org/10.1016/j.renene.2022.06.127

[8] Maniaci, D.C., MacDonald, H., Paquette, J., Clarke, R. (2023) IEA Wind task 46 Technical Report: Leading Edge Erosion Classification System. 52 pp. https://iea-wind.org/wp-content/uploads/2023/02/IEA-Wind-Task-46-Erosion-Classification-System-report.pdf

[9] Johansen, N. F.-J. (2023) IEA Wind task 46 Technical Report: Erosion failure modes in leading edge systems. 28 pp. https://iea-wind.org/wp-content/uploads/2023/06/IEA-WT46-WP4.2-Erosion-failure-modes-in-leading-edge-systems.pdf

[10] Christian Bak, and Meyer Forsting, A. R. (2023). SALT - Simplified Aerodynamic Loss Tool (1.0.0 - beta). DTU Wind, Technical University of Denmark. https://doi.org/10.5281/zenodo.7906333

[11] Hasager, C. B. (2023). Assessment of the Potential Blade Erosion Based on Local Weather data and Satellite Data. In Proceedings of AFORE 2023 (The 12th Asia-Pacific Forum on Renewable Energy) (pp. 76-76). Article IN-RA-069 The Korean Society for New and Renewable Energy. https://orbit.dtu.dk/en/publications/assessment-of-the-potential-blade-erosion-based-on-local-weather-

Task Contact

Charlotte Bay Hasager,
Technical University of Denmark,
Wind and Energy Systems, Denmark.

Email:
cbha@dtu.dk

Website:
https://iea-wind.org/task46/