**RC1: 'Comment on wes-2024-35', Anonymous Referee #1, 23 Apr 2024**

1. Please take care of some typos and incorrect sentences:

- Corrected

2. In the introduction and conclusions, the authors state the novelty of verifying the effect of TI and erosion on the prediction of AEP and performance losses using an aero-servo-elastic simulation tool. This is not new; similar results and comparisons have been presented, for example, in the following literature:

- This comment is valid in that indeed turbulence as been investigated over time. The current paper, however, does not investigate aerofoil performance as a function of turbulence, but instead focuses on rotor performance. Our primary objective is to understand how mean power output is increased at low wind speeds and decreased around the shoulder of the power curve as a function of various turbulence intensities, in a systematic manner. This aspect of the study is new and we shall make this clear in the revised paper. While turbulence is indeed investigated in the referenced papers, some of them focus on turbulence at the aerofoil level, which is not the focus of our research. However, we acknowledge that Cappugi et al. (2021) partly investigate power curves as a function of turbulence intensity and we shall reference their work appropriately in our paper.
  Furthermore, an answer to this comment can be found in the introduction that has been rephrased.

3. I understand the issue of working with proprietary data and models; however, the authors should indicate more clearly how the presented study and results, which are not replicable as the data from the case study are not disclosed and not generalizable as the results apply to a particular erosion type and distribution and to a specific WT model, can be beneficial for industry or research in this field.

- We acknowledge the reviewer's concern about the proprietary nature of the data and models employed in our study. While ideally, we would have preferred to publish all details, there are significant knowledge bases in data from operational wind turbines that cannot be described in detail due to proprietary constraints. Nevertheless, this should not preclude us from analysing the data and deriving valuable insights.

  The trends and relationships identified in our study are highly relevant for the industry. Specifically, wind farm owners and operators, rather than OEMs, face daily challenges reflected in this study, such as lack of access to detailed proprietary information such as aerofoil shapes – a challenge also encountered by the present authors. Understanding these challenges is crucial for researchers to effectively support the industry. Our paper focuses on relative changes in performance rather than absolute values, which is crucial as wind turbine operators should respond to percentage performance reductions rather than reductions measured in megawatts.

  Although the specific results pertain to a particular turbine model and erosion type, the approaches and methodologies employed are generalizable. Consequently, the methods and conclusions presented in the paper should be applicable to various types of wind turbines, advancing the understanding of wind turbine performance under varying conditions.

We shall include a comment in section 2.1 to highlight how this study can contribute to the general understanding of power performance degradation. This addition shall clarify the broader implications and utility of our research for both industry and academic audiences.

4. At pg3: "Although the tested airfoil is not an identical match to that in the HAWC2 model, this approach is deemed a suitable approximation for representing the outboard region of eroded turbine blades." This sentence is not supported by data in the paper; it could be helpful to show that the power curve obtained with the original airfoil matches the power curve obtained with the substituted clean airfoil.

- We appreciate the reviewer's comment regarding the need for clarity on the aerofoil substitution. We did not replace the original aerofoil in the multibody model. Instead, we used wind tunnel data from a different eroded aerofoil to understand the impact on lift coefficient (CL) and drag coefficient (CD). These impacts were then applied as adjustment factors to the original aerofoil characteristics of the proprietary multibody model, specifically for the outer 15% of the blade. This approach allowed us to simulate the effects of leading-edge erosion on turbine performance without altering the fundamental aerofoil design of the model. Therefore, in its clean form, the substituted aerofoil would match the original aerofoil exactly, as would its power curve. Furthermore, we shall include a comment in section 2.2 to clarify this.

5. pg.3 "To represent the effects seen in the wind tunnel experiments, derived factors were used to approximate the results. For simplicity, the lift polar representing the clean airfoil was scaled by a factor of 0.9. Additionally, two artificial drag polars were created by scaling the drag polar representing the clean airfoil by factors of 1.5 and 2.0, respectively." This aspect of the methodology is not very clear and requires clearer explanation in the text. Furthermore, a proper justification should be reported in terms of the scientific soundness of the approach, by reference to existing literature proving the reliability of the approach, or by some verification test or evidence.

- We appreciate the reviewer's feedback regarding the clarity and scientific justification of our methodology. Unfortunately, due to proprietary constraints, we are unable to present the specific polars used in our simulations. To address this limitation, we aimed to represent roughness and erosion effects in a simplified manner.

  The goal is to simulate a realistic scenario where erosion has a measurable negative impact on the aerofoil's aerodynamic characteristics (lift and drag coefficients). While we acknowledge that not all aerofoils degrade in the same way, these factors are meant to represent a moderate and severe level of degradation, respectively.

  Our approach is based on findings from other wind tunnel tests, which showed that one instance of degradation resulted in a lift reduction to 0.9 times the clean lift coefficient (CL_clean) and drag increases to 1.5 times (CD_clean) and 2.0 times (CD_clean), respectively. This does not imply that all aerofoils exhibit this degradation pattern, but rather it represents one scenario of moderate degradation and one of severe degradation. These factors correspond to (CL/CD)_clean ratios of 0.9/1.5 = 0.6 and 0.9/2 = 0.45, respectively. This ensures a significant degradation effect in our data.

In other words, the reduction factors are chosen to ensure the simulated data reflects a meaningful deterioration in performance, even if the exact values might not perfectly match every real-world case.

The reduction in CL and the CL/CD ratio naturally leads to a reduction in power, which is why these factors are applied. We shall include a comment in section 2.2 of the paper to clarify this reasoning. Additionally, we shall reference appropriate literature to support the validity of this approach, demonstrating that it is a scientifically sound method for approximating the effects of erosion and roughness on aerofoil performance.

We believe this explanation shall enhance the clarity of our methodology and provide the necessary justification for our approach.

6. Figs 7, 8, 10, 12, 13 show many overlapping curves and are very difficult to read. I suggest reducing the number of entries to a subset of the most significant ones.

- We appreciate the reviewer's comment regarding the readability of Figs 7, 8, 10, 12 and 13. We acknowledge that we are challenging the reader. In response to your feedback, we shall tried our best to reduce the number of entries in these figures, so as to remove those that are most dispensable. Additionally, the figures are better represented and described. Where highlighting trends, we have enhanced the graphs using colour variations to achieve this. These adjustment shall help enhance clarity and readability, making the data more accessible and easier to interpret.

7. Please improve the clarity of captions for Tables 1 to 5. (From the captions of Table 1 and 2, it is not possible to understand the difference between the data presented in the two tables).

- This is a good comment that we understand when we read them again. They shall be changed to:
  - Table 1. Change in AEP as a function of TI. Row 2 shows AEP change relative to “clean” performance at TI=6%; Row 3 shows AEP change relative to “P400” performance at TI=6%; Row 4 shows AEP change relative to “P40” performance at TI=6%.
  - Table 2. Change in AEP as a function of TI and roughness level: AEP change relative to “clean” performance at TI=6%
  - Table 3. Change in AEP as a function of TI and roughness level: AEP change relative to “clean” performance at TI=6% with V_ave=6m/s
  - Table 4. Change in AEP as a function of TI and roughness level: AEP change relative to “clean” performance at TI=6% with V_ave=6m/s
  - Table 5. Change in AEP as a function of TI and roughness level: AEP change relative to “clean” performance at TI=6% with V_ave=6m/s

8. I understand it is part of the title and the research, however, the discussion about time averaging in the power curve is somewhat off-topic with respect to the other two. Indeed, TI and erosion are features related to the model of the case study, while the time averaging is a data processing parameter. Furthermore, I needed more than one reading to understand the point from section 3.4. I would suggest reducing this part, possibly moving it to an appendix, recalling the main outcome not in the results but in the presentation of the case study and methodology. This will improve the readability of the paper and also simplify the outcomes and conclusions.

- We appreciate the reviewer's comment regarding the discussion on time averaging in the power curve. We believe the averaging of data is very relevant and its inclusion is crucial for understanding the analysis.

  The use of 10-minute average values is a standard approach for investigating data from measurements and since our aim is to enhance the understanding of these measurements, we investigated this through simulations.

  Our investigation revealed that the impact of time averaging is almost as significant as the effects of roughness itself. Therefore, we believe it is pertinent to include this discussion. We do however acknowledge that the current presentation may challenge readability and that this aspect was not adequately explained.

  To address this, we have rephrased the introduction to clarify the rationale behind the analysis of time averaging. As well as rephrasing of section 3.4, with the inclusion of a new Figure 14. The conclusions section is also rephrased.

9. The conclusion section needs some revision. It sometimes presents repeated information ("This research contributes valuable insights into the multifaceted effects of turbulence intensity, blade roughness, and time averaging on wind turbine performance") or conclusions that seem not really related to the data presented ("it highlights how data analysis techniques can either mask or reveal the subtle effects of erosion and turbulence"). Furthermore, a clearer conclusion should be drafted on the discussion about extracting information on erosion-related performance damage from in-field measurements and SCADA data.

- On reflection and in response to this feedback, we have rephrased the conclusion to eliminate redundancies and ensure that it is clearer.