Firenze, 06/02/2026

Dear Editor,

We would like first to thank the Reviewers for the accurate and qualified observations that have made major improvements in the paper possible.

Based on the Reviewers' comments, a throughout revision of the work has been carried out and parts of the paper have been expanded.

Our comments and responses to Reviewers' comments have been highlighted in blue-colored text in this communication and are visible as revisions in the track-changes version of the paper. We really hope that this version can be now worth of publication in *Wind Energy Science*.

Best regards,

Francesco Papi, Pier Francesco Melani, Alessandro Bianchini

Reviewer 2

This paper presents a very interesting and sound methodology for constructing a comprehensive database of aerodynamic characteristics for a variety of wind turbine airfoils covering the full angle-of-attack range from –180° to +180°. The authors generate high-fidelity results using CFD for the conventional operating angle of attack range—approximately between the negative and positive stall angles—and subsequently extend these results to the complete ±180° domain through an empirically based extrapolation procedure. The overall approach is robust, clearly explained, and results in an open database that is highly valuable for lifting line calculations of wind turbines which require such airfoil data. In addition to the remarks provided by my co-reviewer, I would like to offer a few further comments and questions.

1. Line 10: Beyond the stall region... This statement becomes clearer if you explain more explicit that the before mentioned CFD airfoil coefficients are generated for the conventional aoa range only, i.e. from negative to positive stall.
   Correct. We have now clarified this better in the abstract.
2. Line 26: Reference Bussel and W?
   Corrected, thank you.
3. Figure 1 This is certainly an intriguing figure, but it raised so many questions for me that it became more distracting than informative. It made me wonder whether including it is worth the effort—especially since its overall purpose and message are not entirely clear to me. Apart from the non-linear time axis, which looks unusual—and where, for example, the DU airfoils appear to be placed around 1991 even though some of them, such as the DU-00-212 used in the follow-up DNW-HDG test in your paper, were developed later—my main question is how the numerical values were determined. Several DU airfoils exist with 21% and 18% thickness, so which specific variants were used to generate these numbers?
   Thank you for this comment. Indeed, the intended scope of the figure could be improved. We intended this figure as a general overview of the trends designers have been following over the years. We acknowledge that this figure is not exhaustive, as efficiency and bending stiffness, although very important are not the only possible design objectives. Moreover, we chose to use publicly available data to generate the figure, derived with different methods in different conditions, in-line with the intended scope of evaluating general design trends and not compare families directly. Based on the reviewer's feedback we have improved the figure in the following ways:
   - Bending stiffness is proportional to sectional moment of inertia to differentiate airfoils with the same relative thickness
   - The relative thickness that was considered for the root and tip airfoils is reported in the figure
   - The time axis was generalized, emphasizing that some airfoil families in particular were developed over a range of years
   - The caption includes the specific airfoils we considered and the sources of the data used to generate the plots
4. Figure 1: Bending instead of bending
   Thank you, typo corrected.
5. Line 69: CENER instead of CNER
   Thank you, typo corrected.
6. Line 76: Between the lines, you refer to 3D rotational effects, which cause the aerodynamic behavior of a rotating blade to differ from the 2D airfoil characteristics as generated by you. Many readers may think: "It's useful to have these 2D airfoil data, but what is their relevance for actual wind turbine operation?" It would therefore be helpful to elaborate more explicitly on the value of 2D airfoil data. o I would start by identifying the sources of deviation between 2D airfoil performance and the performance on a rotating blade. Beyond 3D rotational effects, there are

also unsteady aerodynamic phenomena (your data are time-averaged) and 3D geometric influences, which may be particularly relevant for quantities such as $cd(90\circ)$, as discussed below. o Nonetheless, as far as I know all methods which correct for 3D rotational effects, geometric effects, or unsteady airfoil behavior still rely on steady 2D airfoil data as their fundamental input. This means your dataset has substantial value (especially in the context of design approaches based on lifting-line models. It may be worthwhile to mention lifting-line models explicitly at an appropriate point in the manuscript).

Thank you for the comment. Based on this, we have added an additional paragraph describing how the coefficients can be applied to wind turbine simulations: *"As discussed in Section 2, this dataset is intended for use in wind turbine applications. Therefore, it must be noted that the coefficients in this dataset are relative to a non-rotating infinite-span uniform wing with. In other words, they are relative to the two-dimensional sections described in Section 2. Before being applied to a three-dimensional wind turbine blade they should be corrected three-dimensional rotational augmentation (Snel et al., 1992), and for finite aspect ratio, which affects the post-stall extrapolation and maximum drag coefficient (Viterna and Corrigan, 1982)."*

7. A question on Line 95 and further, on the maximum value of cd: Are we comparing apples with apples? I wonder whether perhaps some cd values are 2D (e.g. the values around 1.8) where others may be on a blade with finite aspect ratio which may lead to cd values around 1.3?

   The Reviewer is correct. The text was not structured in a clear way. We have indicated the reasons for which lower maximum drag coefficients are often used in wind turbine rotors, and the sources of uncertainty in the estimation process.

8. Line 104: you may be a bit sharper in motivating value of post stall data. It is not only for ultimate blade load estimation in parked conditions but these data may be of relevance for understanding stall and vortex induced vibrations as well. Even though these are unsteady effects I think that steady 2D data form the basis for modelling these effects.

   Thank you for the comment. We have added a remark as suggested in Section 1: "*Although horizontal-axis wind turbines do not typically operate in the post-stall region, these conditions can be encountered when parked, and can give rise to unsteady phenomena such as vortex induced vibration (VIV) which can drive ultimate loading. Even in the absence of unsteady loading on the blade, accurate sectional coefficients at high angles of attack can help reduce modelling errors in engineering tools.*"

9. Line 120: You mention that airfoils with t/c > 21% are included only, but the last one in table 1 has a thickness of 18%

   The Reviewer has a point. We initially included only geometries with t/c>21%. However, we later decided to also include the NACA-64(3)418 as it has been commonly used as a tip airfoil in many relatively recent utility-scale wind turbines (see https://doi.org/10.5194/wes-10-1929-2025). We have added this clarification to the manuscript: *The NACA63(3)418 airfoil is included despite featuring a relative thickness of 18% as it has been used in recent actual wind turbine blades (Braud et al., 2025).*

10. Line 147: You mention the effect of compressibility on the slope of the lift coefficient. Isn't the drag rise equally important (e.g. use the Prandtl Glauert relation for this drag rise)

    The Reviewer is correct, we have added this clarification.

11. Table 3: The abstract says that simulations are done for conditions which are typical for utility scale wind turbines. Still I wonder whether tip speeds of 153.3 m/s are typical for modern wind turbines. This would lead to a significant drag increase from the Prandtl Glauert relation but also to significant erosion issues. It is more than fine to do simulations for a very wide range of conditions but could you explain the reasons why you have chosen these conditions?

    The Reviewer is right in noting that these conditions are highly unlikely. We have included the following clarification: *"As a consequence of the smaller chord of the tip airfoils, because the same range of Reynolds number was simulated for all relative thicknesses, a maximum velocity of 153.3 m/s is considered for airfoils with relative thickness of 21% and below. This velocity should be regarded as a conservative upper bound rather and is unlikely to be reached during steady-state wind turbine operation. However, its inclusion ensures that the dataset remains* *valid under transient scenarios, such as rotor overspeed events, extreme gusts, or rapid changes in operating conditions, which can temporarily lead to significantly increased local inflow velocities."*

12. Section 3.3: I remember some issues in the AVATAR project wrt the γ-Re theta model at the high Reynolds numbers test, which was the reason why many participants switched to the eN transition model or they modified the model. It seems you apply some modifications as well but it may be good to explain how your transition modelling relates to the transition modelling in these references: Ceyhan, O., Pires, O., Munduate, X., Sørensen, N., Schaffarczyk, A. P., Reichstein, T., Diakakis, K., Papadakis, G., Daniele, E., Schwarz, M., Lutz, T., & Prieto, R. (2017). Summary of the blind test campaign to predict the high Reynolds number performance of DU00-W-210 airfoil. In 35th AIAA Wind Energy Symposium (AIAA 2017-0915), Grapevine, TX, USA. Colonia, S., Leble, V., Steijl, R., & Barakos, G. (2017). Assessment and calibration of the γ-equation transition model for a wide range of Reynolds numbers at low Mach. AIAA Journal, 55(4), 1126–1139. https://doi.org/10.2514/1.J055403
    Indeed, we are aware of the shortcomings of the gamma-Re-theta model when it comes to natural transition at very low turbulence intensities and high Reynolds numbers. We have chosen to use this model anyway due to the fact that it can be customized within Ansys Fluent. We agree that this aspect could be better highlighted. We have therefore included the following statement in section 3.3: *When simulating cases with low inflow turbulence some authors have noted some deficiencies in the γ-Re_θ model (Diakakis et al., 2019). However, other studies have also shown that correlation with experiments can be significantly improved in correlation-based transition model though calibration (Colonia et al., 2016, 2017).*
13. Line 254: I agree that modern wind-turbine airfoils—as a matter of fact earlier generations of wind-turbine airfoils as well—experience effectively lower turbulence levels because the rotational component contributes to the resultant velocity in the denominator of the turbulence intensity. However, in my view, the turbulence intensity scales approximately as ~ Iambient/λr For an ambient turbulence level of say 10% and a local tip speed ratio of say 5 the resulting turbulence intensity would be 2%, much lower than 10% indeed but still twice the threshold value of 1% mentioned by you.
    The Reviewer's remarks are very relevant. Indeed, given the fact that inflow turbulence scales with relative velocity, the level encountered by the airfoils depends on many factors, such as their radial position, the operating rotational speed and the inflow turbulence. The value that we indicated is a threshold above which bypass transition may start to play a role, depending on the fluid-dynamics problem at hand. Boundary layer transition mechanisms are discussed in detail in Lobo et al. (2023), where natural transition is identified as the predominant mechanisms causing boundary layer transition in the absence of external flow disturbances such as the wake of another turbine.
    Furthermore, it can be argued that inflow variations with a large enough length scale, which occur slow enough, could be treated as variations in mean inflow from the airfoil perspective, rather than inflow turbulence.
    For all the reasons above, the current dataset includes a set of airfoil coefficients computed with very low inflow turbulence of 0.35% and coefficients computed in fully turbulent conditions. The users can decide to interpolate between the two sets based on the specific needs at hand. We have added this discussion to section 2: "*In addition, this value is in line with the state-of-the-art. For instance, it is not uncommon to see aerodynamic coefficients used in blade design exercise being computed with N_{crit} values in the range of 7 to 9 (Zahle et al., 2024), which correspond to low levels of turbulence intensity, as shown in Eq. 6 discussed later on in this study.*
    It must be noted that the inflow turbulence wind turbine airfoils experience during operation varies widely due to many factors. Depending on the turbulence level in the incoming wind field, the actual turbulence on the blade section scales based on the relative velocity, which depends on the local tip speed ratio of each section. Especially in the case of outboard blade sections, this can lower the turbulence intensity level significantly. The many factors at play make

choosing a single value challenging. However, providing users of the dataset with coefficients computed with low inflow turbulence and a fully turbulent boundary layer, allows for interpolation between the two, in order to fine-tune the coefficients to the application and the level of desired conservativeness, if used for blade design applications."

14. Figure 12: Good to compare with SBES simulations. A question: Have you considered a comparison with measurements? I am not sure if there are measurements for -180+180 at 10M but could a comparison at lower Reynolds have value too? E.g DNW-HDG measurements from -90 to +90 degrees at RE = 6 M or others?
    Thank you for pointing this out. The motivation for using SBES as a reference is that we were unable to find high angle of attack tests on the FFA-W3 airfoil family. In addition to the maximum drag coefficient we are also interested in the shape of the lift and drag curves to choose / calibrate a post-stall extrapolation model. We have included the following statement in Section 3.4: *"While a direct comparison to high angle of attack experimental data was not directly performed in this study, the maximum drag predicted by the SBES simulation is in line with the existing literature, towards which the reader is redirected for more in-depth discussions on the topic (Timmer, 2010, 2020)."*
15. Line 358: derived from THE static characteristics?
    Corrected, thank you.
16. I suggest adding a brief description of the AVATAR experiment at an appropriate point in the text to provide readers a bit of context. For example, you could mention that the campaign involved detailed pressure-distribution measurements, supplemented by drag data obtained from a wake rake in the pressurized DNW-HDG wind tunnel. Despite the model having a chord length of only 15 cm, the pressurization enabled testing at a variety of Reynolds numbers up to 15 million where it is noted that the tunnel turbulence was different (or something like that)
    Thank you for the suggestion. We have decided to insert such a paragraph at the end of Sect. 3: *"Experimental and numerical data generated during the AVATAR project (Schepers et al., 2018) serve as the benchmark for model validation and calibration in this study. During the project, experiments were conducted on the DU-00-W-212 airfoil at Reynolds numbers ranging from 3*106 to 15*106. Such high-Reynolds number data is exceptionally rare and was made possible by the DNW High Pressure Wind Tunnel (HDG) in Göttingen. By pressurizing the tunnel to increase air density, flight-scale Reynolds numbers were achieved on a model with a chord of only 15 cm. The resulting dataset includes aerodynamic coefficients from positive to negative stall, alongside detailed surface pressure distributions. Furthermore, these benchmarks were used by project members to cross-verify various computational tools (Sorensen et al., 2016). The following sections detail the numerical framework: Section 3.1 discusses grid and domain sensitivity; Section 3.2 provides a verification of the fully-turbulent setup against established CFD results; Section 3.3 explores boundary layer transition modeling sensitivity; and Section 3.4 addresses the methodologies for post-stall extrapolation to high angles of attack."*
17. In the abstract, you mention that differences with other open-access datasets are discussed. To me, that discussion feels somewhat limited. You might consider referring to the Aerodynamic Table Generator developed at TNO (formerly ECN): Bot, E. T. G. Aerodynamic Table Generator. A Manual. ECN-C-01-130, December 2001 (in Dutch unfortunately). Aerodynamische Tabel Generator This tool produces aerodynamic characteristics for a wide range of airfoils based on wind-tunnel measurements for the conventional angle-of-attack range and then extrapolates to −180° to +180° using an empirical method. In that sense, its approach is quite similar to yours. The key difference, of course, is that it relies directly on measurements—an advantage in terms of realism, but also a limitation because such measurements exist for only a restricted set of conditions, resulting in far less flexibility than your method.
    The Reviewer is correct in mentioning that comparisons to other existing datasets were limited and not explicit enough. While in the introduction we had provided references for experimental datasets and for the coefficients used in reference wind turbines, we had not explicitly compared to this dataset. We believe the main strength of this dataset, in addition to the inclusion of compressibility effects via high-fidelity simulations, is the fact that multiple families

can be compared/chosen as they are computed in identical conditions. **We have, however, more explicitly discussed the differences between the current and other datasets in the introduction, and in the conclusions.**

Good luck withing finalizing this excellent work!