"Sensitivity analysis of wind turbine fatigue reliability: effects of design turbulence and the Wöhler exponent" (Manuscript number: wes-2023-47)

In this work, the influence of different approaches to determine turbulence values (90th percentile, log-normal and Weibull distribution) on the fatigue reliability of wind turbines is analyzed. This influence in contextualized by determining the influence of model uncertainty (i.e., uncertainty due to the assumption of a linear damage accumulation) and material uncertainty (i.e., uncertainty in the Basquin coefficient) as well.

As turbulence has a major impact on wind turbine fatigue loads and its modelling is discussed controversially, the topic of this paper is relevant to the readers of the WES journal. Moreover, most of the paper is nicely written and the argumentation is mainly clear. Nonetheless, there is a huge number of smaller points that have to be clarified or corrected. Hence, without a major revision, it is not suitable for a publication in the WES journal.

Some important points:

1) Section 2.2: Please, state the simulation time and the time you cut off at the beginning of each simulation to remove the initial transients. Otherwise, the description of the aero-elastic simulations is not complete.
2) Section 2.3.1: Please, highlight that you talk about the turbulence (i.e., the standard deviation of the wind speed) and not the turbulence intensity, which is also frequently used.
3) Section 2.4.1: Be careful, when using expected values of DEL, as $\left[E(DEL_{lifetime}^{m})\right]^{\frac{1}{m}} \neq DEL_{lifetime}$. Furthermore, you use $DEL_{lifetime}$ in the following, but only introduce $E(DEL_{lifetime}^{m})$ in Section 2.4.1. What exactly do you mean by $DEL_{lifetime}$? Please, be consistent and precise. Either use $E\left(DEL_{lifetime}^{m}\right)$ or $DEL_{lifetime}$ in the entire paper or define both.
4) L. 315: If you state that something has been investigated, you must show it. Hence, put the MC validation in the appendix.
5) Most equations are nicely derived. However, your final equations, i.e., equation 26 to 29, are not explained sufficiently. Please, clarify where they come from and what all terms mean. For example, it seems as if equation 28 has the unit "1/year" on the right side, but a probability, i.e., is unit-free, on the left side.
6) L. 419: Again, it is not clear what you are talking about. Is it $E\left(DEL_{lifetime}^{m}\right)$, $\left[E(DEL_{lifetime}^{m})\right]^{\frac{1}{m}}$ or $DEL_{lifetime}$. Be very precise in your notation regarding DELs. Otherwise, thing become confusing.
7) Section 3.1 and all following sections: I am not sure whether it is necessary to show different values for m. In Section 2.4 you state that m and k are highly correlated and that you only consider k as a random variable. I suggest that you should stick to this idea in the entire paper. This would also reduce the amount of information in the paper, which would increase the readability. However, if you have a good reason for showing different values for m, this is also fine. In this case, please, explain your reasoning.
8) L. 534: Again, if you state that you have conducted an analysis, you must show the results, at least in the appendix (cf. comment 4).

Several other less relevant points:

9) Please, rethink the title of the paper. It suggests that a sensitivity analysis is the focus of the paper. However, this is not the case.
10) Perhaps, you can rewrite the abstract. For me, it only became clear after having read the paper. It might help to shorten it and to highlight the main topic of the paper.
11) Fig. 1: "Turbulence standard deviation of the wind and…" is not self-explanatory. What is meant by "and…"?
12) L. 127: You state that you use the "DTU 10MW offshore turbine". However, you use its onshore version. That should be clarified.
13) It would be nice if you explain why you use 200 random seeds (and not more or less).

14) Eq. 1 and in the following: Please, be consistent in your notation, e.g., V_{hub} and v_{hub}
15) Please, make clear that Eq. 2 and 3 are derived from equations given in IEC 61400-1, 2005.
16) Eq. 2 to 6: Please, keep the units consistent.
17) Eq. 2: I think there is a mistake in the equation.
18) Eq. 3: I think that it is supposed to be I_{ref} and not TI_{ref}
19) Eq. 3: Closing parenthesis is missing.
20) Perhaps, it would be good to state that $T \sim LN(\mu_T, \sigma_T)$ for Eq. (2) and (3) and $T \sim Wbl(k, C)$ for Eq. (5) and (6) and to give $F(T)$ explicitly. Otherwise, the meaning of k and C are not fully clear.
21) Eq. 4: Please, make clear that this equation does not give the 90th percentile for each wind speed, but is only a linear regression approximating it.
22) Eq. 5: Is this equation correct? I think I_{ref} has to be removed.
23) Fig. 2: The horizontal axis is the turbulence (T), i.e., the standard deviation of the wind speed, in m/s?
24) Fig. 2: The vertical axis is $\ln(1 - F(T))$, where $T \sim LN(\mu_T, \sigma_T)$ or $T \sim Wbl(k, C)$?
25) Eq. 7: I think that it should be S^{-m}. Otherwise, the number of allowed cycles would increase for an increasing load if m is positive (what it is according to your definition in the following).
26) L. 227: M_{x_i} is only the flapwise bending moment if there is no blade pitching. I think that it is an acceptable simplification for this work, but it should be mentioned.
27) Eq. 11: Use I_y and not I to be consistent, and $(c/I_y)^m$ should not stand in the denominator on the right-hand side of the equation.
28) L. 255: You state that $SS = 200$. However, you only use $SS = 6$ in the entire paper. Hence, this should be changed here. Furthermore, it might help to refer to Section 3.1 at this point to clarify why 200 random seeds are used, but only $SS = 6$.
29) Eq. 17: I think that the operator in this equation is not self-explanatory to all readers.
30) Eq. 19 and 21 (and in the following paragraph): I think it should be $E(DEL_{lifetime}^m)$
31) Eq. 19 and 21 (and in the following paragraph): Use I_y and not I to be consistent.
32) L. 339: What is meant by $R = 10$?
33) L. 340: Without knowing Section 3.1, the reader will wonder why $\log(E(DEL_{lifetime}^m))$ or $\log(DEL_{lifetime})$ is a distribution. Therefore, you should refer to the bootstrapping in Section 3.1 (cf. comment 28)
34) Fig. 3: Units for the horizontal axis are missing.
35) L. 386: The statement "Fig. reveals that […]" is only correct for $F(t) < 0.9$
36) L. 406 and Fig. 4: DEL_{bin} or $E(DEL_{bin}^m)$? If it is DEL_{bin}, the "different seeds" do not make any sense. If it is $E(DEL_{bin}^m)$ the units in Fig. 4 are incorrect.
37) L. 413: The statement "This observation reveals […]" is not correct. Figure 4 does not provide any information about the scatter in each bin, as it shows average values for each bin, i.e., $E(DEL_{bin}^m)$. You probably mean that the variability is higher for varying turbulence values.
38) L. 433: I agree with the statement "The lower variance […]". However, you should demonstrate that this is actually the case by running case 1 with 6*20=120 seeds instead of 6 seeds and show these results in the appendix. Otherwise, the comparison is not fair.
39) L. 434: I do not agree with your second reason "The other reason is […]". If you consider different turbulence levels, you have low and high values. Hence, the variability should be higher compared to the case where you only use high turbulence levels.
40) Fig. 5: Horizontal axis is "normalized DEL".
41) Fig. 5: Where do I see the "best distribution fits" that are mentioned in the caption of the figure?
42) Section 3.2: How are the best fitting distributions determined? Out of which distributions is the best fitting distribution chosen? How is the goodness of the fit judged?

43) Table 4: I think it would help if an equation for the GEV is given somewhere. Otherwise, it is not clear what "Par 1", "Par 2" and "Par 3" are. Even for the lognormal and Weibull it would help (cf. comment 20)
44) L. 468: The statement "[…] that we get the same reliability level in the first year" only refers to case 1 if I am not mistaken.
45) L. 510: Which DEL is meant here?
46) L. 523 and 554: Lifetime DEL? Or which one?
47) L. 524: "This has been made more clear in the sensitivity analysis": Where exactly has it been made clearer? I do not find this.
48) L. 534: $I_{ref} = 0.1$? Or what do you mean here?
49) L. 547: You state that MC can only be done when having the computational resources. However, you only need to evaluate Eq. (21) which should not be computationally very demanding, when knowing the distributions. Running the aero-elastic simulations probably takes much more time. Hence, the use of FORM instead of MC should be discussed in more detail. Or am I mistaken and the procedure is computationally demand. In this case, please explain why this is the case.
50) L. 565: I would not call it "sensitivity analysis" but perhaps "importance ranking". You already stated in Section 3.3 that it is not really a representative sensitivity analysis.

Typos etc.:

51) As you can see in the following, there are quite a lot of typos and inconsistencies. As I have definitely not found all of them, I recommend a thorough proof reading.
52) Please, revise your citation style. It seems to be inconsistent.
53) L. 134: Remove the second parenthesis before "Larsen and Hansen, 2007".
54) Footnote 1: "in the time domain – developed in" not "in the time domain- developed in"
55) Eq. 1: $\exp(x)$ should be e^x and pi should be π
56) Fig. 2: "Lognormal" and not "lognormal"
57) L. 199: 10^3 and not 1e3.
58) L. 205 (and several times more): k and not K
59) Eq. 9: Please, keep indices consistent, e.g., I_y and not Iy
60) Table 2: "radius" not "radious"
61) L. 270: "Equation (15) shows" not "Equation (15)shows".
62) L. 294: Missing citation "marquez2012fatigue".
63) L. 307: "resistance" not "Resistance"
64) L. 335 and 337: 10^{-4} and not e-4
65) Fig. 4: "Probability" not "Pobability" and 0-100% and not 0-20 (both horizontal axis).
66) Fig. 4: "MNm" not "Mnm" (vertical axis).
67) Fig. 4: 0 to 100% and not 0-20 (colour axis)
68) Table 4: "Par 2" and not "par2" and "Par 3" and not "par3"
69) L. 464: "Eq. (29) and" and not "Eq. (29)and"
70) L. 466: I think that there is something missing in the statement "the distributions in 3 are […]"
71) Fig. 6: "b) tower" and not "b)tower"
72) L. 470: "show that in both" and not "show that the in both"
73) Fig. 7: Please, update the legend, e.g., $\ln(\Delta)$ and not "log Delta" and which DEL is meant here?
74) L. 569: "the" and not "The"