WES Paper Review:

Review of rolling contact fatigue life calculation for oscillating bearings and recommendations for use, with examples for wind turbine bearings

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Summary: This paper reviews the concepts and methodologies which have been proposed/developed for application in calculating (rolling contact fatigue) rating lives, as well as seeking to provide guidance on when each of the available approaches might be most suitable. The authors additionally seek to provide a unified view regarding how each of these methodologies relate to each other. Specific focus is placed on applications to slewing bearings in wind turbines.

General comments: This is an important topic which has arguably received less attention in wind research (and in rolling bearing research more generally) than it should, given the criticality of slewing/oscillating bearings to wind turbine function and reliable operation. The authors demonstrate a very high level of expertise regarding this topic, and the manuscript contains a good number of important contributions to support future research in this topic area as well as the improved application of such techniques in wind research more generally. As a result, this reviewer feels there is a clear contribution to the scientific literature, making a paper on this topic both novel and appropriate for publication in WES. Having said that, the submitted manuscript falls short of what I would consider as being immediately publishable (for reasons which will be outlined). I am therefore recommending that major revisions are undertaken by the authors to ensure the full potential of this valuable paper are realised. At a high level the following points need to be addressed:

1) The writing throughout the paper has a tendency to be imprecise and informal. Clarity and specificity are crucial when seeking to elucidate a complex topic. Extensive improvements to language and the rigour with which concepts are discussed is therefore encouraged to ensure clarity and avoid confusing the reader (specific details are provided under “Specific comments”).

2) The paper focuses on slewing bearing in wind turbines, but the introduction/background of the paper does not introduce or outline these bearings in any detail or provide an overview of their design, design trends and load conditions and/or provide information of their failure rates or critical issues as informed by the scientific literature. I believe a more complete background on these bearings is therefore required.

3) Motivation – the introduction appears to indicate that wear is an issue for wind turbine slewing bearings, before saying that rolling contact fatigue will be the focus of this review. As a result, it feels like the authors undermine their own paper at this stage. Please take more time to elaborate on what we know about failure in these bearings, and to motivate why an analysis of rolling contact fatigue analysis remains important here (as it certainly does). The current exposition of this point feels rushed and underdeveloped.

4) Structure – I learned many fascinating new concepts while reading this review, in particular the various important effects present in oscillating bearings. However, these new concepts are dotted throughout the paper, only appearing as they are included in one method or another. It makes it very difficult to develop a clear appreciation for the overall operating/loading conditions, complexities and nuances of oscillating bearings when the information is provided in this manner. I would therefore urge the authors to introduce a new section at the start of the paper, along the

lines of “Operational fatigue conditions in oscillating bearings” in which all of the critical real world aspects are described and discussed, prior to any consideration of the various fatigue models and which effects they account for. This will provide readers with a clear outline of the “ground truth”, based on which they will be better placed to appreciate all later discussions of the various models and what they do or do not include.

5) Throughout the paper, many complex concepts (e.g. subsurface stress time histories in rolling contact, lubrication and grease thickener effects, etc.) are only briefly mentioned, as if familiar to the reader, but without providing any references for further reading. I feel this reduces the overall usefulness of the review to the general WES reader, and so encourage the authors to go back through the paper, adding pertinent references for all such concepts throughout. Remember, many readers will have non-tribological/non-bearing specific backgrounds. In order to maximise the value and impact of this review, such readers should be provided with clearly signposted references in which they can learn more about these concepts. There are also a good few instances where claims/facts are stated without a suitable accompanying reference to back up that claim. Finally, I’d note that this review paper has a relatively low number of references utilised overall. While this may be appropriate in some cases, I believe this particular review would benefit from a broader representation of relevant literature (detailed in “Specific comments”).

6) The guidance provided on which methods to use and when is arguably fairly limited. For example, in one instance, a total of 8 different methods are indicated as being suitable in your flow diagram at one point, without any more specific guidance on which might be best (for instance, I don’t think you explicitly state that approximate methods should be considered as less accurate etc.). Based on your familiarity with the various methods, the foundations of their development and extent of experimental validation (which I am aware is low in all/most cases), I wonder if the authors might be able to provide a clearer path to delineating and selecting an appropriate method. It may be this is simply not possible at this stage. However, if that’s the case then perhaps the best advice is to stick as closely as possible to ISO method(s) and their extensions, including only the necessary add-ons for the case one is dealing with. The logic behind this would be that design certification often require some chain of evidence/justification, which would best be provided by links to an international standard – at least until some other method is clearly demonstrated to be superior. I am very happy to be told I am wrong about this, but either way I think a more detailed discussion of deciding which method(s) to use would be helpful.

7) The paper feels like it’s missing a section on “Current challenges and critical future work”. This is a topic for which it feels like we are still at the beginning of its proper scientific exploration. This review should therefore provide a roadmap for overcoming current challenges and improving the rating life predictions for oscillating bearings in wind turbines. This becomes even more critical if, as discussed in point 6, we don’t currently have any good way to decide between the various available methods in some instances. Can you outline the current knowledge gaps and indicate the necessary experiments, data, analyses and modelling work which would allow us to bridge them?

Specific comments:

Abstract: “calculation” used twice in first sentence. The abstract also feels vague, can your overall recommendations and findings be listed more explicitly? Similarly for the application to wind pitch and yaw bearings.

L11: “change the wind’s angle of attack as it acts on the blade.” Perhaps better as “the blade’s angle of attack”?

L12 “Movements in modern turbines mostly consist of small oscillations with the occasional 90 degree movement to bring the turbine to a halt.” -> “Pitch control actions in modern *wind* turbines mostly consist of small (x degs) oscillations with the occasional 90 degree movement to bring the turbine to a halt” (Language suggestion, plus, please indicate what “small” means here).

L13 “Similarly, yaw bearings rotate the turbine to face into the wind. Their movements are typically fewer and, depending on the site and the yaw system design, longer.” Please revise language, this is unclear and imprecise as written.

L15 “Rolling bearings under oscillatory movements are commonly associated with wear damage to the raceways and rolling bodies (Behnke and Schleich, 2022; Stammler, 2020; Grebe, 2017; FVA, 2022; de La Presilla et al., 2023)” -> Is damage more common in general, or is it that the damage that it does experience is wear more often than not? Please order references chronologically.

L16 “In some cases, such as large amplitudes, varying amplitudes, or the use of oil lubrication, wear is unlikely to occur and rolling contact fatigue becomes more relevant.” -> Large amplitudes of what? (I assume motion, but you could mean load), please be more precise with language.

L18 “and ensure they do not cause a failure of the bearing.” This sentence feels open ended and it’s not immediately clear what it adds.

L19 You indicate that wear is maybe a dominant failures more, except under circumstances that don’t apply to pitch or yaw bearings (as far as I’m aware), but then say that this paper is going to review rolling contact fatigue… It feels as if like you start by outlining why a different paper is needed. Also, when describing wear vs rolling contact fatigue circumstances you don’t outline which yaw and pitch bearings may fail into and why. Please revise this discussion and provide further info on yaw and pitch specific failures.

L20 “There are a number of approaches for rolling contact fatigue life calculation in the literature, see Sadeghi et al. (2009) and Tallian (1992) for an overview, but they are mostly intended for rotating applications.” I think there are other good references to include here, please consider whether those listed are sufficient (I am a big fan of Zaretsky 2016 - Rolling Bearing Life Prediction, Theory, and Application https://ntrs.nasa.gov/api/citations/20160013905/downloads/20160013905.pdf)

Figure 2: I am struggling to interpret the left hand side of this figure, why does is the blue line continuously loading, whereas the red line has zero regions? Please provide a more detailed description to help the reader.

Line 37: “Fundamentally, rolling contact fatigue in oscillating applications is caused by a rolling element repeatedly rolling over locations on a raceway, as is the case in rotating applications.” Maybe the reader could be given a little more lead-in to considering rolling contact fatigue. I suggest this as many engineers will be more familiar with cases of fatigue cracking and rainflow counting methods etc, rolling contact fatigue is quite different to that, since it is the passage of rollers which causes stress cycles and not simply the applied load varying. Some more discussion of this would, I feel, be helpful.

Equation 1 – please use the proportionality symbol here, as the tilde is ambiguous in its meaning.

L44 I’d include a good background reference on this material, e.g. Zaretsky 2016 as above. Also, I’d suggest providing some discussion of the limitations of RCF modelling/prediction.

L46 I’d recommend defining this predicted life as the “rating life” to distinguish it from the observed/service life seen in the field.

L54 “For small oscillation amplitudes, a_osc typically becomes very large” this sentence doesn’t really add much as it is. Are you able to provide some ballpark of the size of a_osc? E.g. “commonly falls in the range 10^x – 10^y” or similar.

L55 “There are two possible definitions of an oscillation “amplitude” ” – technically there are an infinite number of ways one might define this amplitude, I’d change “two possible” to “two common”

L56 “For small oscillation amplitudes, much of the existing literature will predict a high likelihood of wear, particularly for grease-lubricated bearings (Behnke and Schleich, 2022; Stammler, 2020; Grebe, 2017; FVA, 2022). Nonetheless, as discussed in Sec. 3 of this review, it is definitely possible for rolling contact fatigue to occur without wear2 even for oscillating amplitudes as low as θ = 1◦ (ϕ = 2◦).” I agree this is important context, but it feels a little shoe-horned in here. Is this the best place for this information, can you expand a little to give the reader a little more to grab hold of?

Equation 3 – you use the notation a_OSC in Equation 2, but then switch to a_Harris for Equation 3. Please determine a way of making it clear to the reader that the latter is an instance of the former (it is reasonably clear that this is the case from context alone, but for the sake of rigour I’d like to see it made more explicit).

Line 67 “Thus, taking an exemplary bearing that oscillates with an amplitude of θ = 10◦ and that, if it were rotating, would have a life of L10,rev = 1 million revolutions, and applying Eq. 2 and Eq. 3 gives a life of L10,osc = 90◦ 10◦ L10,rev = 9 million oscillations according to the Harris factor. This is because it will execute an arc of A = 40◦ per oscillation, which is considered as 1/9 th of a rotation by the Harris factor” While a worked example does help make things clear for the reader, I wonder whether readers will need such a simple equations explained in such detail?

Line 74 I think it’s perhaps not an exact equivalence between Harris and LRD automatically, since Harris didn’t deal directly with changing load conditions, while LRD does. Is it more correct to say LRD is equivalent to applying Harris independently to each different load case?

Line 78 Please indicate to the reader that these two effects will be described in detail below.

General comment – we are learning about what the loading etc looks like for an oscillating bearing by going through a series of incorrect or approximate approaches. This means the reader has to do a lot of mental gymnastics to keep track of what is actually happening versus what people assumed was a reasonable approximation. I think perhaps the paper would serve the reader better if early on there was a section which simply described the true characteristics of loading (along with any other pertinent effects) in oscillating bearings (as per Fig 5). When discussing the various approaches, the reader will therefore know the “ground truth” and hence be able to better follow where approximate methods miss important aspects of the real world case.

L86 “but without a derivation of the approach” does “the approach” refer to the original or simplified one?

L86 Footnote 6 is rather long and difficult to follow since it seems to assumed familiarity with the works it mentions. Please consider rewriting for clarity and possibly moving this into the main paragraph, rather than as a footnote.

L88 Is it necessary to list every combination of "a_xxx" notation that has been used in the literature for the oscillation factor? We expect differences in notation and naming from paper to paper, but I'd expect readers to be able to cope with that by simply reading the work to find out what notation is being used. There are currently a great many footnotes dealing with notation and it feels unnecessary.

Fig 4 lacks units on the polar plot and is difficult to interpret, what am I looking at here? What does the radial scale mean? why do all fluctuations disappear for theta = theta_crit?

L 105 "The recommendation in Eq. 5" I'm not sure this makes sense, "the form of equation 5" maybe?

General comment – currently this reads as a long list of things people did, with continual caveats, corrections and footnotes. The paper would benefit from a careful consideration of structure and narrative in order to make this is easy to follow for the reader as possible. Perhaps a graphical description of early summary of all developed methods, how they relate to each other and where in the paper they will be discussed would help?

L109 : "Strictly speaking, the life of an unevenly stressed volume (as illustrated 110 in Fig. 4, yellow and blue) is not the same as that of an evenly stressed volume which occurs in a rotating bearing (identical to Fig. 4, red)" Do you have a reference for this?

112: "Recommendation" again, I don't feel this is the correct word here

L120 Footnote 14 is very dense and really gets down into the weeds, in particular it introduces contexts and notation (e.g. load integrals) which are not utilised or fully explained in this review. Either these more complex points are important enough to be included properly, or I'd recommend a briefer footnote which simply gives the reader appropriate context and the main outcomes.

L128 It's been mentioned a few times by now, but I am still unsure specifically what the "Houpert effect" is describing in any sort of detail. Maybe link the name to Figure 5 behaviour more explicitly?

L133 "For very small oscillations $\theta \rightarrow 0^\circ$ ($\phi \rightarrow 0^\circ$) on the other hand, the elements increasingly converge toward the stress cycle history seen in a stationary ring, see Fig. 5" It seems that you're possibly saying that it will converge to the stress cycle history of a stationary ring in a rotating bearing (which I don't think it does), so instead I guess you mean that for small cycles the stress time history for the moving ring in an oscillating bearing becomes similar to the stress cycles for the stationary ring in that same oscillating bearing? Either way I think some clarification is needed here.

Equation 6 how does a_Harris change between stationary and rotating rings? I don't see what's different in the mentioned cases shown in this split equation.

L138 "If applied correctly, the Houpert factor will either be identical to aHarris in the above given cases or shorten the life of the bearing in all other cases. The Houpert effect is thus most noticeable for narrow load zones and small oscillation angles." I don't see why the latter follows the former (as implied by the use of "thus"), perhaps this is additional information rather than being implied by the first sentence?

Footnote 18: Again there is lots of additional info being given about notation used in other work, I am just not sure if that is really adding anything or simply risking confusing the reader. Please consider.

L149 “The above three factors have been covered in a number of publications” please provide a more complete list of these references here, even if you do go on to then point to the most recent.

L164 Why are the various methods below this point introduced in reverse chronological order? Surely you should start with Hai et al. (2012) and work your way forwards in time to Menck (2023).

L165 “whole bearing” does this mean that Menck (2023) calculates life for individual raceways and then combines these into a total bearing life afterwards? If so I’d suggest making that clearer in the description of Menck (2023) in the previous paragraph.

Footnote 21 appears to contradict a sentence which follows, which seems to indicate equivalence only in cases of sinusoidal movements.

L167 “For a stochastic time series, their numerical approach produces a shorter life than either Harris’, Rumbarger’s, or Houpert’s approaches applied to a bin count.” Where is this shorter life shown, can you add a reference or other evidence to demonstrate this?

L173 “and conclude that using these bin counts “overestimates the lifetime for non-sinusoidal loads and speeds”” can you please comment on whether this conclusion is correct or not (I assume not as you indicate they use some erroneous formulations but this isn’t made explicit either way).

L173 “They also produce a simple method to calculate an equivalent load for oscillating loads but it fails to take local effects into account as accurately as Menck (2023).” Can you please indicate where this is demonstrated (in Menck (2023) perhaps?).

L190 Typo “made make”

Section 2.1.5: As mention previously, I feel there needs to be an earlier section describing all relevant real world effects in oscillating bearings, rather than encountering these various concepts one at a time and dispersed throughout discussions of simplified modelling/analysis approaches.

L195 “the orthogonal shear stress below the surface changes from maximum (+τ0) to minimum (−τ0)” There is quite a lot of complexity surrounding these stress components and how they behave, therefore please link to a reference which provides detailed information, e.g. A Review of Rolling Contact Fatigue by Sadeghi et al. 2009 (or similar).

L196 “This load cycle does not take place to the full extent at the outer ends of an oscillation cycle as depicted in Fig. 3.” I don’t think Fig 3 is explicitly showing this, it is maybe something which may be “inferred from” Fig 3, or is a result of the behaviour therein?

L201 “None of these effects is considered in the ISO-based approaches named herein.” To help the reader, can you provide a little more to remind them which of the described approaches fall in this category (e.g. “this being all approaches outlined in Sec X.Y”).

L205 “As far as the authors are aware, there are no simple models to estimate the thickness of the lubrication film as a function of the oscillation and thus determine its potential effects on rolling contact fatigue” You mention that poor lubrication might lead to wear (which is not fatigue), but then indicate that we are currently unable to determine the effect of lubrication on fatigue. Do you perhaps need to include an earlier sentence which indicates that as well as wear damage, lubrication also impacts rolling contact fatigue (although I appreciate that the lines can become fuzzy here, since surface initiated rolling contact fatigue can be argued to include some elements of wear…). Anyway, as written it feels a little confusing for the reader, so please consider a suitable revision in one form or another.

General comment: Throughout the paper, many complex concepts (e.g. subsurface stress time histories in rolling contact, lubrication and grease thickener effects, etc.) are briefly mentioned as if familiar to the reader, but without providing any references for further reading. I feel that this reduces the overall usefulness of the review to the general reader, and so encourage the authors to go back through and add in pertinent references for all such concepts throughout. Remember, many readers will have non-tribological/non-bearing specific backgrounds. In order to maximise the value and impact of this review, such readers should be provided with clearly signposted resources to learn more about concepts that may be important for them to consider within their wind-energy-meets-oscillating-bearings research.

L207 "Therefore, the effect of lubrication is mostly ignored in all models of which the authors are aware." ISO 281/16281 include some effects of lubrication in the modified life factors. I am aware this in no way accounts for oscillating behaviour, but since some accounting for lubrication is present I would ask the authors to be a little clearer in what is included and what is not. E.g. maybe rephrase to something like "Oscillatory effects on lubrication are mostly ignored…"

2.1.6 Binning: You have already talked about binning in some other contexts above, there is risk of equivocation of those various concepts and so I'd suggest a more descriptive title for this subsection.

L211 "The most accurate way to calculate the rolling contact fatigue life… according to the assumptions in Eq. 1 made by ISO related approaches… is to use the Finite Segment Method according to Menck (2023)" This is a fairly strong claim that is being made. Based on what I know of these methods I absolutely concede this is likely to be the case, but has that been demonstrated explicitly anywhere? To fully back up this claim, one would need to have experimental verification I'd think. Perhaps maybe a more qualified statement, such as "<u>It is argued that</u> the most accurate way to calculate… is <u>likely</u> to be the Finite Segment Method according to Menck (2023), because…"

L216 "Doing so for oscillating bearings necessitates the use of bins" This statement is ambiguous, bins of what? Please revise for clarity and specificity.

L220 "along with a number of other assumptions made by Lundberg and Palmgren (1947)". Please provide references to more recent works which critique rolling contact fatigue formulatinos/assumptions (e.g. that of Erv Zaretsky, listed previously). This will provide readers with a more up to date critical analysis.

L222 "Typically, variable load is taken into account in fatigue calculations by using rainflow counting" This is true for classical fatigue of structural components (e.g. beams etc.), but is not used for rolling contact fatigue. Since we have been discussing the latter, there is a risk here that the reader assumes rainflow counting is applied for rolling contact fatigue analysis also. Please provide further clarification here to avoid such confusion.

Equation 7: The notation here is not properly defined, e.g. please be explicit about what Ni, Pi and Pm denote – and please include this immediately following the equation itself.

L231 References not provided in chronological order.

Footnote 30 and Lines 235-238: These both constitute information of additional approximations that either do or may form part of the analysis currently being described. However, there is no further context provided by the reader of the quality of approximation that either may represent. If further information on this (e.g. from analyses in the literature) may be given then please include it. At the very least, please point out that these additional approximations are increasing the uncertainty surrounding the rating life values we obtain (which themselves contain uncertainty as ISO fatigue equations are imperfect to begin with). This is fine, but I feel the reader should be made aware that these additional approximation come at a “cost”.

General comment: There are a lot of approximations and uncertainties being stacked on top of one another in these various methodologies. Given there is also a lack of experimental data to indicate how accurate any of these methods are, surely this provides at least one aspect of “critical future work” which should be highlighted?

L239 Notation in equations, again not defined or explained well.

Equation 8: Please provide one or more references for this equation. As previously mentioned, important background material is not being signposted for readers. Also subscript B missing on denominator phi.

Equation 8: I think this may be in an unhelpful form… As written the phi have the same units as the life values. Hence, the total life of the bearing across all operating conditions (combined) is phi1+ phi2 + … + phiB. This means you actually have to know the complete life of the bearing to form that expression. But, if you multiply the top and bottom of the equation by 1/(phi1+ phi2 + … + phiB) you end up with a form in which you only need the <u>proportion of time</u> spent in each operating condition. Note – using the form you wrote out for a finite set of load cases, and where each phi is just the time spent in each, is essentially equivalent to the proportional approach I outline, but you have to make the implicit assumption that those load cases are proportionately representative of the lifetime conditions. Hence, I feel it better to explicitly include the concept of proportional time for the sake of clarity.

L252 “the most accurate approach … is to use each single step… In order to account for oscillation effects, it would then be required to consider the larger oscillation cycle (amplitude) that a specific step is part of and adjust its life based on that, where the step will typically make up a fraction of the complete oscillation”. As per a previous comment, I’d again suggest a more qualified statement regarding what may or may not be the most accurate approach. Here I say this because you go on to outline how an additional approximation/interpretation of the data becomes necessary to implement in this way. Perhaps you mean accurate in terms of what we’re allowed to do under linear damage accumulation, in which case it may be possible to make a stronger claim. But, I wonder whether overlaying rainflow counted oscillations on top of varying loads moves us outside of where we’re strictly applying the linear damage rule as used by Palmgren-Miner? I am happy to take your lead on this, please just consider these points.

2.2 Non-ISO related approaches: The summary of existing literature/approaches is not in chronological order. Please start with oldest and work to newest unless there is a good reason for deviating from this.

L260 “Individual loads are combined using the Palmgren-Miner hypothesis” Has the linear damage accumulation assumption (does it count as a hypothesis?) been explicitly introduced (in detail) somewhere in the paper, and linked to relevant references in the literature for the reader to learn more if necessary?

L262 “fatigue criteria such as Fatemi–Socie or Dang Van could also be applied” is it helpful to name these if they are not expanded upon? Maybe just say that they point out other criteria could also be applied. If you want to name them then please at least include a relevant reference for each.

L262 “They obtain empirical values used for the Palmgren-Miner hypothesis” empirical values of what?

L264 “and further note that “a large number of tests are necessary for reliable results”.” Had they conducted such tests in their own work? Can you please comment in the paper as to whether they provide evidence that their approach works or is better/worse than others.

L272 “They use orthogonal shear stress” the max value at each point in time?

L276 “the Weibull weakest link principle” Please describe and provide reference to relevant literature (possibly Zaretsky 2016 again, he calls it strict-series-reliability).

L276 “The authors demonstrate their method for a reference case in which a blade bearing was tested.” What was the outcome of this test/comparison? Did it provide a good prediction of observed life?

L285 “The model is applied to rotating and oscillating bearings under constant operating conditions” Does this application imply anything regarding the efficacy of this approach? Please add some further comment or information.

L304 “none of the bearings show evidence of fretting corrosion” until now we have only seen mention of fatigue and wear damage. Why is this new type being included now, should it not appear earlier as well in that case? (I’d suggest including it in my suggested new section of real world information for oscillating bearings).

Footnote 32: You don’t say what x or b are in this note. We are also focussing on fatigue and not wear, hence this parameter has not previously been discussed and is arguably not helpful to readers not familiar with wear testing for oscillating bearings. I think this note can therefore be safely dropped. If it is to be retained then it should relate to material on wear introduced earlier so the reader can interpret the information in a useful way.

L311 “The test duration is equivalent to the L10 of the ball screws“ is this the L10 for rotation or under oscillatory conditions?

General comment: Combining the discussions of deviations between oscillating and rotating bearings with experimental findings; it seems there is a natural expectations that oscillatory (fatigue) lives are longer than the equivalent rotating life (although wear is another animal!). If this is a reasonable inference then could/should this be given as an explicit interpretation? Section 3 currently lacks any concluding discussion which seeks to identify commonalities between experimental findings, if present.

L330 “For the ISO-related approaches, recommendations are given according to the underlying physical phenomena considered in the derivations as described in this paper” So there is therefore an assumption applied that a method which explicitly includes a given phenomena is necessarily superior to one which doesn’t. This is a reasonable basis on which to make these recommendations, but it could also be the case that (for various reasons) a simpler method is superior to a more complex method, even if the latter includes more effects. For instance, this could occur if more complex interactions are present which perhaps counteract impacts from the physical phenomena which the more sophisticated methods attempts to capture. As a result, it is perhaps worth highlighting at this point that recommendations based on included physical effects alone is the best we can do at present, but not guaranteed to produce better results in all cases.

Footnote 33: please include relevant reference(s)

L341 “For the Rumbarger effect, based on Sec. 2.1.2 and App. A, the flowchart recommends combining this effect with the Houpert effect for non-axial loads (i.e., radial and moment loads).”

The flowchart actually indicates this for non purely-axial loads (different to non-axial). The diagram is also a little confusing, since “yes/no” can be followed in two directions in many places, with no indication given as to which is preferential. Note for the legend entry with bold outline “for time series” isn’t super clear. I initially looked for fully white boxes and saw none, only after this did I realise it was referring to the bold outline. I’d suggest a clearer indicator (e.g. dashed green bold outline instead?).

Section 4.1 (General comment): There is fairly limited guidance on which methods to use provided here. For example, at the first stage-gate whether the answer is yes or no a total of 8 different methods are indicated, without any further guidance on which might be best. Based on familiarity with the various methods, the foundations of their development and extent of experimental validation (which I am aware is low in all/most cases) I’d hope the author’s might be able to provide a clearer path to delineating and selecting an appropriate method. It may be this is simply not possible at this stage. However, if that’s the case then perhaps the best advice is to stick as closely as possible to the ISO method (so favouring ISO-based methods), including only the necessary add-ons for the case one is dealing with. The logic behind this would be that design certification often require some chain of evidence/justification, which would best be provided by links to an international standard – at least until some other method is clearly demonstrated to be superior. I am very happy to be told I am wrong about this, but either way I think a more detailed discussion of deciding which method(s) to use would be useful.

L365 “An exemplary cardan joint connects two shafts whose axes are inclined to each other” A simple diagram would be helpful here.

L370 “According to Fig. 7” I think this would read better as “In the context of Fig. 7” At present it seems to imply that the time invariance is because of Fig. 7.

4.2 and 4.3 Applications: These are both very simplistic examples which basically demonstrate how to follow a flow diagram. Would it not be possible to go on to apply realistic loads for those components and example bearings in order to obtain life values, perhaps also comparing to what you’d get if a simpler formulation had been used instead of the recommended one?

L387 References given in reverse chronological order, please switch to chronological.

L390 “Moreover, according to Sec. 3, the experimental validation for these models is still lacking. Therefore this section will focus on ISO-based approaches, which remain the most common life calculation methods for rolling contact fatigue.” Here you seem to apply some of the logic I suggested including in your recommendations for which methods to use, so it seems we are somewhat in agreement in the underpinning logic at least.

L393 “Moreover, the load direction changes slightly, though mostly for smaller loads (Menck et al., 2020)” Can you please expand on this for clarity. Surely the gravitational loads are constantly cycling and hence driving large load direction changes a lot of the time? (Is this perhaps overcome by one of the other load components?). I’d also suggest including a fuller description of the load conditions of pitch and yaw bearings in my suggested expanded Background section on slewing bearings in wind turbines.

L394 “Therefore, according to Fig. 7, the Finite Segment Method (Menck, 2023) would be the most appropriate ISO-based method for an engineer to use” This is not a given from Fig 7 alone. Yes the figure indicates the other ISO-based methods are approximate, but the figure and accompanying text never make the claim that approximate methods are necessarily poorer than the rest. If such guidance is being given, please include this in Section 4.1 more clearly.

L405 “is large enough to have rolling elements cover the entirety of the raceway at one point or another” reference?

L414 “The five approaches are ordered with increasing accuracy to the right of the figure” Accuracy implies “more correct with respect to the ground truth”, here I believe you are instead claiming accuracy under the assumption that linear damage accumulation is a reasonable approximation, please clarify this in the paper. Similarly for “This is the most accurate method and can be used as a reference for the others.”

Footnote 40: References?

Figure 8: Why not have L10 in years, that’s much more meaningful to wind engineers. Similarly, results indicate rating lives of around 100 days or less, is this realistic? Please discuss.

L445 “The design of yaw bearings thus lends itself to binning, since detailed time series will typically not be available” This is due to a lack of information, rather than this necessarily being a route to accurate deign lives. I’d suggest rephrasing to indicate this is out of necessity only (while highlighting that further information on yaw time histories should be prioritised). Is this another point to include in “critical future work”, a better understanding of yaw bearing movement time histories?

L450 “Finally, the design of large scale yaw bearings, like that of pitch bearings, usually includes a large number of rolling elements in excess of 50 or even 100 and more per row, giving small critical angles” The critical angle will depend on both the bearing geometry/size as well as the number of rollers. Can you provide some further information or analysis to show that even for large diameter bearings this conclusion still holds? Additionally, do you have a reference for the numbers of rollers?

L464 “Since yaw bearings, like pitch bearings, are strongly affected by a tilting moment, a life which is around 10% shorter than that obtained with the Harris factor is to be expected.” I am not sure how the conclusion follows from the opening of this sentence, can you please elaborate for clarity.

L466 “If the main wind direction is truly evenly spread over all compass directions, it is permissible to use the equivalent load of a ring that rotates relative to the load for the outer ring, approximately equivalent to simply using the Harris factor” Is this because of rollers rotating internally? I am not sure I follow the logic here. In addition, this is a fairly strong claim which is being made. There will never be a perfectly circular wind rose, and no guidance is provided to serve as a cut-off for “evenly spread”. Is there any data or a short analysis which can be presented to help indicate when this is safe to apply? (At present it feels a bit hand-wavy).

General comment: The paper feels like it’s missing a section on “Current challenges and critical future work”. This is a topic on which it feels like we are still at the beginning of its proper scientific exploration. This review should therefore provide a roadmap for overcoming current challenges and improving the rating life predictions for oscillating bearings.

L470 “Most of these approaches have been proposed and used in the literature without an explanation as to when they apply. The aim of this paper was to explain when which approach can be applied.“ This particular aim was achieved, but I feel there could be more guidance on how to select a method from the set of those which could be applied in any given case.

L477 “All ISO-based approaches shorten the calculated life compared to the results using the Harris factor (or are identical to it) if applied correctly.” I am not sure if the review paper provides a detailed discussion of why this is the case, is it that oscillation always means at least one part of the raceway is worse off than in an "equivalent" rotating bearing?

L482 "Some results from the ISO-based approaches suggest that their predictions may be relatively close to the actual life" I'm not sure if "relatively close" was ever quantified. I assume you are referring to results in the experimental section? Please add some clarification here, or earlier in the paper.