

Virtual sensing for strain estimation in wind turbine support structures based on a single accelerometer

Answer to the reviewer's comments

The authors would like to thank the editor and reviewers for their time and effort to review the article and for their constructive and relevant comments. We appreciate the chance to clarify the addressed points. This will undoubtedly help in improving the quality of the manuscript. The article is revised according to the reviewers' remarks and queries, with detailed responses and explanations of the edits given below. Edits in the manuscript have been highlighted in **red color for the first reviewer**, in **blue color for the second reviewer** and in **cyan color for the community comment**. We note that during the revision, the number of lines has been changed. Therefore, in the proceeding paragraphs, we refer to the revised article.

Reviewer Comment 1

In their manuscript, the authors present a method for virtual sensing in wind turbine support structures that relies on a single biaxial DC capable accelerometer. The approach allows for displacement and strain estimation in the low frequency range that includes the quasi-static contribution as well as the one from the lower structural modes. The key idea in the method is to compensate the measured acceleration for the tilt error. The method is validated first using data from a laboratory test with excitation at a known location and next actual data from an actual off-shore wind turbine. The performance of the method is quantified through the error in damage equivalent strains as well as the normalized root mean square error.

The manuscript addresses a highly relevant problem and proposes a novel method with potential for industrial application. The method is clearly described, the assumptions properly formulated and the validation by lab and field data convincing. I would recommend a minor revision of the manuscript where the authors address the following comments:

We thank the reviewer for their constructive and helpful feedback. We have taken your comments into account and changed the manuscript accordingly. The changes are explained in detail below.

- **The method requires a single biaxial and DC capable accelerometer. I would suggest to also state it in this way in the title of the paper.**

The authors changes the title to include *biaxial*. We consider it sufficient to mention *DC-capable* in the first sentence in the abstract (page 1 line 2):

*This paper introduces a novel model-based approach for virtual sensing of wind turbine support structures for full-field strain estimation using a single **biaxial**, DC-capable accelerometer.*

New title: *Virtual sensing for strain estimation in wind turbine support structures based on a **biaxial** accelerometer*

- **Line 79. Please specify that the accelerometer is capable of measuring down to DC.**

We added the sensor requirements (page 3 lines 81-82):

*As strains are related to structural displacements, a double integration of the measured accelerations **from a DC-capable accelerometer** is necessary for strain estimation.*

- **Lines 95-98. Please reformulate, the structure of these two sentences is grammatically incorrect.**

We reformulated the respective sentences (page 4 lines 97-101):

By splitting the entire frequency range into multiple frequency bands, the multi-band approach allows the consideration of more vibrational modes than the number of accelerometers would typically permit. Furthermore, it enables the reconstruction of the quasi-static strain by spatially extrapolating the measured strain using the strain distribution in the static bending line instead of the first bending mode.

- **Lines 114-115.** The present formulation suggests the term Ritz vector is proposed in the quoted reference. Please adapt.

We reformulated the respective sentences (page 5 lines 117-119):

The consideration of different deflection shapes in addition to the mode shapes is often referred to as Ritz vectors in the context of strain estimation according to Skafte et al. 2017, who used Ritz vectors to better represent wave loading on offshore structures. The concept has been employed by Augustyn et al. 2021 and Toftekær, Vestermark, and Jepsen 2023.

- **Equation (3).** Please indicate whether m would depend on the considered frequency band.

We added a sentence after Equation 4 (page 7 lines 174-175):

The tilt constant m is only determined for the static case as the tilt error is neglectable in the dynamic frequency range dominated by structural eigenmodes of current wind turbines.

- **Table 2.** Are the MAC values determined based on the accelerometer data only? Please specify.

We specified that only the acceleration measurements are used for operational modal analysis (page 14 lines 314-315):

In the FE model, the boundary condition at the base of the structure is updated to match the modal parameters of the first three bending modes in the x -direction identified from the acceleration measurements during the free decay from $t=310$ s to $t=395$ s using operational modal analysis

and (page 14 lines 318-320):

The mode shapes of the real structure are determined from the acceleration measurements using operational modal analysis and are herein compared to the mode shapes from the FE model using the modal assurance criterion (MAC).

- **Line 403.** Why is the conventional MAC value not used to compare the measured and predicted mode shape? Please explain the S2MAC as this is not a conventionally used metric and indicate why it has been used here.

The conventional MAC value is well suited to compare mode shapes. However, in case of closely spaced modes, the mode shapes can only be identified with significant uncertainty using operational modal analysis. As shown by Jonscher et al. 2023, the majority of the uncertainty lies in the orientation within the mode subspace. Since the S2MAC compares a mode shape to the mode subspace spanned by two modes, this alignment uncertainty can be excluded when the S2MAC is used for comparison instead of the MAC. The S2MAC is equivalent to the MAC when only the dominant direction is considered.

We added a short reasoning for using the S2MAC (page 21 lines 425-427):

By comparing the mode shapes with the S2MAC, the alignment uncertainty within the mode subspace is excluded, which can be significant for tower structures with closely spaced modes as shown in Jonscher et al. 2023. The comparison of the modal parameters reveals a good agreement of the calculated first bending mode pair with the measurement data from the real structure.

- **Caption of table 8 contains a repeated article “the” in front of eigenfrequencies.**

We changed the caption (page 23 Table 8):

Comparison of structure and the FE model: deviations of the ~~the~~ eigenfrequencies and the mode shape assessed via the S2MAC.

- **Line 440. Please specify that the accelerometer needs to be biaxial and DC capable.**

We specified the sensor requirements (page 25 line 471):

*The results of this study show that accounting for the tilt error in strain estimation on wind turbine support structures enables an accurate strain estimation using a single **biaxial and DC-capable** accelerometer.*

References

- Augustyn, Dawid et al. (2021). “Feasibility of modal expansion for virtual sensing in offshore wind jacket substructures”. In: *Marine Structures* 79, p. 103019. ISSN: 09518339. DOI: 10.1016/j.marstruc.2021.103019.
- Jonscher, Clemens et al. (2023). “Influence of system changes on closely spaced modes of a large-scale concrete tower for the application to structural health monitoring”. In: *Journal of Civil Structural Health Monitoring* 13.4, pp. 1043–1060. DOI: 10.1007/s13349-023-00693-6.
- Skaftø, Anders et al. (2017). “Experimental study of strain prediction on wave induced structures using modal decomposition and quasi static Ritz vectors”. In: *Engineering Structures* 136, pp. 261–276. ISSN: 01410296. DOI: 10.1016/j.engstruct.2017.01.014.
- Toftækær, Johan F., Jonas T. Vestermark, and Michael Sandholm Jepsen (2023). “Uncertainty of Virtually Sensed Stress Ranges in Offshore Wind Support Structures”. In: *Volume 1: Offshore Technology*. American Society of Mechanical Engineers. ISBN: 978-0-7918-8683-0. DOI: 10.1115/OMAE2023-101045.

Reviewer Comment 2

The introduction to the work, and the state of the art is complete and without clear error. I appreciate the authors' effort and care.

I also appreciate the effort to make the code and data open access.

Overall the work is clear, the ambitions and methods of the authors are clear and in my opinion fairly novel. While there is still much to do to truly validate this technology, the authors are aware of this and do reflect it in their conclusions. It is honest and fair, in its shortcomings and objectives.

I've written down my comments as I read the document, some comments were later addressed by the authors, I'll use (UPDATE) to highlight comments that were updated as I continued reading the document.

We thank the reviewer for their constructive and helpful feedback. We have answered the comments in detail below and updated the manuscript accordingly.

Bigger comments:

- It is maybe nitpicking but I would argue that the authors are using 'transmissibility' functions $T(\omega)$ to compute the virtual sensor, rather than transfer functions $H(\omega)$. A transfer function is a system property and independent of the load, it provides the relation between inputs and outputs, respectively forces and responses.

Opposingly, Transmissibility functions relate responses to other responses (even if they are different physical quantities, like strain and displacement) AND transmissibility functions depend on the localization of the forces.

In my reading, I would pose that the authors are using transmissibility functions. Fundamentally this doesn't change anything about the methods, but it might be relevant to consider for clarity to not use the term transfer function and the typical symbol H .

Thank you for this comments, which improved the correctness of the manuscript. The authors agree with the reviewer's comment on the terminology. Since we relate system outputs (displacements) to system outputs (strain), we are indeed using transmissibility functions. Even though this does not change the proposed methodology, we updated the terminology accordingly by replacing the words *transfer function* with *transmissibility function*. Since this occurs at multiple occasion, not all changes to the manuscript are included here. Furthermore, we adopt the proposed symbol T for the transmissibility function instead of H . Additionally we changed the axis description in Figure 5 (page 12 Figure 5):

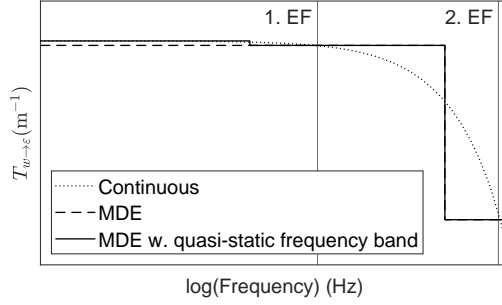


Figure 5: Displacement-to-strain [transmissibility function](#) $T_{w \rightarrow \epsilon}$ for different MDE approaches. All approaches are exact at the eigenfrequencies (EFs) but deviate from the continuous $T_{w \rightarrow \epsilon}$ between the EFs and below the 1. EF.

- **Interesting the authors do not introduce a yaw transformation at any point. This is somewhat surprising as the thrust load is aligned with the nacelle. Meaning that one could consider using a different transfer/transmissibility function in FA and SS. Don't get me wrong, there is beauty in simplicity not doing a yaw transformation.**

The authors agree that for a more refined FE model with a detailed rotor modelling and consideration of directional soil properties, the mode shapes / bending line would depend on the the yaw position. Both the tilt constant m and the transmissibility function $T_{w \rightarrow \epsilon}$ would then depend on the yaw angle. However, the FE model utilised in this proof of concept is axisymmetric, hence a yaw transformation is not necessary.

Furthermore, the directionality of the loading might necessitate a yaw transformation when different loading conditions are considered, which was not done here for the presented proof of concept.

We changed the manuscript accordingly (page 22 lines 435-440):

The values of $T_{w \rightarrow \epsilon}$ in this frequency range are therefore determined from the static bending line resulting from a horizontal force applied to the top of the tower, regardless of the direction. Furthermore, since the FE model is axisymmetric, any directional dependence of $T_{w \rightarrow \epsilon}$ is neglected here. More complex load assumptions and a more detailed FE model with a detailed rotor and directional soil model would result in direction-dependent tilt constants m and transmissibility functions $T_{w \rightarrow \epsilon}$.

and (page 26 lines 498-499):

More detailed modelling of the EOC-dependent excitation using multiple Ritz vectors and a continuous and direction-dependent transmissibility function might further improve the results and allow for an accurate strain estimation even for locations below the waterline.

- **Along with comment 2 I think the authors should give a way forward when wave loads become more present, they are a bit trickier than thrust load. So it would be appreciated if the authors spent a little bit of time discussing expected challenges with those. A similar comment applies to the accuracy of this method when looking at submerged sensors. Sensors below the ‘impact point’ of the waves might struggle more.**

(UPDATE: this is later mentioned in the Benefits and limitations, it is ok for me like this, but I also wouldn't mind a more extensive discussion)

We agree that the simplification regarding the load assumptions should be discussed a bit more extensively. We modified the following paragraph (page 26-27 lines 493-499):

Additionally, for this application, the rotor thrust is assumed to dominate the quasi-static response. However, a wind turbine experiences a variety of different loads in addition to the thrust load, caused, e.g., by waves or the eccentricity of the rotor load. Furthermore, the amplitude and therefore composition of the different loads can vary with different operational conditions (Skafte et al. 2017; Toftækær, Vestermark, and Jepsen 2023). A more detailed modelling of the EOC-dependent excitation using multiple Ritz vectors and a continuous and direction-dependent transmissibility function might further improve the results and allow for an accurate strain estimation even for locations below the waterline.

Minor comments:

1. “By design, this approach does not allow for compensation of alignment errors in the yaw direction.”

The use of “By design” implies that this was a deliberate choice to not compensate the yaw misalignment. While in reality it simply is not possible with the given setup, please remove the ‘by design’.

We changed the manuscript accordingly (page 10 line 226):

~~By design~~, This approach does not allow for compensation of alignment errors in the yaw direction.

2. Eq 15 – 17: In these equations it is IMO important to flag that the mode shape matrix is truncated (i.e. not all infinite modes are preserved). Moreover, it is also important to flag this is a Real mode shape matrix, else you would have complex time domain signals, while in theory the mode shape matrix is Complex.

These are subtle things but do impose some (albeit minor) restrictions/limitations to the method and it is relevant to flag these ‘shortcuts’.

The authors agree with the reviewer and changes the manuscript accordingly (page 10 lines 240-242):

Since not all infinite modes can be preserved in this step and high frequency modes can safely be disregarded for wind turbine tower fatigue assessment, the mode shape matrix Φ and the strain mode shape matrix θ are truncated to only include a finite number of real modes.

and (page 11 lines 257-258):

The number of modes considered in the MDE is limited by the number of input sensors and must therefore be truncated.

3. The authors ambition a virtual sensing strategy, and particularly focus their attention on the quasi static content. This is a fair ‘focus’ but one should be attentive that (1391) filtering everything beyond 1Hz is

a bit harsh, especially for smaller turbines I would not recommend to employ such a stringent lowpass filter if a full fatigue picture is to be preserved. It is ok within the context of this paper, but it should be put to the readers' attention that this is not offering the full picture. I'm particularly concerned about how this handles very sudden events, it might 'clip' the peaks of the strains and thus underestimate fatigue loads.

We added a paragraph to stress the limitation for reconstructing the full fatigue relevant response after low-pass filtering at 1 Hz (page 20 lines 408-413):

Both accelerations and strains were sampled at 25 Hz and low-pass filtered with a cutoff frequency of 1 Hz for evaluation, therefore including only the quasi-static frequency range and the first eigenmode. However, it should be noted that frequencies above 1 Hz, which are dominated by the rotor dynamics and higher tower eigenmodes, can also influence the fatigue loads in the support structure, for example by reducing the amplitude during sudden events like shut-down or start-ups. Despite this, the cutoff frequency is chosen as 1 Hz to focus on the performance in the quasi-static range.

4. **Table 8 Can the authors motivate the use of the S2MAC over the classic MAC (as was done in Table 2)? Is this motivated by the fact that MAC values tend to be very high for 'sparse' setups?**

Thank you for the comment. We agree that the motivation for using the S2MAC was not given in the submitted manuscript. We addressed this comment in the answer to RC1 (see above).

5. (l. 411) **"It is assumed for this proof of concept that the dominant load in the quasi-static frequencyrange is the thrust load on the rotor."**

– > to avoid ambiguity (dominant = \= only), do the authors mean it is the ONLY load? – > Or were waves considered?

The authors agree that the current phrasing is somewhat ambiguous. From the assumptions that the rotor thrust is the dominant load follows that we only consider the rotor thrust, as a simplification. We reformulated the sentence accordingly (page 22 lines 435):

It is assumed for this proof of concept that the dominant load in the quasi-static frequency range is the thrust load on the rotor. Therefore, as a simplification, only the thrust load is considered here.

6. (l 419) **The use of the high-pass filter implies that very low frequency loads, including the static loads, are ignored. How do the authors plan to handle the very low frequency variations in load (eg. Diurnal cycles) . Something that can be picked up readily with a strain gauge. Arguably you could say the method is no longer 'DC-capable'**

(UPDATE; the authors raise this sufficiently in their conclusion, OK for me)

The authors agree that with the considered measurement setup an estimation of the DC component is not possible. We would however argue, that this is due to the sensor's inability to actually measure the true DC-component without noise rather

than the method's inability to estimate the DC-component. We added a sentence (page 23 lines 447-448):

This drift is likely caused by measurement noise and not inherent to the method formulation. However for this measurement setup, the high-pass filtering limits the method's ability to estimate the DC-component of the strain.

7. **Figure 17, I understand the authors have some requirement to normalize the scale, but it would be clear if the first mode is clearly indicated (not by number but just as a line). What are the spikes to the right of the black box? And how does the black box relate to the first mode (e.g. 25%?)**

The authors agree that an indication of the first modal frequency is helpful and updated the figure accordingly. Furthermore, we applied a window using 30000 samples for the calculation of the spectrum to make the deviations better visible. The cause of the spikes below the first eigenfrequency is not known to the authors. However they appear in both the measured and estimated strain signal. To enhance visibility, we extended the zoom on the right side to also include some of the spikes (page 25 figure 18):

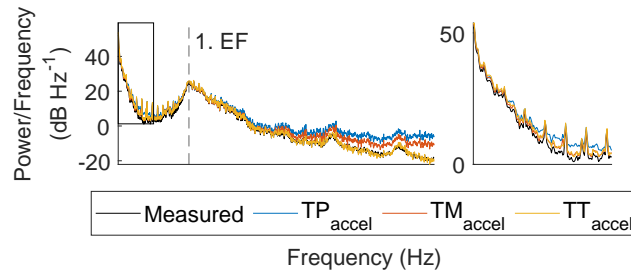


Figure 18: Spectrum of the strain estimation at TP at 35° using the accelerometers at the TT, TM and TP and a Hanning window of 30000 samples. The zoom shows the spectrum in frequencies up to 50 % of the first eigenfrequency. Due to the similarity of the estimated and measured signals, some signals might not be visible in the plot. For reasons of confidentiality, the frequencies cannot be disclosed.

Can the orientation of the turbine at that time (nacelle position/yaw) and wind speed be indicated for that record?

We added a sentence (page 23 lines 454-455):

The high-pass filtered results of the proposed method for strain estimation are shown as an example in Fig. 16 for the strain gauge position at 35° next to the 10 minute mean values of the yaw angle and the wind speed in Fig. 17.

and a figure (page 25 Figure 17):

8. **Figure 18, is the settling of the error in the beginning of the time series linked to the high pass frequency?**

This is true, the settling of the error in the beginning of the time series is indeed linked to the high pass frequency. There is a very low frequency error which is in the authors opinion caused by low frequency drift in the measured strain and acceleration. To exclude this in the further analysis, we decided to apply a high pass

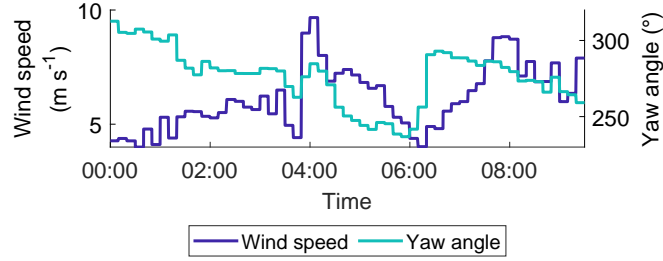


Figure 17: 10 minute mean values of the yaw angle and wind speed during the considered period.

filter with a very low frequency (0.1 mHz corresponds to 3.4 cycles in the considered period). Since we are particularly interested in the quasi-static component, a higher cutoff frequency would not be meaningful. However, this low cutoff frequency also causes a slow settling. For comparison find the same Figure but with a cutoff frequency of 1 mHz below. Additionally, we added the following sentence to the manuscript (page 23 lines 455-457):

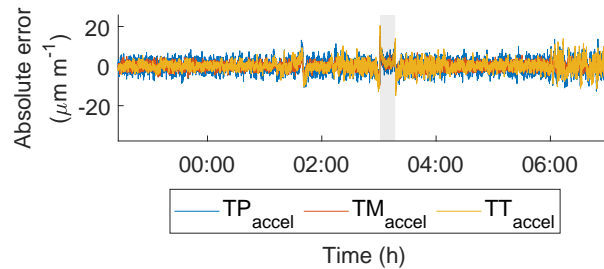


Figure 19: Error of the strain estimation at TP at 35° using the accelerometers at the TT, TM and TP. The shutdown event is highlighted in grey. (Figure not included in the manuscript)

The long duration of the settling is caused by the low cutoff frequency; a higher cutoff frequency would reduce the error during the first hour.

9. Table 10, is nice but is only shown for $m=3$, potentially the results are better/worse for $m=5$, it would be interesting to also see the results for this other slope that focuses more on the few large cycles in the record.

The results in Table 10 are actually shown for $m = 5$. For comparison find the results for the different slope $m = 3$ in the Table below. Δ DES are slightly lower for $m = 3$ but the conclusions remain unchanged. Therefore the authors decide to not change the manuscript.

References

- Skaftø, Anders et al. (2017). “Experimental study of strain prediction on wave induced structures using modal decomposition and quasi static Ritz vectors”. In: *Engineering Structures* 136, pp. 261–276. ISSN: 01410296. DOI: 10.1016/j.engstruct.2017.01.014.

Table 10: Comparison of Δ DES (%) (Table not included in the manuscript)

Acceleration level	Strain gauge orientation					
	35°	90°	155°	215°	275°	335°
TT	18.02	12.97	10.69	14.21	13.21	6.49
TM	11.80	9.70	12.17	8.20	10.24	7.91
TP	16.27	10.61	9.66	12.52	10.89	5.50

Toftækær, Johan F., Jonas T. Vestermark, and Michael Sandholm Jepsen (2023). “Uncertainty of Virtually Sensed Stress Ranges in Offshore Wind Support Structures”. In: *Volume 1: Offshore Technology*. American Society of Mechanical Engineers. ISBN: 978-0-7918-8683-0. DOI: 10.1115/OMAE2023-101045.

Community Comment 1

Thurn et al. (2026) present a model-based approach for virtual sensing of wind turbine support structures for full-field strain estimation using a single DC-capable accelerometer. The method is explicitly aimed at the quasi-static frequency range and is presented as enabling strain estimation while saving costs by relying solely on accelerations from a single accelerometer as input. The concept is technically interesting, but this central claim is stronger than the method formulation and validation evidence can support.

We thank the reviewer for their constructive and helpful feedback. We are aware of the assumptions and limitations pointed out by the commentator, namely the reliance on a sufficiently accurate structural model and on correct load assumption, and agree that they could be placed more prominently in the manuscript. This has in parts already been addressed in the answer to the reviewer's comments.

Generally, we would like to highlight that the novelty of the paper lies in the application of the combined tilt error compensation and double integration for strain estimation. As discussed in the paper, the tilt error compensated displacement can also serve as input to other methods if multiple sensor are available (Section 2.2 *Strain estimation from displacements*), but is shown here for one input sensor, as this is a relevant scenario for industrial application (page 5 lines 142-145):

In industrial applications, an instrumentation with multiple accelerometers on more than one turbine, the so-called fleet leader, is rarely done (Tsiapoki and Colomer Segura 2024). However, instrumenting all turbines within a wind farm with one biaxial and DC-capable accelerometer is becoming more common to capture turbine-specific vibration. Therefore, the method is applied here to acceleration measurements obtained from a single DC-capable accelerometer.

1. The proposed single-accelerometer virtual sensing is theoretically conditional on an accurate structural model, rather than being established solely from one acceleration input. [...]

The authors agree that a sufficiently accurate FE model is required for this method as is the case in any model-based strain estimation method. However, the scope of this contribution is not to answer whether a model calibration using one sensor position is possible but to show that strain estimation using measurement data from one sensor position is possible. Therefore, we applied the proposed method to measured data from an operating offshore wind turbine using the uncalibrated design FE model instead of a prior model update.

To further stress the necessity of a sufficiently accurate FE model in the manuscript, we modified the following sentences (page 1 lines 2-3):

*This paper introduces a novel model-based approach for virtual sensing of wind turbine support structures for full-field strain estimation using a single **biaxial**, DC-capable accelerometer and a sufficiently accurate structural model.*

and (page 1 lines 13-14):

The remaining errors can be attributed to modelling uncertainties and simplified load assumptions.

and (page 27 lines 515-517):

The approach requires a sufficiently accurate structural model and relies on load assumptions for quasi-static strain estimation.

It was validated using a laboratory experiment and using measurement data from an operating offshore wind turbine.

and (page 28 lines 541-542):

The proposed method should be applied to wind turbine measurement data spanning longer time periods to identify damaging operational conditions, with the goal of developing strategies for lifetime-oriented operation of wind turbines, potentially necessitating a continuous model update to account for structural changes like scour development or marine growth.

2. The low-frequency displacement estimation is governed by a prior kinematic assumption rather than by independent identification from measurement.[...]

The author agree with the statement that the low-frequency displacement estimation is governed by a prior kinematic assumption, which cannot be identified from measurements from a single accelerometer. As discussed in the Section *Benefits and limitations*, this state-of-the-art assumption (discussed in the introduction) is known to be a simplification as the turbine experiences a variety of different, EOC-dependent loads. We modified to manuscript to point out the load assumptions more prominently (page 12 lines 289-290):

As a simplification, only one additional Ritz vector — the static response to a horizontal force at the tower top representing the thrust load — is often used e.g. in Iliopoulos et al. 2017; Noppe et al. 2016.

and (page 26 line 479):

However, the approach necessitates a sufficiently accurate finite element model and correct load assumptions.

and (page 27 lines 515-517):

The approach requires a sufficiently accurate structural model and relies on load assumptions for quasi-static strain estimation.

It was validated using a laboratory experiment and using measurement data from an operating offshore wind turbine.

3. The validation evidence is too narrow to support a full-field reconstruc-

tion.[...]

The aim of the wind-turbine validation study was to test the method’s performance if both requirements, the accurate FE model and the known load, are known to be somewhat violated. Despite the violation the method showed convincingly accurate strain estimation results, especially in the quasi-static frequency range. Since this is the frequency range of interest, we decided to exclude frequencies above 1 Hz. In accordance with RC2, we modified the respective section (see RC2).

The current measurement setup unfortunately does not allow for validation of the strain estimation at other elevations. The authors are aware that this weakens the informative value of the validation study. It is planned to validate the method for more locations in the future. We modified the manuscript accordingly (page 26 lines 480-482):

Due to a limited dataset, the method could only be validated for one position, for which a strain estimation accuracy comparable to other publications could be achieved.

and (page 28 lines 532-533):

In future research, the proposed method should be validated against strain measurements on more target locations. The uncertainties in the strain estimation should be further investigated, particularly the influence of uncertain design parameters on the estimation accuracy.

References

- Iliopoulos, Alexandros et al. (2017). “Fatigue assessment of offshore wind turbines on monopile foundations using multi-band modal expansion // Fatigue assessment of offshore wind turbines on monopile foundations using multi-band modal expansion”. In: *Wind Energy* 20.8, pp. 1463–1479. ISSN: 10954244. DOI: 10.1002/we.2104.
- Noppe, N. et al. (2016). “Full load estimation of an offshore wind turbine based on SCADA and accelerometer data”. In: *Journal of Physics: Conference Series* 753, p. 072025. ISSN: 1742-6588. DOI: 10.1088/1742-6596/753/7/072025.
- Tsiapoki, Stavroula and Carles Colomer Segura (July 2024). “Seven Years SHM of Offshore Wind Turbine Foundations: Review, Experiences and Outlook”. en. In: *e-Journal of Nondestructive Testing* 29.7. ISSN: 1435-4934. DOI: 10.58286/29681. URL: <https://www.ndt.net/search/docs.php3?id=29681> (visited on 03/23/2026).