

Original Manuscript ID: wes-2025-1

Original Article Title: “Wind Turbine Gearbox Operation Monitoring Using High-Resolution Distributed Fiber Optic Sensing”

To: Wind Energy Science

Re: Response to reviewers

Dear Editor,

Thank you for allowing the resubmission of our manuscript, with an opportunity to address the reviewers' comments.

We appreciate the detailed and constructive comments and questions from the reviewers. We hope the revised manuscript addresses all the comments.

Best regards,

Linqing Luo on behalf of the authors

Reviewer#1, Comment # 1: Lines 13-17: I did not notice it during the first review, but the phrase “...captured millimeter-scale distributed strain profiles...” may be a little confusing, as this I think implies the strain being measured is on the order of millimeters, rather than being measured every few millimeters. That is the quantity being measured is related to strain (distance) and is measured at a fine spatial resolution (distance), so care is needed here. This is stated later in the paragraph with “...measured strain across all monitored locations ..., with data collected every 2.6 mm”. After rereading (including similar text in the Conclusions), I suggest the following wording for these 2 sentences “...we measured circumferential strain from planetary gear passage every 2.6 mm around the ring gear under different input torque levels. Our results show accurate identification of planet gear locations in real time and rotation speed (10.42 revolutions per minute) with a strong linear correlation ($RR^2=0.9997$) between applied torque and measured strain across all 2,500 measured locations.”

Author response: The authors appreciate the reviewer's comment and modify the manuscript accordingly.

We changed the text in the abstract from:

“we captured millimeter-scale distributed strain profiles of the ring gear from planetary gears passage under different input torque levels. Our results show accurate identification of planet gear locations in real time and rotation speed (10.42 revolutions per minute) and a strong linear correlation between applied torque and measured strain across all monitored locations ($R^2=0.9997$), with data collected every 2.6 mm.”

To

“we measured circumferential strain from planetary gear passage every 2.6 mm around the ring gear under different input torque levels. Our results show accurate identification of planet gear locations in real time and rotation speed (10.42 revolutions per minute), with a strong linear correlation ($R^2 = 0.9997$) between applied torque and measured strain across all 2,500 measured locations.”

We also modified the conclusion from:

“This study introduces a novel approach to measuring fully distributed strain profiles along a planetary gearbox using DFOS. By measuring circumferential strain every 2.6 mm around the ring gear under varying input torque, DFOS achieves high-resolution strain mapping with an accuracy of approximately 1 microstrain at a 12.5 Hz sampling rate, collecting around 2,500 data points simultaneously around the gearbox.”

To

“This study introduces a novel approach to measuring fully distributed strain profiles along a planetary gearbox using DFOS. By measuring circumferential strain every 2.6 mm around the ring gear under varying input torque, DFOS achieves high-resolution strain mapping with an accuracy of approximately 1 microstrain at a 12.5 Hz sampling rate, collecting around 2,500 data points simultaneously around the gearbox.”

Reviewer#1, Comment# 2: Lines 21-22: I understand the authors' perspective and recent changes here, but the authors' response is better stated than the current sentence. That is, the DFOS alone doesn't “enhance structural integrity and operational efficiency” – or really what “operational efficiency” means in this case, which I tend to interpret literally as power transmission efficiency. I recommend instead a sentence similar to that described in the authors' response, such as “The approach offers a scalable and practical solution for early fault detection and support of design validation, and when combined with modeling can lead to a more durable and optimized design.”

Author response: The authors appreciate the reviewer's comment and modify the manuscript accordingly.

This sentence has been modified from:

"The approach offers a scalable and practical solution for early fault detection, enhancing the ring gear's structural integrity and operational efficiency, addressing critical challenges in the wind energy sector."

To

"The approach offers a scalable and practical solution for early fault detection and support of design validation, and when combined with modeling can lead to a more durable and optimized design."

Reviewer#1, Comment # 3: Line 32: I appreciate the authors' recent change here. However, rather than quoting the number of replacements, which in the case of 2,000 per year is specific to the US market, it makes more sense to simply say "Approximately 1% to 2% of gearboxes are replaced annually (Haus et al., 2024)."

Author response: The authors appreciate the review's comment and modify the manuscript accordingly.

This sentence has been modified from:

"As of 2024, approximately 2,000 gearbox failures were reported annually."

To

"Approximately 1% to 2% of gearboxes are replaced annually."

Reviewer#1, Comment # 4: Line 63: The phrase "...measure strain continuously at millimeter-scale resolution around..." may seem contradictory or confusing as described above. I suggest simply "...measure strain every few millimeters around..."

Author response: The authors appreciate the review's comment and modify the manuscript accordingly.

This sentence has been modified from:

"To overcome these limitations, this study proposes using Distributed Fiber Optic Sensing (DFOS) to measure strain continuously at millimeter-scale resolution around the entire gearbox circumference."

To

"To overcome these limitations, this study proposes using Distributed Fiber Optic Sensing (DFOS) to measure strain every few millimeters around the entire gearbox circumference."

Reviewer#1, Comment # 5: Line 99: The phrase "...enabling continuous sensing at millimeter-scale resolution" may seem contradictory or confusing as described above. I suggest simply "...enabling sensing every few millimeters along the length of the optical fiber"

Author response: The authors appreciate the review's comment and modify the manuscript accordingly.

This sentence has been modified from:

"DFOS systems measure changes in light properties along an optical fiber, enabling continuous sensing at millimeter-scale resolution."

To

"DFOS systems measure changes in light properties along an optical fiber, enabling sensing every few millimeters along the length of the optical fiber."

Reviewer#1, Comment # 6: Line 169: I appreciate the authors' revisions; however, I might recommend a slight modification to "...caused by frictional heat generated by shearing of the oil between the gear teeth and in the bearings, while..." I ask the authors to please though check my interpretation of their statement for accuracy – I believe it's really a matter of stating the main cause(s) of temperature rise in a gearbox.

Author response: The authors appreciate the comment. The suggested modification has been added to the manuscript.

This sentence has been modified from:

"The darker red horizontal strips were attributed to rising temperatures caused by frictional heat generated between the gears, while the diagonal strips were linked to the mechanical strain from the meshing of the rotational gears."

To

"The darker red horizontal strips were attributed to rising temperatures caused by frictional heat generated by shearing the gear teeth when gears rotate, while the diagonal strips were linked to the mechanical strain from the meshing of the rotational gears."

Reviewer#1, Comment # 7: Line 238: I appreciate the authors' response regarding "ratcheting". Considering that, I recommend adding the provided short description to the term such as "...ratcheting (i.e. the progressive, incremental deformation that occurs in a material when it is subjected to cyclic loading), inadequate lubrication...".

Author response: The authors appreciate the comment. The suggested modification has been added to the manuscript.

"However, as the gearbox ages, deviations from this linearity may appear due to factors such as material fatigue, ratcheting (i.e. the progressive, incremental deformation that occurs in a material when it is subjected to cyclic loading), inadequate lubrication, or tooth wear, such as micropitting."

Reviewer#1, Comment # 8: Line 291: Similar to previous comments about the meaning of "operational efficiency", here I believe this refers to making O&M easier in general and reducing O&M costs. So, I recommend this be simplified to "...enabling proactive maintenance. This is particularly important for offshore wind farms, where reducing downtime and O&M costs is critical."

Author response: The authors appreciate the comment. The suggested modification has been added to the manuscript.

This sentence has been modified from:

"These features support comprehensive monitoring of the gearbox, enabling proactive maintenance and improving operational efficiency. This is particularly important for offshore wind farms, where reducing downtime and O&M costs is critical."

To

"These features support comprehensive monitoring of the gearbox, enabling proactive maintenance. This is particularly important for offshore wind farms, where reducing downtime and O&M costs is critical."

Reviewer#1, Comment #9: Lines 309-311: Similar to previous sentences, I think the phrase "...millimeter-scale spatial resolution and a strain measurement accuracy of approximately 1 microstrain at a sampling rate of 12.5 Hz, with approximately 2,500 data points collected simultaneously around the gearbox" can be more clearly stated as "...a strain measurement accuracy of approximately 1 microstrain at a sampling rate of 12.5 Hz simultaneously over approximately 2,500 measurement locations spaced every 2.6 mm around the gearbox circumference".

Author response: We appreciate the reviewer for the suggestion.

The manuscript has been modified from:

"This study introduces a novel approach to measuring fully distributed strain profiles along a planetary gearbox using DFOS. Leveraging OFDR technology, DFOS achieves millimeter-scale spatial resolution and a strain measurement accuracy of approximately 1 microstrain at a sampling rate of 12.5 Hz, with approximately 2,500 data points collected simultaneously around the gearbox."

To

"By measuring circumferential strain every 2.6 mm around the ring gear under varying input torque, DFOS achieves high-resolution strain mapping with an accuracy of approximately 1 microstrain at a 12.5 Hz sampling rate, collecting around 2,500 data points simultaneously around the gearbox."

Reviewer#1, Comment # 10: Line 325: Related to the changes in the Abstract, I think a more accurate phrase than "...optimizing tooth design for improved mechanical performance and refining gearbox control systems" is "...optimizing tooth design for improved reliability and refining turbine control systems".

Author response: We appreciate the reviewer for the suggestion.

The manuscript has been modified from:

"This capability can contribute to optimizing tooth design for improved mechanical performance and refining gearbox control systems."

To

"This capability can contribute to optimizing tooth design for improved reliability and refining turbine control systems."

Reviewer#1, Comment # 11: Line 292: Should be "the current DFOS system also has limitations."

Author response: We appreciate the reviewer for the suggestion. The "have" is modified to "has".
