Response to Referee Comment #1, wes-2021-69

Thank you for your positive feedback and constructive comments, which we consider very helpful and will improve the quality of our paper. All comments have been addressed below and the manuscript will be revised accordingly.

General comments:

The article discusses an interesting and useful application of fiber Bragg grating sensors for torque-measurement and planetary load-sharing characteristics in wind turbine gearboxes, including full—scale verification testing. In general, I like the article and idea and have made some specific comments. The following comments may be personal preference, but I think some of the detailed descriptions could be shortened, especially in sections 3 and 4, and figures omitted to produce a more succinct article. In a similar fashion, I'd recommend a greater focus or structuring on the two uses and results of this technology (torque measurement and load-sharing) rather than the two methods (peak-to-peak and coordinate transformation). The Conclusions I think could be better written to reflect some of the same things in the Abstract, which is well written. After having read the paper, I am wondering if the title should reflect a greater focus on "Methods", like "Methods for Measuring Input Torque of Wind Turbine Gearboxes Using Fiber Optical Strain Sensors"?

We agree with your suggestion that some figures can be omitted and some of the detailed descriptions shortened. In this regard, the manuscript will be revised as detailed below in the specific comments. However, we believe the current structure is more suitable to describe the proposed method while focusing on the torque measurement application, which is the article's main aim.

We have decided to keep the original title in the revised manuscript because in our opinion conveys the article's content. In previous versions of the article, we did have a similar title to the one you suggested, but we replaced it with the current one to make it less wordy.

Specific comments:

In 1 Introduction:

- The discussion of gearbox dynamics (p. 2 lines 36-43) feels a bit incomplete. The lack of understanding and the importance of gearbox dynamics are

indeed described, but what I think is implied (but left out) is the ability of this particular sensor to measure the dynamic characteristics of the torque at the frequencies necessary for such investigations – especially as described by the "second signal processing procedure" described in the Abstract and elsewhere. An easy way to improve this might be as easy as adding "dynamic" on to the sentence "It is, therefore, highly desirable to be able to measure the dynamic torque from the rotor acting on the gearbox accurately and reliably."

We agree with your recommendation and have added it to the revised version of the manuscript.

- It might be worth referencing recent work by Winergy on their Digital Gearbox (https://www.winergy-group.com/en/DigitalGearboxUseCase). If I understand correctly, this system is envisioned to be installed on operational wind turbines, rather than the more "one-off" systems (Guo and Rosinski) currently referenced. Maybe it is also important to state in the first sentence that "The traditional method to measure gearbox input torque…"

Thank you for this suggestion. We have added this reference as, indeed, it makes the argumentation to need a direct high-frequency torque measurement stronger.

- I think the sentence describing the main contributions of the paper could be rewritten – the existing sentence is a bit "mixed" I think. In summarizing what this paper is, I wrote the following 2 sentences. They are even a more condensed version of what appears in the Abstract, which I think it already well written: "This paper develops a method to measure input torque on wind turbine gearboxes from ring gear strain measured with optical fiber Bragg grating sensors and demonstrates it through full-scale dynamometer testing. The applicability of this method to also determine planet load-sharing characteristics is also explored."

We acknowledge your comment and will rephrase the contributions paragraph in the revised manuscript.

In 2 Background:

- In the first sentence of the Background, I think it would be better to say "The primary function of the gearbox is to transfer the power generated…"

We agree and will change "torque" to "power" in the revised manuscript.

- I think it might be worthwhile to say "The radial and tangential components of the mesh force, resulting from the helix angle in most gears, acting from the planets to…"

  Thank you for this suggestion. We have added a clarification in the revised manuscript to explicitly state that the pressure angle in the gears causes the radial and tangential components of the mesh force and that the helix angle causes the axial component.

- Figures 4 through 7 are all interesting but might be hard to see and don't necessarily add much to the paper. If any changes for brevity were needed, I believe any of these could be omitted. This is just an opinion, though. Maybe others find them very valuable. There are 23 total figures in the paper, which does seem like a large amount.

  We agree with your suggestion and have decided to omit Figures 4 and 6 in the revised manuscript. The interested reader can find Figure 4 in the reference provided and Figure 6 can be omitted without losing much information about the surface preparation before installing the fibers. However, we believe Figure 5 is helpful to understand the position of the sensor used for detecting the position of the planet carrier and the arrangement of the planet gears. We think Figure 7 offers a detailed view of a fiber grating after installation, which we hope some readers without practical experience using optical fiber sensors will find useful.

- I think the sentence in 2.4 should be "First, tests with a linearly increasing torque command."

  We have rephrased this sentence in the revised manuscript.

- It feels like a better title of section 2.5 might be "Data acquisition and vetting" more so than signal processing, as it feels like sections 3 and 4 are the "real" signal processing steps. This could just be a matter of opinion.

  We appreciate this comment and have reworded the section's title to "Data acquisition and signal pre-processing".

In 3 Torque Estimation:

- There are misspelled "toque" at 2 places in 3.2.

  Corrected in the revised manuscript.

- I think some condensing of figures between 11 – 15 could occur. This relates to my general comment that the results and discussion are a bit "method heavy" rather than "results-focused".

Figure 11 has been omitted in the revised manuscript.

In 4 Torque Estimation using a coordinate transformation

- Figures 17 – 20 are barely discussed. This relates to my general comment that the results and discussion are a bit "method heavy" rather than "results-focused".

  We believe these figures are helpful to understand the data manipulations presented in Section 4 and have decided to keep them.

In 5 Discussion:

- Figure 21 mis-spells "Weight" in the upper portion.

  Corrected in the revised manuscript.

- In terms of reducing figures as commented earlier, Figures 22 and 23 (right) are not discussed (or barely mentioned) in the text and are probably not needed.

  We believe these figures are the central element of the discussion/results section and have decided to keep them. We will add further clarification in the revised manuscript to emphasize their importance.

- I am left with the impression that the coordinate transformation consistently yields better results than the peak-to-peak method. Is this correct, or are there pros and cons to each? If the coordinate transfer method is indeed "better", then I have to wonder the value (in a journal article) of even discussing the peak-to-peak method any more than very briefly. This could be a matter of opinion as it really only relates to the overall length of the paper. Then again, having looked at things more – can load-sharing only be estimated with the peak-to-peak method?

  We appreciate this comment but believe the peak-to-peak procedure does have its pros and provides valuable information, mainly to validate advanced models and to enable the investigation of the load-sharing behavior between the planets. We will revise the discussion section to emphasize these points.

In 6 Conclusions:

- Fully summarizing key points I think could be very helpful. For example, instead of "…optical fiber strain sensors were used because of their advantages over more conventional electrical strain gauges", I would suggest to say something like "…optical fiber strain sensors were used because of their higher signal-to-noise ratio, immunity to electromagnetic interference, and faster installation compared to conventional electrical strain gauges" (or whatever the authors feel appropriate). I mention this because by the time I read the Conclusions I couldn't remember what the advantages are, so I had to search back through the document to find the explanation. In a similar fashion, I suggest better summarizing "The key findings obtained during the development of the proposed method to measure input torque have been discussed…together with recommendations for future work." Please state them here!

  We find this suggestion very valuable and will revise the Conclusions section to include explicitly the main advantages of fiber optical sensors, our study's key findings, and the suggestions for future work.

Thank you!