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WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "A novel rotor blade fatigue test setup with elliptical biaxial resonant excitation" *by* David Melcher et al.

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General comments:

This paper summarizes some key aspects of performing resonance fatigue tests of large wind turbine blades and the challenges faced when considering biaxial testing of these blades. The new work presented in the paper is applying a 3-dimensional harmonic model to evaluating and designing a fatigue test. However, the information disclosed regarding the implementation of the model is insufficient to enable another researcher to implement this approach directly. It is discussed that scaling the deflection mode shape is performed but not clear how this is accomplished in the biaxial case. Also, the tendency of a typical blade to not have perpendicular movement in the

flap and lead-lag directions due to the twist and relative frequencies is not addressed. While the actuators might be placed at angles, the blade motion might also be at an angle. Finally, no mention of incorporating the bend twist coupling in the model is addressed. Thus, the authors fail to address or take advantage of any potential benefits of the proposed 3D modelling approach – reserving that for future work. So, they have added complexity to the model while not demonstrating the superiority or even the difference between this approach when compared to performing the 2 simultaneous 2D harmonic models employed by Post et al. (Post 2016).

The use of spring elements is suggested – however, it is not obvious how such springs could be implemented effectively on a test since in this application they are subjected to reversing load cycles and most typical long displacement springs are either compression or tension, not both. Also withstanding the number of load cycles could be difficult. There is a brief discussion of the actuator displacements in a skew coordinate system which the reader assumes is used in the simulation (are they taken as displacement actuators rather than force actuators in the simulation?). It is not clear if the controls in the simulation assume contribution of each actuator in each direction. Since the change in angles of the actuators with displacement is neglected in the model it isn't clear what information is gained in this part of the analysis rather than just setting up the actuators to be perpendicular in the test.

Validation of the results was not conducted experimentally, nor were the results compared to previous simulation approaches in a rigorous way. A note that the resulting moments are within 3

Specific comments:

Page 3, 1 – 10. Reference is made to spring elements in the context of Post 2016. However, that report does not discuss the use of spring elements and instead uses the concept of negative virtual masses created with a hydraulic actuator to "remove" or carry mass from the blade and load frames. While the effect is similar in that both a spring or a negative virtual mass provide a force in the opposing and proportional to the displacement (and the equivalent spring contestant $k = -mA(2\pi f)^2$ for a virtual mass with negative value of m with displacement amplitude A and frequency f) this is not a discussion that is included in Post 2016. In that report the authors discuss using actuators to remove the effect of mass thus introduction negative virtual masses into the test design. Recommend rewriting these paragraphs to accurately paraphrase the Post 2016 report and then introduce the concept of springs and the associated math separately.

Page 4, lines 19-24. This part of the paragraph doesn't make sense to me and I am not sure what the authors are trying to convey. How does the blade oscillate in different directions? Are we talking about for a uniaxial test or a biaxial test? The sentence "The effect of an element on the eigenfrequency, which is not to be affected, shall be minimized." makes no sense to me. Each element of the blade or saddle, mass, virtual mass or spring will change the eigenfrequency. Also, it isn't clear how this leads to the following sentence that the elements (which elements? load elements?) must be perpendicular to the mode shape of the blade. And what is not to be affected? I take it that you are trying to say that the load element vectors should be perpendicular to the local movement of the blade in the other mode-shape so as not to impart energy in that direction? I think that this relationship might influence the phase angle of the test and relative amplitude of the directions, but it is unclear how it would significantly impact the frequency or mode shape. Also, the actuators will be of finite lengths so the angles will change throughout the test and thus will impart some virtual mass effect in the perpendicular direction. Finally, the skew of the actuators discussed on page 5 seems to go counter to the argument made here.

Page 5, line 7 and 8. The authors state "The phase angle needs to be controlled during the test therefore, the hydraulic actuators need to be attached at the same position along the blade length". What is the reason for this? It is not clear to this reviewer that this statement is true. While you do need to control the phase angle, this is controlled

with the relative phase of the excitation of each actuator. The blade will move in its mode shape and phase angle regardless of where each exciter is placed along the blade length.

Page 6, line 2-3. Neglecting the non-linear displacement seems like a large oversight given the 3D model. Are the actuators force or displacement actuators? Depending on how significant the angles are and recognizing that for an elliptical test with a 90 deg phase angle, the maximum force of the actuator occurs at maximum angle it seems like this could be a significant loss in test efficiency and thus greater than simulated forces would be required in reality to run the test. Suggest expanding this discussion and better highlighting the impacts of the assumptions made and how the forces are introduced in the simulation.

Page 6, line 29-30: For a biaxial test, isn't the objective to modify the flap and lead-lag frequencies to be the same (1:1 test) so it isn't clear why they are different to start with. Do you mean that you are taking the mean of the uniaxial test cases as the guess for starting the biaxial test case?

Page 7, lines 4-8: While the iteration on the damping is included it isn't clear how this process adjusts the masses and springs to achieve the same frequency in both mode shapes for the biaxial test. At some point you are optimizing for maximum frequency within the bending moment limits but again it isn't clear how this is performed for the biaxial test while keeping the frequency in the flap and lead-lag directions the same. A flow chart or itemized list of steps of the simulation and optimization process would be helpful to clarify when each step is performed and what the objective functions are for each step.

Page 8, lines 10-11: As mentioned previously this comparison of the model results to the transient test (and how the transient test was constructed) would be good to include here (or later when comparing results in which case don't mention it hear but do describe the other simulations that you compare the results to. Also a comparison to a simpler 2D harmonic approach would be very interesting as well and make this a stronger paper.

Page 8, line 17: spring elements are assumed to be massless? It is unclear how this would be accomplished. At a minimum a load frame is required to introduce the load to the blade from the spring and real springs do have mass so this seems like a gross oversimplification when designing the test.

Page 13 line 2: Allowing higher overloads outside of test regions is definitely something that would need to be taken on with care. Maybe if there is significantly more safety factor in that region of the blade it would be ok but it would be surprising if this is in generally reasonable. Same with reinforcing the blade in those regions – which will be difficult to do without creating stress concentrations.

Page 13, line 10. How did the optimizer end up exceeding one of the constraints? This needs to be explained since it should have found a solution within the constraints imposed, right? While this might be the "best" test solution for the blade, it isn't clear how the would have gone there without the user allowing it.

Technical corrections:

Page 2, line 14: "In order to safely proceed testing . . ." should be "In order to safely proceed with testing"

Page 3, line 3: Reference (Post, 2016) is not included in the list of references at the end of the paper.

Page 5, line 18: "Angle of attack" isn't a term that makes sense here since we generally think of that as an aerodynamic term. I think you mean the angle of incidence to the blade (or loadframe) – the alpha and beta in Figure 3. Suggest rewording this.

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