Dear Reviewer #2:

Thank you for your comments and suggestions. Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researchers. We have studied comments carefully and have made correction which we hope meet with approval. Now I response the comments with a point by point. Full details of the files are listed. We sincerely hope that you find our response and modifications satisfactory and that the manuscript is now acceptable for publication.

Responds to the reviewer's comments:

Comment 1:

In line 200-202, authors should describe the transfer-matrix method (TMM) to let the reader better understand.

Response 1:

Thank you very much for pointing out these problems, we will add the following to the revised paper in section 3.2.

Add content to the original lines 200-201: "To ensure the applicability of the model, modal analysis is carried out and compared with the transfer-matrix method (TMM) and the test data, taking the calculation of the flap-wise direction as an example, as shown in Table 1. The transfer matrix method is an approximate theoretical method used to calculate the natural frequencies and modes of systems with chain structures. The transfer matrix method separates the structure with inertia and elasticity and obtains the relationship between the discrete elements. The natural frequencies and modes of the systems can be solved according to the boundary conditions. The transfer matrix method belongs to the physical discrete method of continuous system, which is suitable for numerical solution of blade model."

Detailed description of TMM

For the cantilever beam model of blades, a typical element is composed of massless beam and concentrated mass. The deflection y, angle θ, bending moment M and shear force Q at each section are selected to form the state vector $\boldsymbol{Z}$. The force analysis of massless beam and concentrated mass is shown in **Fig. m+1**, where m_k is the concentrated mass, l_k is the length of the beam, EI_k is the bending stiffness of the beam, x_k is the span-wise coordinate of the section k, the subscript i represents the unit number, and the superscript L and R are used to distinguish the state vector of the left and right sections of the concentrated mass.

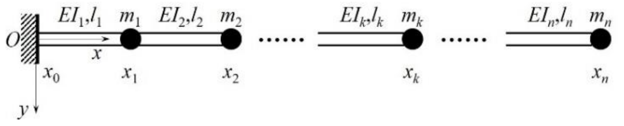

Fig. m Cantilever beam model of wind turbine blade

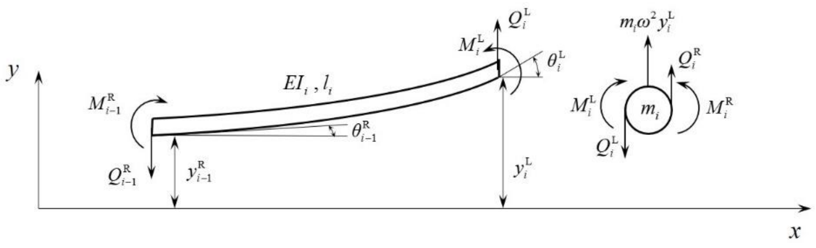

Fig. m+1 Force analysis diagram of massless beam and concentrated mass

The transfer matrix H_i^{B} of the state vector for the massless beam from left to right is

$$\begin{bmatrix} y \\ \theta \\ M \\ Q \end{bmatrix}_i^{\mathrm{L}} = \begin{bmatrix} 1 & l_i & \dfrac{l_i^2}{2EI_i} & -\dfrac{l_i^3}{6EI_i} \\ 0 & 1 & \dfrac{l_i}{EI_i} & -\dfrac{l_i^2}{2EI_i} \\ 0 & 0 & 1 & -l_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} y \\ \theta \\ M \\ Q \end{bmatrix}_{i-1}^{\mathrm{R}} \tag{n}$$

The transfer matrix H_i^{M} of the state vector for the concentrated mass from left to right is

$$\begin{bmatrix} y \\ \theta \\ M \\ Q \end{bmatrix}_i^{\mathrm{R}} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -m_i\omega^2 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} y \\ \theta \\ M \\ Q \end{bmatrix}_i^{\mathrm{L}} \tag{n+1}$$

Since the state vector of the left section of the massless beam i is the same as that of the right section of the concentrated mass i-1, and the mechanical state of the element is represented by the state vector of the right section of the concentrated mass, the transfer relationship of the state vector between adjacent elements is shown as $H_i = H_i^{\mathrm{M}} H_i^{\mathrm{B}}$. The transfer matrix of each element can be multiplied left to establish the total transfer matrix from the root to the tip as $H = H_n \cdots H_2 H_1$. Then, the transformation relationship between the root state vector $\boldsymbol{Z}_0^{\mathrm{R}}$ and the tip state vector $\boldsymbol{Z}_n^{\mathrm{R}}$ is shown as follows.

$$\begin{bmatrix} y \\ \theta \\ M \\ Q \end{bmatrix}_n^{\mathrm{R}} = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \\ h_{31} & h_{32} & h_{33} & h_{34} \\ h_{41} & h_{42} & h_{43} & h_{44} \end{bmatrix} \begin{bmatrix} y \\ \theta \\ M \\ Q \end{bmatrix}_0^{\mathrm{R}} \tag{n+2}$$

By substituting the boundary conditions at the root $y_0^{\mathrm{R}} = 0$, $\theta_0^{\mathrm{R}} = 0$ and the tip $M_n^{\mathrm{R}} = 0$, $Q_n^{\mathrm{R}} = 0$ into the **Eqs.** (n+2), the local matrix relationship is obtained as

$$\begin{bmatrix} h_{33} & h_{34} \\ h_{43} & h_{44} \end{bmatrix} \begin{bmatrix} M_0^{\mathrm{R}} \\ Q_0^{\mathrm{R}} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Since the deflection and shear force at the root are nonzero, according to the condition that the homogeneous linear equations have non-zero solutions, that is to say, the determinant of the coefficient matrix is zero, the following relation can be obtained

$$h_{33}h_{44} - h_{34}h_{43} = 0 \tag{n+3}$$

The coefficients of the total transfer matrix include the vibration frequency ω, and the modal frequencies of the blade can be obtained by solving the above equation.

Comment 2:

In section 4.3, effects of virtual masses on biaxial test are considered and described in Figure 11. Authors should add a figure to describe the biaxial trajectory of the blade when the virtual masses are translational. The comparison of the two results (translation and rotation of virtual masses) can better illustrate the effect of virtual masses on blade biaxial test.

Response 2:

Taking 94m blade as an example, two conditions of virtual masses translation and rotation are compared to obtain the motion trajectory of the blade during biaxial test under the simulation environment. The exciting parameters and the tuning masses are the same as those in Section 3.3 and Table 3.

For rotation, select mechanism dimension as $R = 4m, L = 4m$.

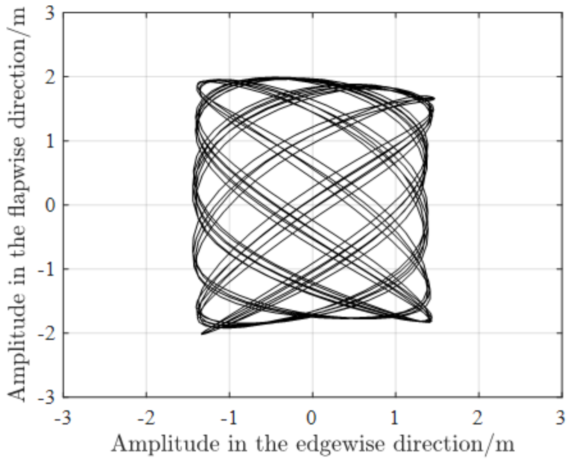

Fig. m+2 Motion trajectory at exciting point

For ideal translation, select mechanism dimension as $R = \infty, L = \infty$ to simulate the virtual masses acting in only one vibration direction.

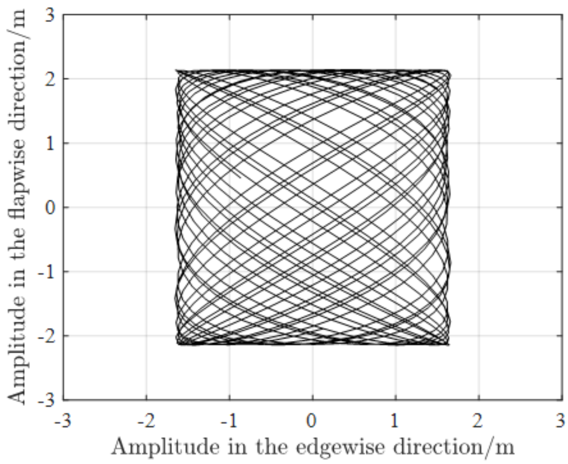

Fig. m+3 Motion trajectory at exciting point

When the exciting force amplitude keeps the same, the vibration amplitude is more stable and larger under the condition of virtual masses translation, and the motion trajectory is regular quadrilateral.

Comment 3:

What effect does the nonlinear effect introduced by virtual masses have on the actual test? Authors need to add further explanations.

Response 3:

As mentioned in the paper, the nonlinear effects during the blade fatigue testing are mainly due to the rotation of the virtual masses while the rotation radius and blade amplitude will affect the resonance frequency of the blade. According to the amplitude-frequency characteristic curve, when the excitation frequency deviates from the resonance region, the amplitude of the blade will drop sharply, resulting in the waste of energy of the fatigue test equipment. At the same time, specific areas of the blade are not sufficiently loaded to meet the certification requirements, but further loading requires additional energy consumption. Therefore, in view of the nonlinear effects introduced by virtual masses, it is necessary to improve the rapidity and accuracy of resonance frequency search during actual test.

Comment 4:

In Figure 8(d), there is (a) in this figure. Please check.

Response 4:

Thank you for your careful examination. The (a) in Fig. 8(d) is redundant and should be eliminated.

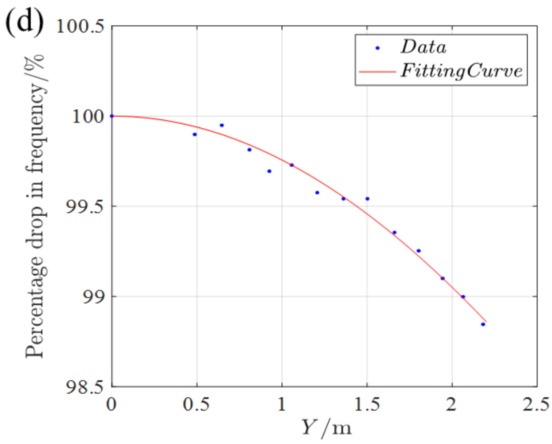

Figure 8: (d) 94m blade in edge-wise direction

We will make corresponding changes in the future revised paper and try our best to improve the manuscript. These changes will not influence the content and framework of the paper. Please do not hesitate to contact us if there are any questions. We appreciate for your hard work, and hope that the correction will meet with approval. Once again, thank you very much for your comments and suggestions.

Yours sincerely,
Jinlei Shi