Study Committee B2

Overhead Lines

10303_2022

Experimental Study of Dynamic Bending Stiffness of Typical Overhead Conductor with Formed Wires

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Motivation

Overhead conductor is made of a set of metal single wires. In the actual lines, the conductor is almost always subject to aeolian vibration. The long-term vibration can lead to fatigue failure of the conductor and even the line breakage. The dynamic bending stiffness of conductor has an important influence on the deformation and fatigue characteristics of conductor near the clamp when aeolian vibration occurs. It depends on the friction between the adjacent single wires of the conductor. There is nonlinear slip between single wires and layers during conductor vibration, which makes the calculation of bending stiffness very complicated. Under the condition of no slip, the maximum stiffness of the conductor can be calculated. And when the friction between strands is not considered, it can achieve the minimum bending stiffness. However, there are tens or even hundreds of times difference between the maximum bending stiffness and the minimum value of the conductor. For conductors with formed wires, the section of some single wires may be irregular, so the calculation becomes more difficult. Therefore, the bending stiffness evaluation of conductors with formed wires base on experiment is a problem worthy of study.

Method/Approach

Through the aeolian vibration model of conductor,the calculation formula of dynamic bending strain at the outlet of clamp can be derived, which is shown as follows,

$$\varepsilon_{max} = \frac{\sqrt{2}Dy_{max}}{4}\sqrt{H}\sqrt{H-\frac{p^2}{2}} \quad (1)$$

In the equation (1), ε_{max} is the maximum dynamic bending strain of the conductor at the outlet of the clamp ; *D* is the conductor diameter (m); *H* is an intermediate variable, which can be described as follows,

$$H = \sqrt{q^4 + p^4/4} \quad (2)$$

$$p^2 = T/EI \quad (3)$$

$$q^4 = m\omega^2/EI \quad (4)$$

where *T* is the conductor tension (N), *EI* is the global dynamic bending stiffness of the conductor (N.m2), *m* is the conductor mass per unit length (kg/m), *ω* is the circular frequency of conductor vibration (rad). The dynamic bending stiffness can be calculated by the combination of equation (1), a series of structure parameters of conductor and test data.

Objects of investigation

The object of this investigation is to obtain the method of the dynamic bending stiffness evaluation of this kind of conductor.

Experimental setup & test results

The vibration shaker is arranged at one end of the test bench, which can output sinusoidal signal to excite the conductor and simulate the aeolian vibration of the conductor. The displacement sensor is arranged near the other end. The vibration waveform of the conductor will change with the changing of vibration frequency. It is necessary to move the sensor to ensure that it can measure the antinode amplitude of the first free half wave of the conductor. The strain sensors are pasted on the outermost strand at the outlet of the square-faced bushing.

The conductor is excited with different frequencies and amplitudes. When the conductor vibrates stably and the value of strains (0-peak) at the outlet of square-faced bushing is close to 70 με, 140 με, 210 με, 280 με and 350 με, the actual strain value and its corresponding amplitudes of the conductor are recorded.

Discussion

For the convenience of discussion, we define the ratio of the calculated value of dynamic bending stiffness to the maximum one as the stiffness coefficient. The stiffness coefficient can be calculated by the test data, but the law of the variation of the conductor stiffness coefficient with the amplitude is not obvious.

The average values of conductor stiffness coefficient have a linear relationship with vibration frequency. By fitting the stiffness coefficient of conductor at different frequencies, a linear function relationship between stiffness coefficient and frequency can be obtained. Using this linear function, the approximate stiffness coefficient of conductor at different frequencies can be calculated, and then we can obtain the dynamic bending stiffness of conductor.

Substitute the calculated stiffness value into equation (1), and comparing the result with the measured one. The comparison show that the maximum relative error is less than 12%.

Conclusion

Use the method mentioned in this study to determine the dynamic bending stiffness of the conductor with formed wires can ensure a certain accuracy when performing fatigue test or calculating the aeolian vibration of the conductor. And it can be used as a reference for other conductors, including other types of conductors with formed wires and the conventional overhead conductors. It is of great significance for the aeolian vibration numerical simulation and the fatigue test of conductors.

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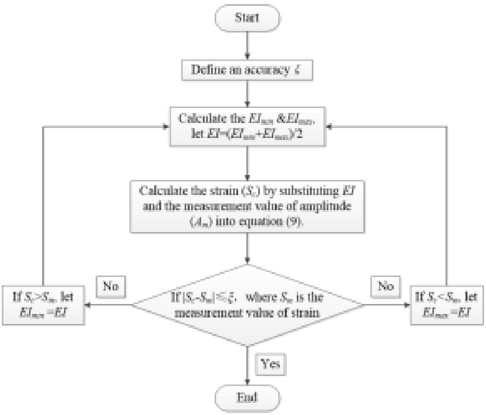
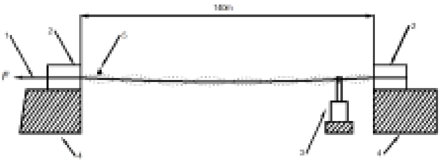
Process of bending stiffness solution

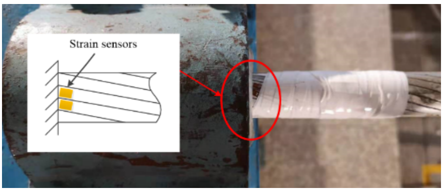


Test bench



1 is constant tension device, 2 is rigid square-faced bushing, 3 is vibration shaker, 4 is the foundation, 5 is displacement sensor.

Strain sensors on the conductor

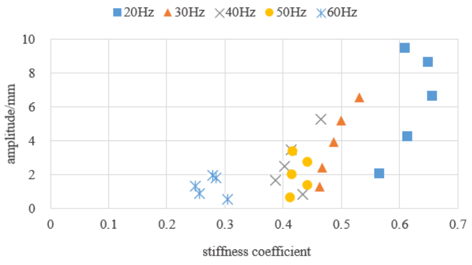


The estimation of maximum dynamic bending stiffness

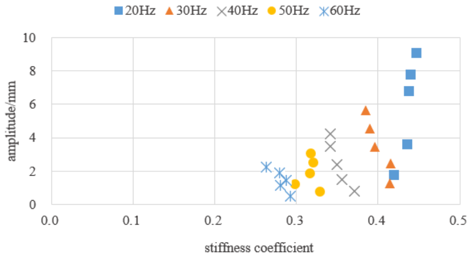
$$EI_e = E_c I_c$$

where EI_e is the estimated value of dynamic bending stiffness (N.m[2]), E_c is the comprehensive elastic modulus of the conductor (Pa), I_c is the equivalent area moment of inertia of conductor (m[4]).

The stiffness coefficient calculated by the test data



(a)



(b)

(c)

(a), (b) and (c) are the stiffness coefficients under the condition of 18.4%RTS, 22.4% RTS and 26.7% RTS respectively.

According to (a) ~ (c), the distribution of the stiffness coefficient in the coordinate system tends to be concentrated first and then dispersed with the increase of tension. However, the change of stiffness coefficient with vibration frequency has a clear regularity. The stiffness coefficient of conductor under the same frequency is relatively concentrated.

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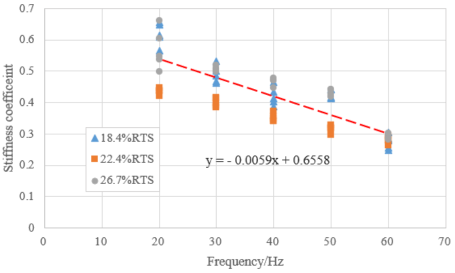
Fitting of the stiffness coefficient

The average values of conductor stiffness coefficient have a linear relationship with vibration frequency, and the conductor stiffness coefficient gradually decreases with the increase of vibration frequency. By fitting the stiffness coefficient of conductor at different frequencies, a linear function relationship between stiffness coefficient and frequency is obtained. Using this linear function, the approximate stiffness coefficient of conductor at different frequencies can be calculated, and then we can obtain the dynamic bending stiffness of conductor.



Validation of the estimation method

By using the functional relationship described in the figure above, the dynamic bending stiffness of the conductor at each frequency can be obtained. Substitute the calculated stiffness value into equation (1), and compared the strain result with the measured one. The comparison show that the maximum relative error is less than 12%.