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Study on Equivalent Bending Stiffness of 1250mm² Large Section Conductor

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Abstract. Current calculation method of tension stringing construction does not include the influence of bending stiffness of conductor. There are relative errors between the calculated results and the measured results of a series of important parameters, such as conductor wiring length, maximum pull tension, sag between the various sections, which have adverse effects on construction safety. Aiming at 8×JL1/G2A-1250/100 conductor in UHV engineering, the simulation model was established by the finite element software for the equivalent bending stiffness of the large section conductor. The coupled displacement constraints were applied to the whole section of the two ends of conductor. Changing the vertical displacement of one end section, the conductors with different lengths were simulated by the explicit kinetic method considered the contact friction between wire strands. Combined with the mechanical cantilever beam model, the equivalent bending stiffness of the conductor under different working conditions was obtained. By analyzing the curves of the equivalent bending stiffness of the conductor, the equivalent bending stiffness of the long conductor suitable for engineering calculation is obtained. The research result provides key parameter for the accurate tension control in tension stringing construction of UHV project.

1. Introduction

Current calculation method of tension stringing construction is based on the parabola method formula of fully flexible suspension cable, which does not include the influence of bending stiffness of conductor [1]. It has been pointed out in the literature that there is a relative error between the calculated results and the measured results of a series of important parameters such as conductor wiring length, maximum pull tension, sag between the various sections of the large section conductor in tension stringing construction with large height difference and large span, and the main cause of the error is the bending stiffness of the conductor [2-4]. Therefore, it is necessary to study the bending stiffness of the large section conductor.

In this paper, the finite element simulation method was used to calculate the curves of the equivalent bending stiffness of the conductor, and the equivalent bending stiffness of the 1250mm² large section conductor was studied, which provides a more accurate tension control basis for tension stringing construction of UHV project.



2. Structural Model of 1250mm² Large Section Conductor

2.1. Establishment of Three-Dimensional Model

The type of conductor is 8×JL1/G2A-1250/100 conductor. Three dimensional software is used to build the geometric models of steel wire and aluminum wire respectively, and the three-dimensional model of conductor is obtained through assembly [5-6], as shown in figure 1. Set different conductor lengths for simulation calculation.

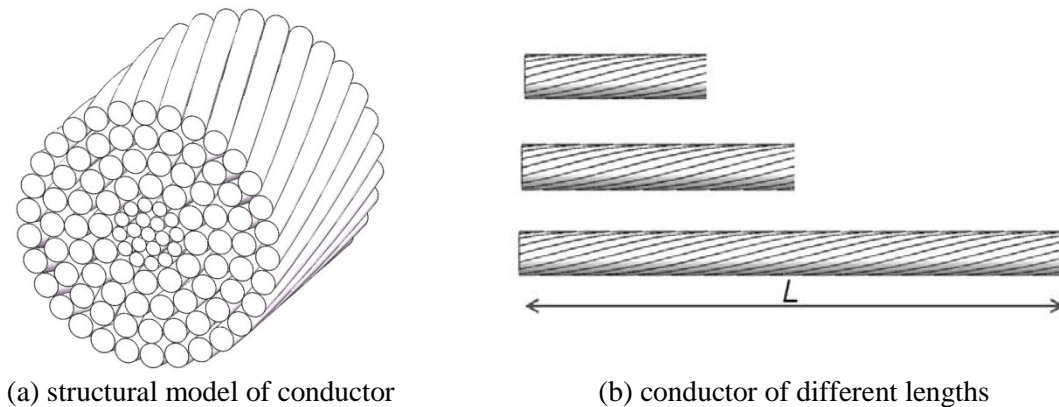


Figure 1. Three-dimensional model of conductor.

The model built using three dimensional software is imported into finite element simulation software for finite element analysis. The conductor model is built with 3D Deformable Solid, the model element type is C3D8R, and the number of model elements is 22400.

2.2. Material Properties

The 1250mm² large section conductor is composed of steel wire and aluminum wire. The steel wire and aluminum wire are simplified as isotropic materials, and the material parameters are shown in table 1.

Table 1. Material parameters of 1250mm² large section conductor.

Material	Modulus of elasticity (GPa)	Poisson ratio	Density (kg/m ³)
Steel wire	110	0.31	7800
Aluminum wire	70	0.33	2700

3. Simulation of Bending Stiffness

3.1. Loading Mode and Boundary Conditions

Coupled displacement constraints are applied to the whole section of the two ends of conductor. One end section of the conductor is constrained to a reference point where applying a displacement constraint. The other end section of the conductor is constrained to a reference point where applying a displacement constraint in the vertical direction. In the contact properties of the model, the normal behavior uses general contact type, and the tangential behavior uses penalty function equation with a friction coefficient of 0.35 [7-10].

According to the formula of deflection curve of uniform beam:

$$y_m = -\frac{PL^3}{3EI} \quad (1)$$

In the formula:

EI – Equivalent bending stiffness of conductor, N·m²;

P – The vertical force, N;

L – The length of the conductor, mm;

y_m – The maximum vertical displacement, mm.

Thus:

$$EI = -\frac{PL^3}{3y_m} \quad (2)$$

By calculating the relationship between maximum vertical displacement y_m and vertical load P with finite element method, the curves of equivalent bending stiffness EI is analyzed, and the equivalent bending stiffness of the conductor is obtained.

3.2. Analysis of Simulation Results

Five different lengths of conductors, 400 mm, 500 mm, 600 mm, 700 mm and 800 mm, are simulated respectively. The conductor model of displacement loading mode is established, and different vertical displacements are applied respectively.

Definition of "proportional displacement": the ratio of the maximum vertical displacement y_m at the end section of the conductor to the length of the conductor L , $y_{mL} = y_m/L$.

Taking the conductor with length of $L=800\text{mm}$ as an example, when vertical displacement $y_m=5\text{mm}$, 10mm , 15mm and 20mm are applied respectively, proportional displacement $y_{mL}=0.00625$, 0.0125 , 0.01875 and 0.025 . The stress distribution and stress time history curve of the conductor model are obtained by simulation.

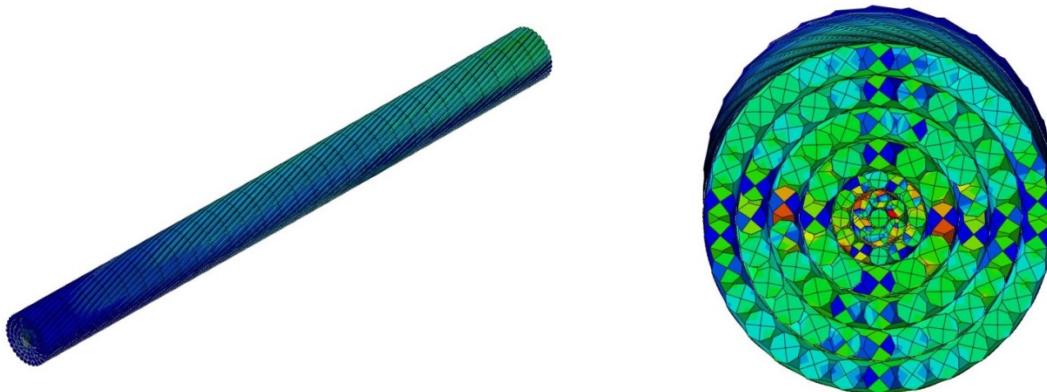


Figure 2. Stress distribution of the conductor model under vertical displacement condition ($L=600\text{mm}$).

According to the stress distribution of model, under the condition of applying vertical displacement, due to the vertical force, the extrusion pressure is generated between the wire strands of each layer of the conductor, and the contact stress of the wire strands in the vertical direction is large, as shown in figure 3.

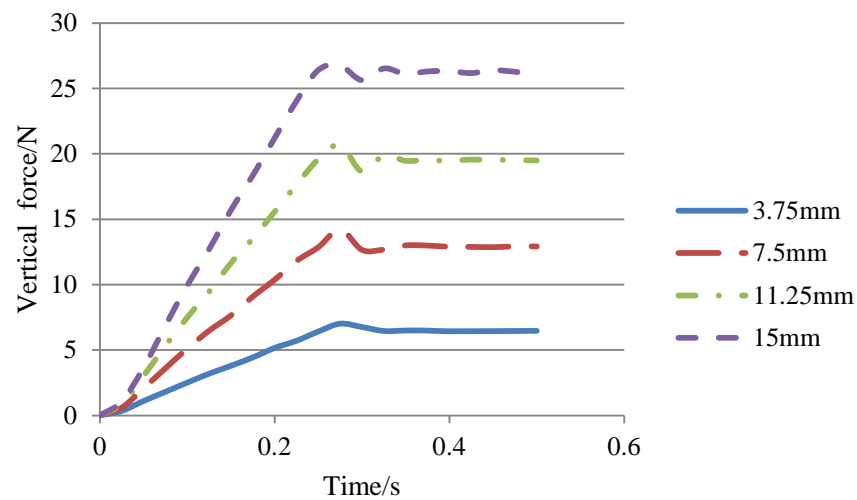


Figure 3. Curves of vertical force versus time under vertical displacement condition ($L=600\text{mm}$).

According to the simulation results, the curves of vertical force and equivalent bending stiffness varying with proportional displacement are drawn under conditions of different conductor lengths, as shown in figure 4 and figure 5.

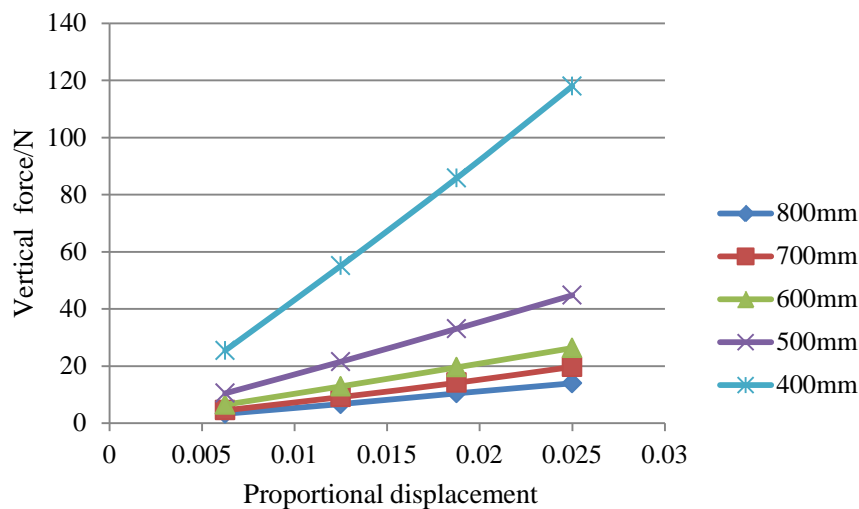


Figure 4. Curves of vertical force versus proportional displacement of conductors with different lengths.

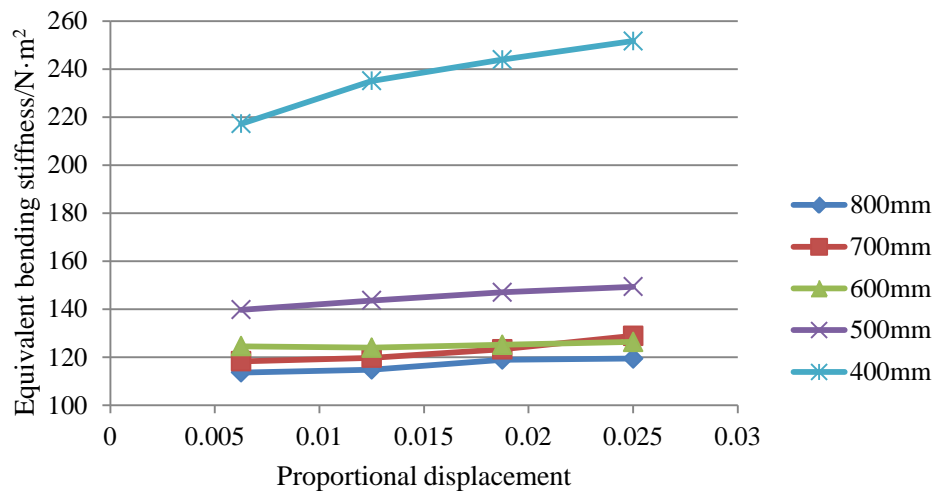


Figure 5. Curves of equivalent bending stiffness versus proportional displacement of conductors with different lengths.

It can be seen from the curves of vertical force versus proportional displacement of conductors with different lengths, with the increase of vertical displacement, the vertical force on the conductor increases linearly. When the vertical displacement is given, the vertical force on the conductor decreases with the increase of the length of the conductor. The larger the length is, the smaller the relative bending deformation is and the smaller the vertical force is.

It can be seen from the curves of equivalent bending stiffness versus proportional displacement of conductors with different lengths, when the length of the conductor is given, with the increase of proportional displacement, the bending deformation of the conductor increases, and the contact friction between the wire strands increases, which results in a relatively small increment of bending deformation, thus the equivalent bending stiffness of the conductor increases, however, the increase in equivalent bending stiffness value is small by numerical simulation.

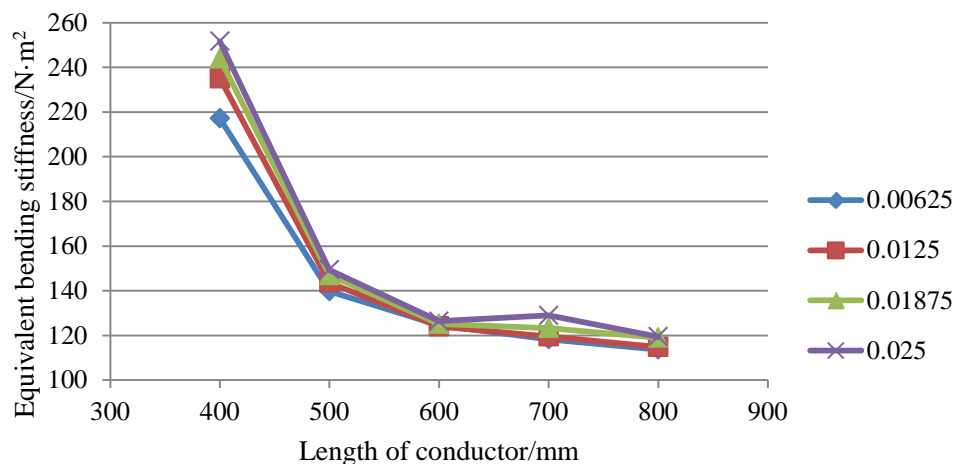


Figure 6. Curves of equivalent bending stiffness versus length of conductor under conditions of different proportional displacement.

As shown in figure 6, the equivalent bending stiffness of the conductor decreases with the increase of the length of the conductor, and the equivalent bending stiffness tends to reach the limit value,

which can be used as the equivalent bending stiffness of the long conductor. Therefore, the equivalent bending stiffness of the conductor is $113.678 \text{ N}\cdot\text{m}^2$.

4. Conclusion

In this paper, the equivalent bending stiffness of conductor with different lengths is simulated by setting vertical displacement of end section of the conductor, and the conclusions are as follows:

(1) When the length of the conductor is given, the vertical force on the conductor increases with the increase of the vertical displacement. The increase of bending deformation leads to the increase of the contact friction between wire strands, and thus the equivalent bending stiffness of conductors increases.

(2) When the vertical displacement is given, the longer the conductor length is, the smaller the relative bending deformation is, so the smaller the vertical force is. The equivalent bending stiffness of the conductor decreases with the increase of the length of the conductor and eventually reaches the limit value. The limit value is $113.678 \text{ N}\cdot\text{m}^2$, which is used as the equivalent bending stiffness of the long conductor.

5. Acknowledgments

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6. Reference

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