Dynamic Modeling of Braided Wire Rope Maintenance System

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Abstract. Aiming at the complicated condition of the wire rope maintenance system, the dynamics modeling rules of the braided wire rope maintenance system were proposed. The modeling of the system was simplified to the wire rope winding guide wheel model construction, and the main parameters such as bushing force and contact force were determined. In this paper, using ADAMS's secondary development function macro program, using bushing force connection, adding contact force between the wire rope and the pulley, creating a wire rope wheel winding model, realizing dynamic modeling of the braided wire rope maintenance system, for wire rope maintenance, The line dynamics simulation laid the foundation.

1. Introduction
Braided wire rope has good torsion resistance and is widely used in the field of power network construction. Because of the harsh field working environment of the wire rope, the development of the maintenance system for steel wire rope is carried out in the first time. However, the system is not perfect, so it is necessary to build the dynamic modeling of the maintenance system for the wire rope, and lay the foundation for the following system dynamic simulation and the structure optimization.

A series of studies have been carried out on domestic and foreign scholars on rope dynamics modeling and simulation. DZ Cao established a flexible multi-body dynamics model of the rope by using the cable unit formed based on the absolute node coordinates[1]. XingFu MA took the elevator wire rope as the research object and established the simulation model of the elevator wire rope system by using the ADAMS macro program[2]. LI Junwen successfully used the secondary development function macro command of ADAMS to successfully establish a coupling system model of impact drill wire rope and impact drill[3].

The dynamics modeling of wire ropes at home and abroad is mainly for a single system, and the multi-module dynamics modeling for wire rope maintenance systems has not been studied. Therefore, this paper discusses the simplified modeling rules of the system, and studies the dynamics modeling of the wire rope maintenance system based on the flexible body modeling theory and the ADAMS macro language.

2. Analysis of woven wire rope maintenance system and its working conditions
The overall structure of the woven wire rope maintenance system developed by the research team is shown in Figure 1. The system includes cleaning module, detection module and maintenance module.
The dry brush device of the cleaning module mainly uses the wire brush set to initially sweep the surface of the wire rope, and then uses the warm water soaking device to soften and clean the deep oil stains of the wire rope, and complete the thorough cleaning of the wire rope through the high pressure water jet and the dehumidifying device. In order to ensure a certain soaking time of the wire rope in the warm water soaking device, a multi-winding wheel device as shown in Fig. 2 was designed. The detection module mainly comprises an online tension detecting device for the wire rope and a broken wire detecting device, which realizes the pulling force and the broken wire detection of the wire rope. The maintenance module consists of a hot dip unit and a drain unit. Similar to the warm water soaking device, in order to ensure a certain wire rope immersion time, a multi-wound wire rope immersion device as shown in Fig. 2 is also designed. In addition, a tension take-up device and a traction take-up device are respectively provided at the beginning and the end of the maintenance line to provide the operating power of the entire maintenance system and complete the winding work of the wire rope.

In view of the operation of the wire rope maintenance system, the wire rope is mainly driven through the pulley under the action of the traction device, and the multi winding wheel structure is set up in the soaking device and the hot oil soaking device. The wire rope winding pulley should be the main structure of the dynamic modeling of the system.

**Figure 1 layout of wire rope maintenance system**

1- dry brush device 2- immersion device 3- water jet cleaning device 4-dehumidifier 5-broken wire detection device 6- tensile testing device 7- oil immersion device 8- leach oil device 9- take-up device 10- wire laying device

**Figure 2 model of winding roller of wire rope**

3. Dynamic modeling of braided wire rope maintenance system based on ADAMS macro language

In this paper, the woven wire rope YS28-16×25Fi commonly used in power grid construction engineering is taken as an example to carry out the dynamic modeling of the woven wire rope maintenance system.

3.1. The model construction rules of wire rope maintenance system

The characteristics of the wire rope maintenance system are analyzed. When the wire rope is turned through the pulley, the former pulley pulling force is the pulling force of the rear end of the wire, thus the wire rope maintenance system can be simplified as a wire rope winding model. In this paper, a flexible body wire rope model is established based on the modeling method of ADAMS macro language, and the whole wire rope is discrete to a number of small cylindrical rigid bodies. The bushing force is added between the two adjacent small cylinders to complete the wire rope modeling, and the contact force between the wire rope and the guide wheel is added to complete the wire rope
winding model. This modeling method can simulate the winding relationship between the wire rope and the pulley. Under the reasonable setting of the relevant parameters of the shaft sleeve force and contact force, the dynamic characteristics of the wire rope and the dynamic characteristics of the collision contact between the wire rope and the pulley can be simulated.

3.2. The important parameter determination of wire rope model

3.2.1. The determination of the geometric parameters of the micro section of a wire rope
Braided steel wire rope YS28-16×25Fi, its equivalent diameter is \( d = 22 \) mm. Pulley diameter \( D_{\text{wheel}} = 560 \) mm. From Figure 3, formulas (3.1) can be obtained, so that the length of the micro section of the wire rope can be obtained by \( l_{AC} = 50.92 \) mm. The rotation angle of the wire ropes around the pulley is 10 degrees.

![Figure 3 Schematic diagram of wire rope micro-parameter calculation](image)

\[
I_{AC} = 2l_{AB} = 2l_{OB} \tan \frac{\alpha}{2}
\]

(3.1)

where, \( L_{OD} \) is the radius of the pulley and \( l_{DB} \) is the equivalent radius of the wire rope.

3.2.2. Determination of the parameters related to the bushing force
For rope body modeling, it is necessary to add the shaft sleeve force between the small cylindrical rigid bodies, and determine the stiffness coefficient and damping coefficient of the axle sleeve. The braided steel wire rope YS28-16×25Fi is selected according to its material 45 steel and its damping coefficient is 10N s/mm\(^4\). The main characteristics are the elastic deformation of the wire rope along the length direction in the operation of the maintenance system. The main characteristic of the wire rope is the elastic deformation, and the coefficient of rigidity is mainly the coefficient of tension. It can be obtained from equations (3.2) and (3.3)

\[
K_1 = \frac{E A}{L} = \pi d^2 \beta E_{45}/4L = 7.46 \times 10^5 \text{N/m.}
\]

(3.2)

\[
E = \beta E_{45}
\]

(3.3)

where, \( K_1 \) is the tensile coefficient; \( E \) is the elastic modulus of the wire rope; \( A \) is the cross section area of the wire rope; \( L \) is the length of the wire rope micro segment; \( \beta \) is the coefficient, \( \beta = 0.5 \); \( E_{45} \) is the modulus of elasticity of the 45 steel, \( E_{45} = 2.0 \times 10^5 \text{MPa.} \)

3.2.3. Determination of related parameters of contact force
Modeling of wire rope maintenance system requires adding contact force between wire rope and pulley, resulting in twining relationship between wire rope and pulley. The elastic modulus of wire rope has been obtained by formula (3.3). The rigid contact coefficient of contact force can be obtained by formula (3.4):

\[
K_2 = 3.11 \times 10^3 \text{N/m.}
\]

The contact damping coefficient is 10N s/mm\(^4\).
where, $E_1$ is elastic modulus of steel wire rope; $E_2$ is the elastic modulus of pulley, $E_2=E_{45}$. $v_1$, $v_2$ is the poisson ratio of the two, $v_1=v_2=0.269$; $R_1$, $R_2$ is the radius of both.

3.3. Dynamic modeling of wire rope maintenance system

Based on the determination of the parameters mentioned above, a wire rope maintenance system with YS28-16×25Fi as example is modeled. The modeling steps are as follows:

(1) creating a small cylindrical geometry model of a wire rope

The number of micro segments of the model is 200. The length and diameter of the wire rope small cylinder have been determined in section 3.2.1. The geometric model of wire rope micro section is established by using ADAMS Modeling Toolbox.

(2) Creating geometric model of wire rope

Through the ADAMS macro program to complete the wire rope micro column replication and movement. The key macro programs are as follows:

```fortran
defaults model model_name=.shengzi   !(shengzi is the name of the wire rope model) ...
while condition=(ip<200)         ! (200 is the number of wire rope micro segments)
!set part
part copy part=.shengzi.part_1 new_part=(unique_name("part"))     !(Copying work)
...
move object part_name = (eval(".shengzi.part_"//(ip+1))) &
c1=0 c2=50.92 c3=0 &
cspart_name = (eval(".shengzi.part_"//(ip)))                     !(Moving work)
...
```

(3) Apply the sleeve force to create the wire rope model

The bushing force is added between the adjacent micro-broken cylinders, and the wire rope model is completed as shown in Fig. 4. The correlation coefficient of the bushing force is obtained in 3.2.2, and part of the bushing force add macro is as follows:

```fortran
defaults model model_name=.shengzi
...
while condition=(ip<200)
...
for create element_like bushing &
bushing_name = (eval(".shengzi.bushing_"//ip)) &
...
damping = 1, 1, 1 &               !(Set the bushing force damping coefficient)
stiffness = 7.46e5, 7.46e5, 7.46e5 & !(Set the bushing force stiffness coefficient)
...
```

(4) Create a geometric model of the pulley

This paper uses Solidworks 3D design software to carry out 3D modeling of the guide wheel as shown in Figure 5. The guide wheel model is imported into ADAMS.

(5) Winding between the rope and the pulley

The macro program ensures the geometric relationship between each micro-break and the pulley of the wire rope. Part of the entangled macro commands are as follows:

```fortran
variable create variable_name=wh integer_value=101 ...
```
while condition=(wh<=118) !(Determine the number of wire rope winding)

... move rotation part = (eval(".shengzi.part_"//ip)) & csmarker = (eval(".shengzi.part_"//wh//".MARKER_1"))& a1=0.0 a2=10d a3=0.0 about=yes !(Determine the rotation angle of the microsegment)

... (6) The establishment of wire rope winding model by adding contact force.
The contact force between the wire rope and the guide wheel is added to the wire rope winding model, as shown in Figure 6. The related parameters of the contact force have been obtained in 3.2.3, and part of the contact force add macro is as follows:

defaults model model_name=.shengzi
variable create variable_name=ip integer_value=71
while condition=(ip<=200) !(Select the micro segment number to add the contact)
create contact &
contact_name = (eval(".shengzi .contact_"//ip)) & !(Create contact force)

... stiffness = 3.11E+004 & !(Setting the stiffness coefficient of contact force)
damping = 10.0 & !(Setting the damping coefficient of contact force)

... Figure 4 wire rope model Figure 5 3D model of the pulley

Figure 6 wire rope winding model

Through the modeling of the braided wire rope, the modeling of the rope wheel and the construction of the wire rope winding model, the construction of the dynamic model of the wire rope maintenance system can be realized by the foregoing modeling rules.

4. Conclusion
This paper completes the overall design of wire rope maintenance line, analyzes the wire rope maintenance system and work situation. A dynamic modeling rule for the maintenance system of braided wire rope is put forward, and the model is simplified as a wire rope guide wheel model. The ADAMS macro language is used to complete the modeling of the wire rope, and the contact force is added between the wire rope and the guide wheel to complete the wire rope winding model.

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