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The Effect of Splicing Error on the Friction Force of the Arc Motion Rolling Guide

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Abstract

It is difficult to use traditional bearings for the telescope base in extreme environments, and the use of spliced arc guides can solve this problem. This paper studies the change of the friction force of the arc motion rolling guide under the condition of splicing error. In this paper, simulation methods are used to explore the speed change of the arc guide under different splicing error conditions, the Coulomb model is used to calculate the friction force change, and then the polynomial fitting is used to observe its fluctuation. The research results show that when the splicing error is 0.005 mm and 0.01 mm, the friction force of the arc motion rolling guide is roughly 10-15 N. Moreover, when the splicing error is 0.01 mm, the frictional force changes more discretely.

Keywords-Arc Motion Rolling Guide; Friction Force; Splicing Error

1. INTRODUCTION

Space, Antarctica and the Moon are currently recognized as the best astronomical observation sites. Among them, the Antarctic Dome A has an excellent observation environment and conditions. Since 2007, Chinese National Antarctic Research Expedition (CHINARE) has been to Antarctica many times to establish the foundation of astronomical equipment [1-3].

However, these places have extreme environments and transportation is extremely difficult. The hydrostatic bearings and mechanical rolling bearings commonly used in large telescope shaft support are difficult to use. This research topic proposes the use of arc splicing guide rails to realize super-large direct shafting support under ultra-low temperature environment. The super-large-diameter arc guide is formed by splicing several segmented arc modules. The splicing accuracy of each segmented module directly affects the final motion accuracy and stability of the arc guide, which in turn affects the pointing and tracking accuracy of the telescope.

There are many studies on linear motion rolling guide, such as studying its friction, friction coefficient, dynamic characteristics and kinematic performance. However, there are few related studies on the change of friction force in the motion of arc motion rolling guide and the change of friction force caused by the error of splicing guide. This paper carries out simulation calculation on this.

2. THEORY AND METHOD

2.1 Working Principle

The arc motion rolling guide is mainly composed of arc guide rail, rolling element, slider, reverse end cover, retainer and sealing device. The structure of the arc motion rolling guide is shown in the Figure 1.

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Research [4] studied the dynamic analysis of the contact problem of the rolling guide. During the normal movement of the slider, the closed section enclosed by the steel ball, the guide rail and the reverse end cover performs cyclic motion.

The motion state of the steel ball in the load-bearing area is more complicated. In the kinematics simulation of this article, the gyro motion and spin motion are ignored, and the interior of the slider is simplified into a single-row steel ball arrangement.

In engineering practice, various errors will occur during the splicing process of arc guide rails, such as radial errors, mutual tilt errors, and spacing errors. These factors will cause the friction of the slider to change during the movement. If the friction changes too much, it will interfere with the control system of the telescope, thereby affecting the control accuracy of the telescope. This paper will study the frictional force change during the movement of the rolling arc guide under the condition of radial error.

2.2 The Method of Solving Friction and the Principle of Radial Dislocation Error

The simulation software has a powerful virtual prototype analysis function, which can conveniently analyze the statics, kinematics and dynamics of the virtual mechanical system. Considering the calculation time and the research object, we simplified the arc motion rolling guide model to save time and obtain data.

Because the simulation software used in this study cannot directly obtain the friction force, based on the Coulomb model [5-6] proposed by some scholars on the basis of experimental research:

$$F_f = N f_c sgn(v) \qquad (1)$$

F_f ——friction force;

N ——Positive pressure;

f_c—— Coulomb friction coefficient;

v——Relative speed

Where N and f_c are known parameters, the simulation software is used to solve the change of the movement speed of the slider in the model, and then the formula is used to solve the change of the friction force.

The radial misalignment error is shown in the Figure 2. During the splicing process, there is a certain deviation t between the guide rail A and the guide rail B in the radial direction. Under this deviation, the frictional force change during the process of the slider passing through the guide rail A and the guide rail B is calculated.

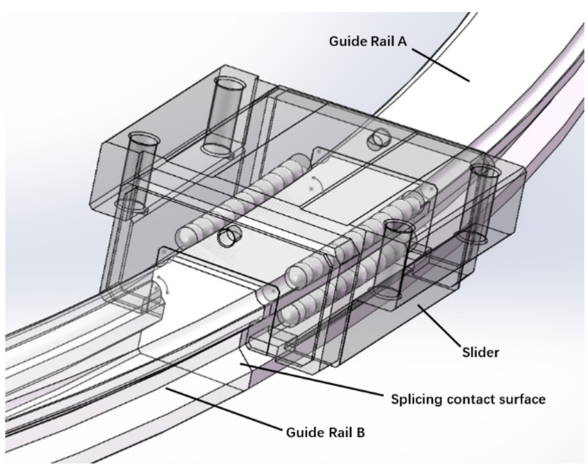

Figure 1. Simplified arc motion rolling guide model

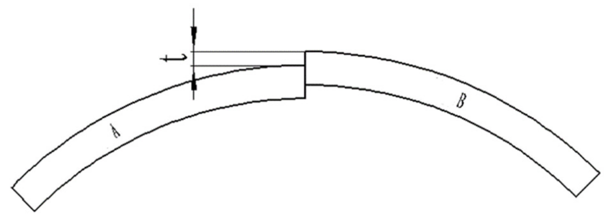

Figure 2. Radial misalignment error caused by splicing error

3. Kinematics Modeling and Simulation

Import the model from the drawing software to the simulation software.The simplified model is shown in Figure 1. The specific parameter settings before simulation in the simulation software are as follows:

TABLE I. SIMULATION PARAMETER SETTING OF ARC MOTION ROLLING GUIDE MODEL

Object name	Setting type (setting parameters)
Guide	Constraint (fixed to the gound)
Guide	Material (cast iron)
Slider	Material (cast iron)
Slider	Point movement (100mm/s)
Slider	Load (40000N)
Steel ball	Material (cast iron)
Steel ball	Constraint (contact)
Simulation time	2s
Simulation steps	50

TABLE II. MODEL PARAMETERS

Parameter name	Parameter
Guide radius	1000 mm
Slider length	195.9 mm
Slider's rated load	141 kN
Steel ball's radius	6.1 mm

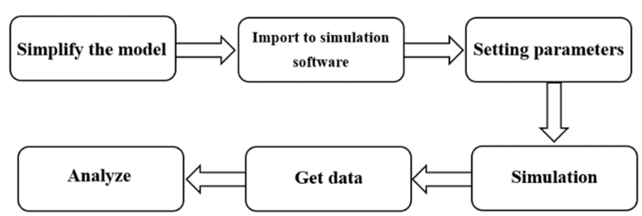

Figure 3. The simulation flow chart

TABLE III. PARAMETERS OF RADIAL MISALIGNMENT ERROR

Model number	Deviation t (mm)
1	0.005
2	0.01

Among them, for the material setting, we choose the cast iron provided by the software. According to the size parameters of the model (TABLE II), the movement speed is set to 100 mm/s, the origin is the origin of the slider coordinate system, and the moving direction is the z direction of the slider coordinate system. The load is set to 40000 N, the force point is the origin of the slider coordinate system, and the force direction is the plumb-weight direction. The steel balls are set to contact the slider and the two sections of guide rails, set one by one, and the dynamic friction coefficient is 0.004.

Kinematics simulations were carried out on Model 1 and Model 2, respectively, and the respective deviations are shown in Table III. Other settings of model 1 and 2 follow table I and table II. The overall simulation process is shown in Figure 3.

The starting position of the simulation is the position when the first steel ball inside is tangent to the splicing contact surface in the forward direction of the slider.

4. SIMULATION RESULTS

The simulation obtained the movement speed change data of the slider (Figure 4 and Figure 5), and the friction force (Figure 6 and Figure 7) was calculated by formula (1),N is 40000 N,f_c is 0.004.

It can be seen from the speed change graph that when the splicing radial misalignment error is 0.005 mm and 0.01 mm, Model 1 and Model 2 are relatively stable during the movement, and the overall speed is maintained at 75-100 mm/sec. Figure 4 and Figure 5 can clearly see that there are three abnormal points, because the steel ball rolling track in the slider is simplified into a rolling track instead of a circular rolling track, so that there is a collision between the ball and the ball in the rolling track, resulting in the speed of the slider will change indefinitely in a short period of time.

After calculating the collected data, the result of Figure 6 and Figure 7 are obtained. When the splicing radial misalignment error is 0.005 mm and 0.01 mm, the friction force is maintained between 10-15 N. The minimum friction force of Model 1 is close to 1 N, and the maximum value is approximately 27 N; the minimum friction force of Model 2 is also close to 1 N, and the maximum value is approximately 23 N.

The friction force data is fitted with a polynomial, and the fitting results under two different splicing errors are shown in the Figure 8 and Figure 9.

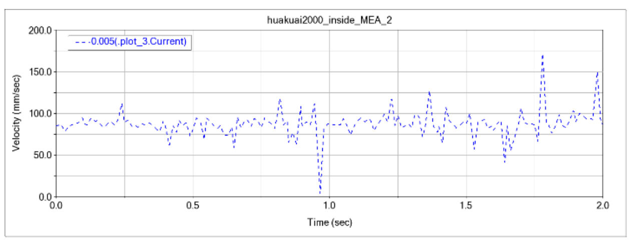

Figure 4. The speed change curve of the slider when the radial misalignment error is 0.005mm

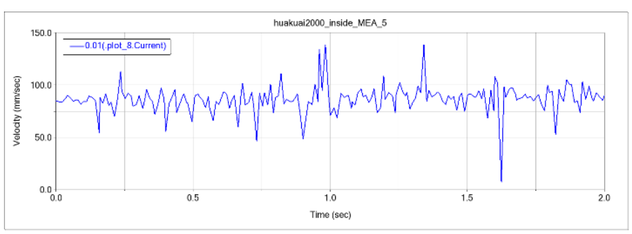

Figure 5. The speed change curve of the slider when the radial misalignment error is 0.01mm

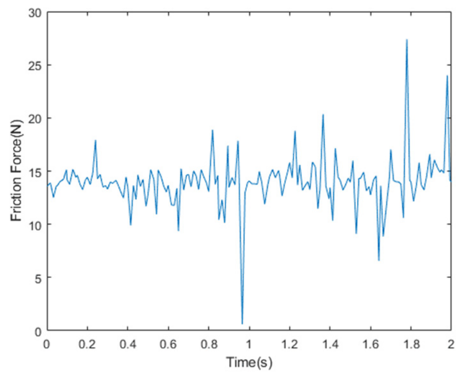

Figure 6. The friction force change curve of the slider when the radial misalignment error is 0.005mm

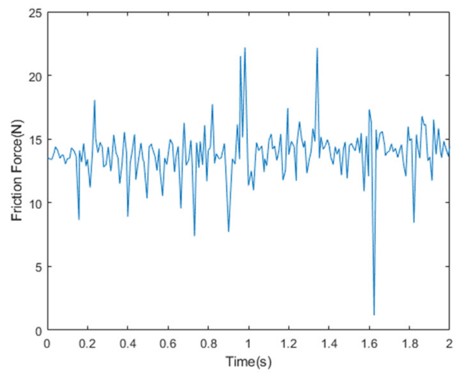

Figure 7. The friction force change curve of the slider when the radial misalignment error is 0.01mm

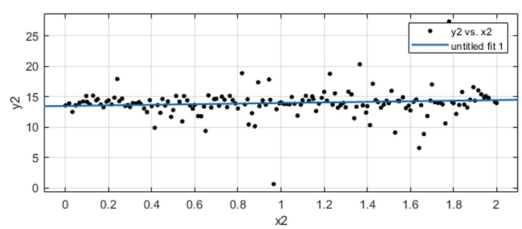

Figure 8. Fitting results of friction force when the radial misalignment error is 0.005mm

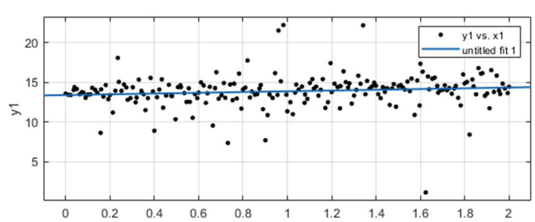

Figure 9. Fitting results of friction force when the radial misalignment error is 0.01mm

It can be seen from the fitting results that the common point of Model 1 and Model 2 is that the friction force they are subjected to is mostly around 10-15 N. Since the study of this article is an arc guide, compared to a linear guide, the frictional force of the arc guide fluctuates larger under the condition of stable operation.

Under different splicing error conditions, the frictional force changes less when the splicing error is small. It can be seen from the Figure 8 and Figure 9 that the friction force of Model 2 is more discrete than that of Model 1.

5. CONCLUSION

From the simulation results, it can be known that under different splicing errors, the friction force of the arc motion rolling guide studied in this paper varies from 10 to 15 N, and there are some uncertain speed fluctuations during the movement of the slider. In addition, compared to the working condition with a radial error of 0.01 mm, the frictional force of the arc motion rolling guide changes more linearly with less fluctuation under the working condition of a radial error of 0.005 mm.

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