

## **Mechanical Simulation of Multi-rope Hoisting System based on Recurdyn**

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**Abstract.** By using virtual prototype technology, and the multi body dynamics simulation Recurdyn successfully created a multi rope winding hoisting system model. In view of wire rope hoisting system as one of the most important parts, through the finite element method successfully established the wire rope model. The dynamic response of the wire rope and the lifting vessel is obtained by simulating the lifting process of the hoisting machine with the step speed input, which lays the foundation for further analysis of the stability and safety of the hoisting machine.

### **Introduction**

The mine hoist system is the throat of the equipment in mineral construction, plays an important role in the exploitation of resources, The hoist system is the key link on inoue and underground, bears transport personnel, improves ore, scrap and downhole equipment. The hoist in the process of ascension, swing of the cage can cause the uncomfortable of the passengers, and even affects the normal operation of the lifting machine, causing a major accident. In the hoist working condition, the vessel velocity reflects the actual speed of the system, it also can reflect the magnitude of the vibration motion stability of system, Therefore, from the analysis of the vibration of the lifting vessel and the tension of the wire rope, can get the operation of the system, so it is very necessary to study the dynamics analysis to improve the system. Many experts cholars at home and abroad, have done a lot of research on the dynamic system of mine hoist, and also made lots of achievements. The [1~4] derived vibration equation of wire rope by the principle of the Hamilton , the [5~8] in oder to ADAMS as a platform established the model winding system using 3D software, through constrainting the load corresponding of each component, geted the establishment of winding hoist three-dimensional virtual prototype, studied the kinematics and dynamics simulation. Liu Yi, Li Jishun, Yang Fang et al of Henan University of Scienceand Technology [9~10] based on virtual prototype technology, established virtual prototype modelof lifting system. The body dynamics based on Recurdyn the key to enhance the transition dynamics analysis of hoisting machine to provide a theoretical basis for the whole simulation of lifting machine analysis.

### **Mechanical Model and Principle of Multi-rope Hositing System**

The current domestic production and wide application of hoist including hoist and multi rope friction hoist single rope winding, the two lifting system according to the working principle of its own, such as differences in structural characteristics in shallow well and deep well enhance the multi level upgrade respectively is shallow. With the exploitation of coal resources exhausted, I national deep promotion more and more. In order to make full use of coal resources, developed a large, efficient, hoist safety becomes urgent. Foreign countries have studied and used a multi rope winding hoist, it can be used in deep and ultra deep wells, China has also developed a independent multi rope winding hoist the following are the multi rope. Friction type multi rope winding hoist.

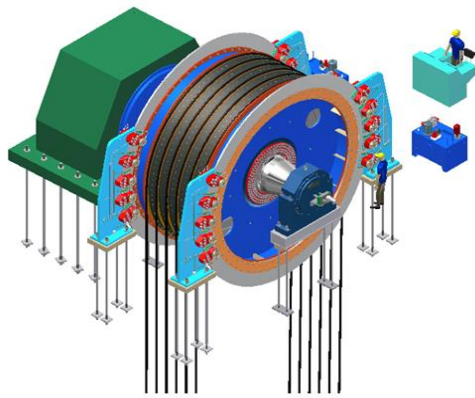


Figure 1 . Multi-rope friction hoist

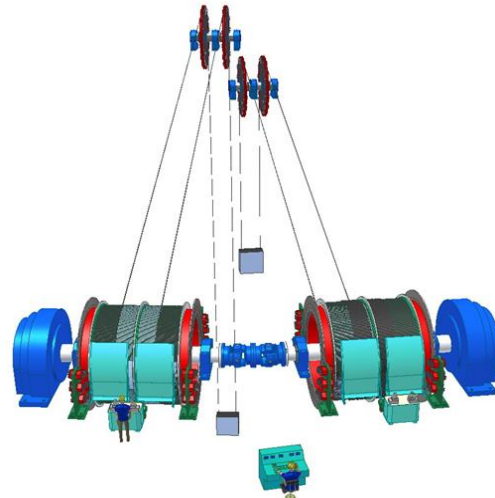


Figure 2 . Multi-rope winding hoist

Multi rope winding hoisting machine is the use of two and more steel wire rope is connected with the lifting container, each wire rope is fixed on each reel, reel between baffle separated, adjusting each rope tension difference between the rope adjusting device. The balance drum wound or decentralization, thereby enhancing the container material, increase or decrease in the shaft hoist. Compared to the single rope winding hoist multi rope winding hoisting wire diameter of the drum diameter and drum width were decreased, compared with the friction hoist tail rope not eliminated, bring the tail rope in deep well. So multi rope winding hoist can transport For large, deep and ultra deep well in high speed.

### Simulation Model

Multi rope winding hoist machine is a complex system, in the premise of not affecting the analysis results should try to simplify. Taking into account the main drum, main shaft, pulley, wire rope, tank, hoisting container modeling, modeling work in view of multibody system dynamics software Recurdyn can be relatively weak, should be more professional the 3D drawing software is modeled with the third party, the lifting machine modeling process.

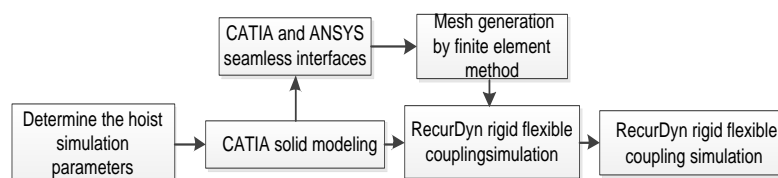


Figure 3 . The process of virtual prototype to realize

Wire rope hoist is the carrier of power transmission, coupled with head sheave and lifting container coupled, has very complicated dynamic characteristics. The key is to enhance the system components for modeling of wire rope should be as realistic as possible reaction dynamics, established the model of wire rope by the finite element beam. the specific process is the lifting steel rope line model in CATIA, saved as IGS format; Beam4 unit into ANSYS, the length of the element is set to 50mm ( to ensure that each segment of the cylinder has a corresponding circumferential angle less than 1 degrees), mesh, get CDB model; Into Recurdyn, click "PBeam1" column"Material" set button, set the elastic modulus of steel wire rope 0.5 times and 100000MPa, density  $7.85e-6\text{kg/mm}^3$ ,Poisson's ratio is 0.28; click" Data "setting button, as shown in Fig 4, from the formula(1),(2),(3) were set unit cross-sectional area  $AREA = 6936.26$ , torsional inertia  $I_{xx} = 7664984.99$ , the area of inertia moment  $I_{yy} = 3832492.49$ ,  $I_{zz} = 3832492.49$ ,  $I_{yz} = 0$ .

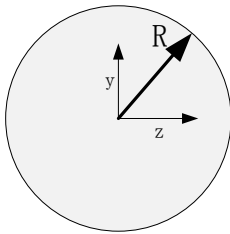


Figure 4 . The inertia moment of wire rope

$$I_{yy} = \frac{\pi d^2}{64} \tag{1}$$

$$I_{zz} = \frac{\pi d^2}{64} \tag{2}$$

$$I_{xx} = I_{zz} + I_{yy} \tag{3}$$

Finally, the model is obtained in Recurdyn, as shown in fig 5.

The winding hoist machine virtual simulation system,the model of constraint allocation as listed in Table 1 .

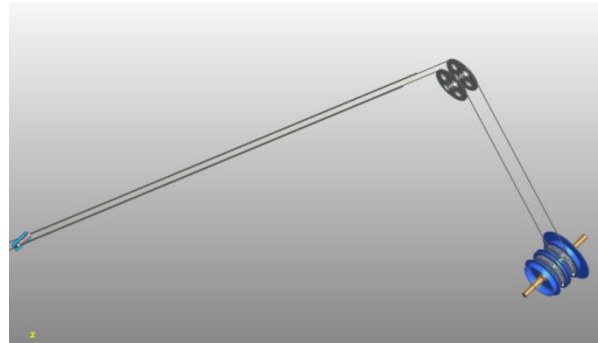


Figure 5 . The model of hoister

Table 1 . Constraint allocation of hoisting system

Part one	Part two	Constrained type
Ground	Main axis	Revolute joint
Main axis	Coiling block	Fix joint
Coiling block	Wire rope one	Spherical joint
Coiling block	Wire rope two	Spherical joint
Wire rope one	Container	Fix joint
Wire rope two	Container	Fix joint
Cage guide	Container	Revolute joint

Where in a rectangular body is formed at the bottom of the lifting container, the container is contacted with the ground by fixing a pair, so that the container is contacted with the surface of the container so as to simulate the heavy load leaving the ground.

### Kinematic Analysis of Lifting System

The equipment belongs to the periodic motion of lifting equipment in coal mine, this paper mainly studies from 0 seconds to 2 seconds to enhance the container off the ground, 2 seconds to 8 seconds to accelerate the upgrading of the hoisting container, 8 seconds to 24 seconds steadily, 24 seconds to 31 seconds of braking caused by static, dynamic rope whole upgrade process response process. By giving some vice spindle rotation speed drive, lifting speed curve to simulate system.The spindle speed function is as follows:

$$IF(time - 2 : 0, 0, step(time, 2, 0, 8, 2.25) + step(time, 24, 0, 31 - 2.25)) \tag{4}$$

The lifting height is 200m, the simulation time is 31 seconds, the simulation step is 650.The results are as follows:

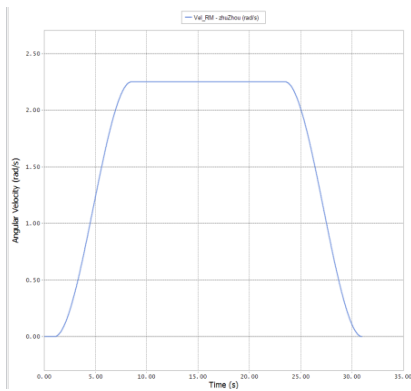


Figure 6. The time curve of spindle speed

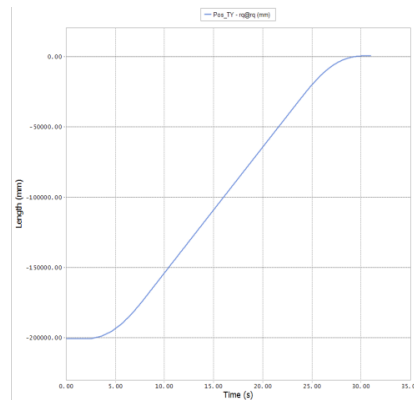


Figure 7. Displacement time curve of the container

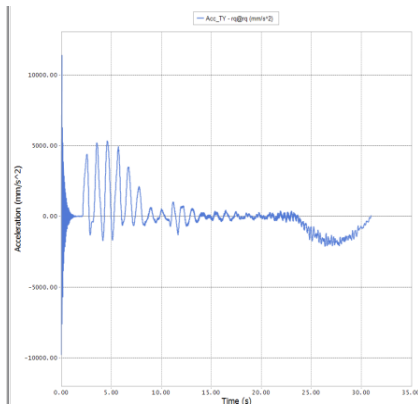


Figure 8. Variation time curve of the container

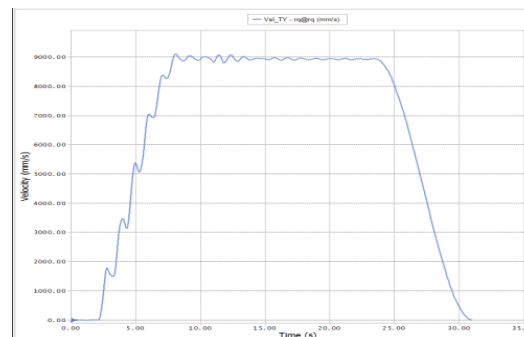


Figure 9. Velocity time curve of the container

Velocity time curve of the container

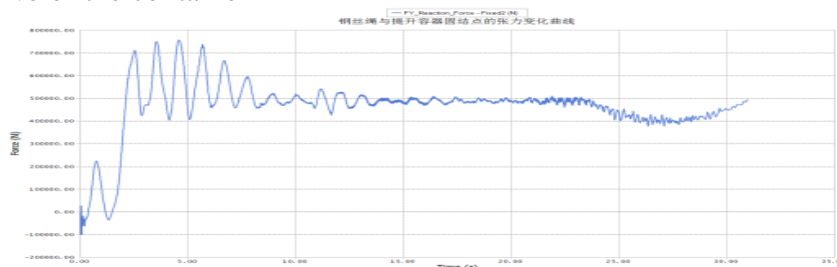


Figure 10. Dynamic tension time curve of the container

In the actual design of the hoist, according to the actual conditions, the speed and the acceleration is a compromise, efficiency not only should take into efficiency of the lift, but also should take into the effect of the dynamic response , the hoisting container cannot make larger vibration or will cause vessel instability accidents. The change of time in Figure 9 lifting speed container of ascending direction trend compared with the spindle input speed is consistent, indicating the accuracy of the model. At the same time the improve container acceleration and the time change of dynamic tension image has the same trend, also in line with Newton's second law. Fig10 lifting vessel tension changes,at the improve the initial moment, because of the wire rope instability characteristics of itself, the tension of a mutation suddenly increase, when in accelerating stage, the dynamic tension fluctuation range is larger,because wire rope length is longer. but with the decrease in the length of the wire rope, when in entering the constant stage tension is uniform. The amplitude and frequency of vibration tend to be stable and eventually stabilized near 500000N, which equals to the weight of the container.

## Summary

In the multi-body dynamics simulation software Recurdyn, the virtual model of the multi - rope winding hoist is established by adding the driving constraint and setting the boundary condition, which lays the foundation for the successful analysis the dynamic response of the hoisting machine. In this paper, the wire rope as the main research object, through the dynamic simulation of the steel

wire rope, received the response of the wire rope in the dynamic transition and stable operation ,for the subsequent simulation of hoist closer analysis, research to improve the extraction and dynamic load strength checking machine and the similar structure, provides ideas and methods.

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