Modal Analysis of Belt Conveyor Roller

Quanwei Wang[1], Wei Xiong[1] & Xiaolan Wang[2]

[1] Department of Shandong University of Science and Technology, Shandong266590, China

[2] Department of Taishan Polytechnic，Shandong 271000，China

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Abstract. This paper builds a three-dimensional solid model by Solidworks for study of a large belt conveyor drive roller. The quality of the roller optimized by the zero order algorithm and the optimization target is minimizing quality. Modal analysis of the conveyor roller is carried out in two different cases by ANSYS. Finally, it obtains the intrinsic frequency and mode shapes of the belt conveyor drive roller. The purpose is to provide a basis for the further static structure analysis and design of the roller.

1 Introduction

Belt Conveyor is currently the main way of bulk material handling. With the continuous development of modern industry, belt conveyors have become an important component in the production process part of the sectors of the national economy. As a core component of the conveyor, rollers bear the power transmitting action. Reliability and stability of the structure and vibration problems will directly affect the roller conveyor work. This paper will use ANSYS for large conveyor roller modal analysis to obtain the conveyor roller natural frequency and mode shapes.

2 Modal analysis of the mathematical model

Modal analysis is used to study the dynamic characteristics of the structure, and it is also an application of system identification method in the field of engineering vibration [1].Conveyor Roller is virtual split into a limited number of interconnected monomers, and the whole quality of roller discrete gathered on many nodes. Dynamic analysis of interconnected particle system are belongs to multi freedom vibration problem. Calculation shows that each particle of damping has little effects on the frequency and vibration model of the roller. Thus, the commonly used formula (1) of the undamped free vibration equations to find the natural frequencies and mode shapes of vibration roller [2].

$$[M]\{\ddot{\delta}\} + [\mathrm{K}]\{\dot{\delta}\} = 0 \qquad (1)$$

In the formula: $[M]$, $[\mathrm{K}]$ are the total mass matrix and stiffness matrix of roller. $\ddot{\delta}$, $\dot{\delta}$ are the acceleration vector and the displacement vector of the roller.

Because each node is doing simple harmonic motion at the time of free vibration, then:

$$\{\delta\} = \{\delta_o\}\sin(\omega x + \varphi) \qquad (2)$$

In the formula: $\{\delta\}$ is modal. ω is the frequency of the corresponding mode.

$$\{[K] - \omega^2[M]\}\{\delta\} = 0 \qquad (3)$$

The formula has non-zero solution conditions are the determinant of the coefficients to zero, then:

$$\{[K] - \omega^2[M]\} = 0 \qquad (4)$$

This is frequency equation of the free vibration. Modal analysis is to solve the eigenvalue $\omega_i^2 (i = 1,2,$ ……，n）of vibration equation, thus obtained roller natural frequencies and mode shapes.

3 Modeling and modal analysis of belt conveyor roller

3.1 The optimization design

Based on the demand for the lightweight design of the roller and the diameter and length of the model have been confirmed, while the structure size of the roller thickness, the center shaft diameter and the thickness of spokes does not limit. These structures have a great impact on the overall quality of the roller, so set as the design variables [3]. In general condition, the maximum stress should be less than strength of the material yield. Therefore, the selection of roller maximum stress and maximum bending as constraint conditions, roller quality minimum as the optimization target, and the optimization results obtained after the zero order algorithm, as showed in table 1.

Table 1 The variable structure parameters of belt conveyor roller

Structural Parameters	Before optimization numerical	The optimized numerical
The optimized numerical (mm)	30	25
Spokes thick (mm)	20	23
Central axis diameter (mm)	260	257
Quality (kg)	2122	1953

3.2 The establishment of 3D solid model of the drum

This paper uses SolidWorks to establish conveyor roller shaft, shell, radial plate and the other parts, and then to assemble the entity components, the structure parameters are shown in Table 2.

Table 2 The structure parameters

The name of the structure	size（mm)
The length of the shell	1800
Radial plate spacing	1600
Bearing spacing	2300
Wheel diameter	450
Radial plate thickness	20
Shell thickness	30
Drum diameter	800
Shaft diameter	260

Then components were assembled entity and the 3D solid model of assembled roller is shown in figure 1.

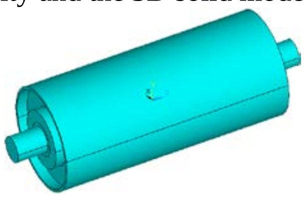


Fig.1 3D solid model of the conveyor roller

3.3 The establishment of the analysis model

3.3.1 The material properties

The roller model is imported into ANSYS by the seamless connection of Solidworks and ANSYS for modal analysis. Material properties as shown in table 3.

Table 3 Material properties of belt conveyor roller

Material parameters	Drum shaft	radial plate	Hub	Cylindrical shell
Material	Modulation treated 45steel	ZG25	ZG25	Q235
Modulus of elasticity (MPa)	1.935e5	1.75e5	1.75e5	2.0e5
Poisson's ratio	0.28	0.29	0.29	0.28
Density(kg/mm³)	7.8e-6	7.8e-6	7.8e-6	7.8e-6

3.3.2 Meshing

ANSYS provides users with two types of meshing: free meshing and mapped meshing. The free meshing is reflected in no specific criteria, no restriction on the shape of unit and generated irregular units, it can be basically applied to all models. Mapping grid required to meet certain rules. Mapping plane only includes triangular or quadrilateral element. Grid mapping body include hexahedral element only. The shape of units is regular and suitable for the regular shape of face and body. Drum model can get ideal grid by free meshing [4]. By calculating the proportion, the control unit size, carries on the grid division for the before and after optimization models. The meshed drum model is shown in Figure 2.

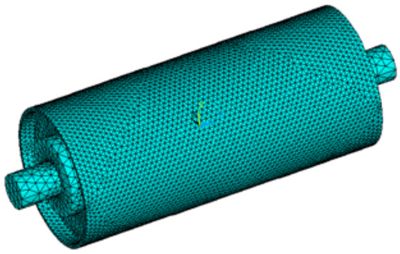


Fig.2 Drum model after meshing

3.3.3 Adding constraints

In the process of work, on both sides of the drum is supported by bearings, therefore, on the surface of the shaft nodes add full constraints [5].

3.3.4 The solution of analysis model

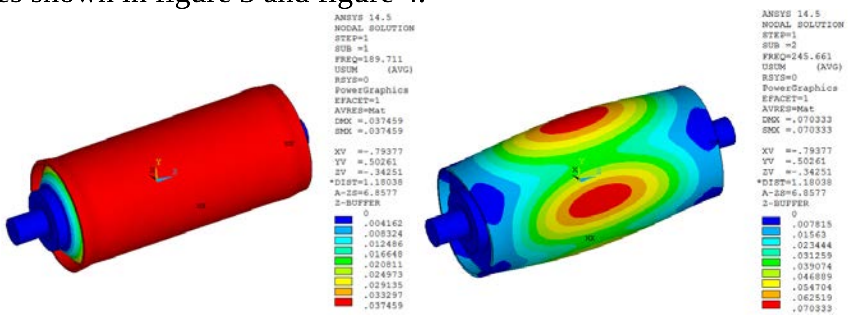
The type of analysis is the modal analysis. We input modal of extension 5 into the set of analysis, and unlimited frequency range, use Block Lanczos algorithm for solution. This method is suitable for large symmetrical characteristic value to solve the problem, and its calculation precision is higher and computing speed is faster than the other extraction methods [6].

Natural frequency obtained after the solving complete, Belt conveyor roller on the natural frequencies of the first 5 order before and after optimization is shown in table 4.

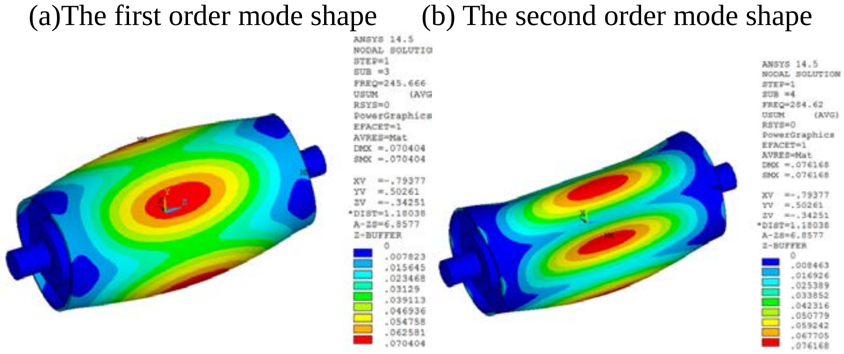
Table 4 The first 5 order natural frequency of conveyor roller

Order number	Before optimization model	The optimized model
1	189.71	204.48
2	245.66	256.53
3	245.67	256.53
4	284.62	302.58
5	284.63	303.83

Modal analysis of the conveyor roller are carried out before and after optimization, the first 4 order mode shapes shown in figure 3 and figure 4.

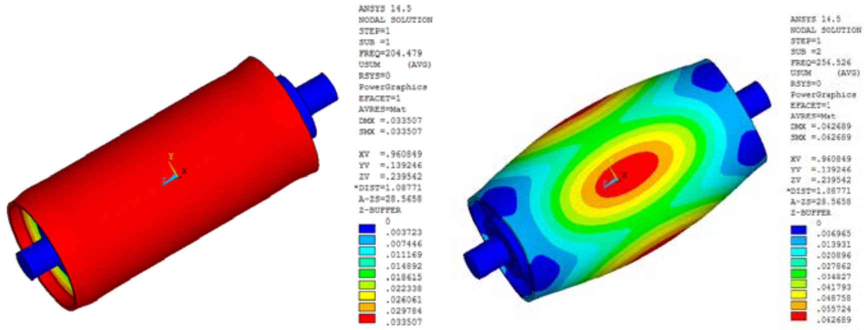


(a)The first order mode shape (b) The second order mode shape

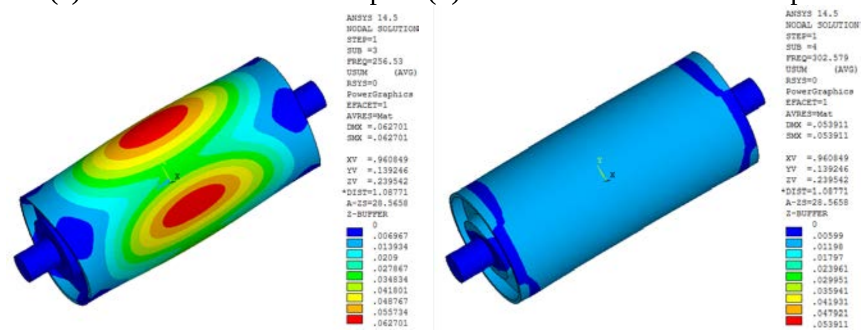


(c)The third order mode shape (d) The fourth order mode shape

Fig.3 The first four order mode shapes before optimization



(a)The first order mode shape (b) The second order mode shape



(c)The third order mode shape (d)The fourth order mode shape

Fig.4 The first four order mode shapes after optimization

It can be seen from the figure 3 and figure 4 that the natural frequency at the same time also has certain enhancement after optimization of belt conveyor roller quality, however, the vibration modes have no significant change. Cylinder under the first order of natural frequency, vibration mode is mainly that cylindrical shell and plate are doing torsional vibration along the X axis direction. Cylindrical shell and plate are doing torsional vibration along the Z axis direction when the system frequency at 245 Hz ~ 256 Hz. The maximum amplitude position is in the middle section of the cylindrical shell. Belt conveyor belongs to low and middle speed and far below the first order critical speed. Results show that appropriate reduction of the thickness of drum and the center axis diameter and increase the radial plate thickness of the method is feasible. The results of the analysis have practical significance to the study high-speed rotors.

4 Summary

This paper uses ANSYS for large conveyor roller modal analysis, as a new design method, it provides some supports for the conveyor roller further structural analysis and optimization from the dynamic characteristics. The result shows that minimum driving drum modal frequency is 204.48 Hz and the highest modal frequency is 303.83 Hz, which meet the design requirements. In addition to the fourth and fifth order, the maximum amplitude of position is on the shell. In the roller design, the middle position of cylinder shell and cylindrical shell need structure optimization.

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