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# Study on Mechanics of Driving Drum with Superelastic Convexity Surface Covering-Layer Structure

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**Abstract**

Belt conveyor is one of the main transport equipment in coal mine and the driving drum is its key part. With the method of bionic design, the mushroom morphological structure is applied to the design of covering-layer structure of driving drum surface of belt conveyor. Superelastic rubber with large deformation is adopted as the covering-layer material. Nonlinear constitutive model of rubber, which is of superelasticity and large deformation, is established. The stress states and deformation principles of driving drums including both bionic covering-layer and common covering-layer are obtained by static intensity analysis with Finite Element Analysis (FEA) software ANSYS. The values of the stress and strain on the driving drum surface are gotten and the dangerous area is determined. FEA results show that the superelastic convexity surface structure can enlarge the contact area between the driving drum and viscoelastic belt. The results also show that in comparison with common driving drum, the bionic surface driving drum can not only increase the friction coefficient between drum and belt but also prolong its service life.

**Keywords**: bionics, convexity, driving drum surface, finite element analysis



## 1 Introduction

Belt conveyor is one of the main transport equipment in coal mine and the driving drum is its key part. Friction principle is used to initiate mechanical drive for belt conveyor. So friction is the driving force. In order to raise transportation efficiency of belt conveyor, driving force of drum must be increased. The value of maximum effective driving force is determined by Euler equation

$$F_{\max} = S_2(e^{\mu\alpha} - 1) \ , \qquad (1)$$

where $F_{\max}$ is the maximum effective driving force, $\mu$ is friction coefficient between conveyor belt and driving drum, $S_2$ is the relaxed side pulling force, $\alpha$ is the surrounding angle between the conveyor belt and the active roller.

According to Euler equation, there are three methods to increase driving force: increase initial tension of belt, increase wrap angle of drum and increase friction coefficient. If the initial tension is increased, the tensile deformation will increase, therefore, the super tension belt must be used. But the result of using super tension belt is that the driving drum will be damaged and the life of bearing will be shortened. Although this method to increase traction force is feasible, correspondingly both the section of conveyor belt and the structure size will be increased, which is not economical and its application is limited. If the second method is adopted, there are many methods to increase wrap angle including using double drum, but it is subjected to some limitation on the conditions. Research has shown that increasing the friction coefficient is more effective than to increase wrap angle[1].

Many researches have been conducted aiming to increase the traction force through the increase in the friction coefficient. The typical material of driving drum is ceramic, which can improve traction force effectively. But it has some shortcomings: first, ceramic is brittle and

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is easy to be fractured; second, it is difficult to process using the cold vulcanization technique, by which the rubber strip with ceramic liner is pasted on covering-layer of drum; third, this technique has not been well mastered in China that defects of the key technology do exist[2–4].

Bionic technology provides a new solution for solving this question. In this paper we mainly study the covering-layer structure of the driving drum that increases the friction coefficient with the bionics principle and finite element analysis.

## 2 Bionic design of covering-layer of driving drum

From the point of view of the product form bionics, surface structure of driving drum covering-layer is designed by the inspiration of the form of mushroom pileus[5,6].

The mushroom pileus has various forms, such as bell shape, bamboo hat shape, and spherical crown shape and so on, which are shown in Fig. 1. The diameter of pileus ranges from 0.4 cm to 20 cm. There are some appendages on the surface of mushroom pileus. The amount of appendages also evolves from many to few as shown in Fig. 2.

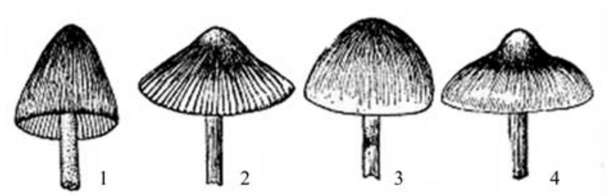


**Fig. 1** Mushroom convexity pileus (1-bell shape; 2-bamboo hat shape; 3-spherical crown shape; 4-central protuberance shape).

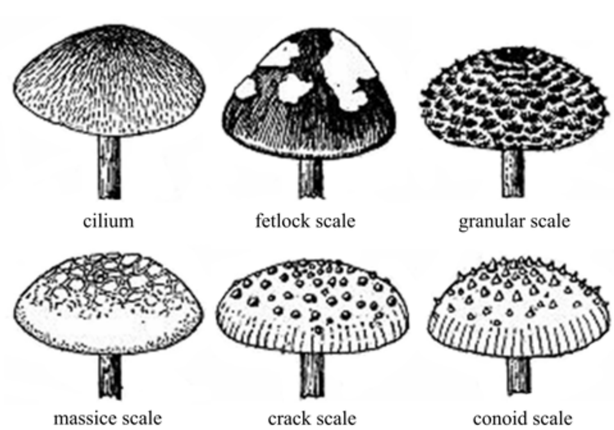


**Fig. 2** Appendage on the surface of mushroom pileus.

Considering the difficulty of processing of non-smooth morphology, mechanical parameters of drum and working requirement, the form bionic design of covering-layer is that the geometric surface of convexity is spherical crown shape, the size of bionic structure on the covering-layer is the same and its arrangement is uniform distribution[7].

Suppose the radius is $R$, the height is $h$, the spacing in $X$ direction is $X_1$ and in $Y$ direction is $Y_2$, and the projection round diameter of spherical crown is $b$. The equation of convexity at origin and its surrounding regions, $x^2 + y^2 = r^2 \le a^2$, is:

$$Z = \begin{cases} h - R + \sqrt{R^2 - r^2} & r^2 \le b^2 \\ 0 & b^2 \le r^2 \le a^2 \end{cases} \tag{2}$$

where

$$a^2 = \left[ X_1 - \sqrt{R^2 - (R-h)^2} \right]^2 + \left[ Y_2 - \sqrt{R^2 - (R-h)^2} \right]^2 ,$$

$$b^2 = R^2 - (R-h)^2 .$$

By repeating experiments, the structure data of convexity covering-layer surface is determined, which is shown in Table 1. The three-dimensional model and simulative chart of single spherical crown is shown in Fig. 3 and Fig. 4 respectively[8].

**Table 1** Structure data of convexity covering-layer surface

| Shape | $X_1$ | $Y_2$ | $b$ | $h$ | Distribution |
|---|---|---|---|---|---|
| Convex | 100 mm | 100 mm | 50 mm | 5 mm | Uniform |

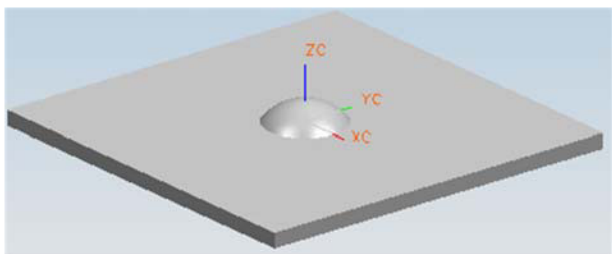


**Fig. 3** Three-dimensional model of single spherical crown.

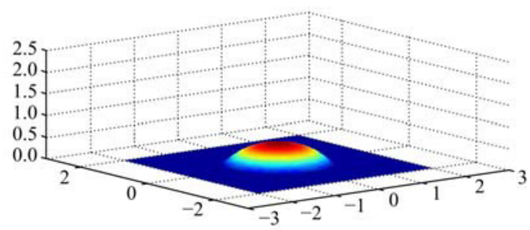


**Fig. 4** Simulative chart of single spherical crown.