Bearing Grounding Mechanical Properties of Engineering Vehicle Retreaded Tire

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Abstract: In this study, a multivariate composite layer model, computer geometry models, contact pair models, finite element analysis (FEA) models, and bearing grounding mechanical property test system were constructed. FEA and experimental study on the bearing grounding mechanical properties of retreaded tires of engineering vehicles were processed. Therefore, features and rules of load grounding pressure, load grounding mark, load grounding area, load grounding coefficient, and load grounding hardness coefficient of retreaded tires under the static grounding working condition were summarized, from which load-bearing grounding mathematical models of 26.5R25 engineering vehicle retreaded tire were constructed. Analysis results show that the grounding pressure at the tread center of grounding pressure and grounding friction, which increased along the tire width and rolling direction at different degrees, were the smallest under the static grounding working condition. The shape of the earthing marks turned from circular to elliptical, and then close to the rectangle with the load increase, and finally into an approximate saddle shape. When the tire pressure was certain, the earthing area increased gradually with the increasing load and the increasing trend was nonlinear. The ground pressure and grounding force on the tire shoulder of the engineering retreaded tire was the largest, which could be damaged easily.

1 Introduction

In recent years, mining, construction, and other industries have developed rapidly. Thus, the demand for engineering vehicle tires has increased on a daily basis. Engineering vehicle tires are typically used in open-pit mining areas, such as those of soil and stone, which are loaded with large, frequent starting and braking, and are affected by bulge; thus, the production rate of waste tires is rapid and the production yield is large (Junxiong, 2016; Daochun, 2016; Jun 2014). The amount of rubber used for an engineering vehicle tire is approximately 15% of the total rubber consumption of the tire manufacturing industry. Therefore, increasing the renovation rate of waste engineering vehicle tires can effectively improve the utilization rate of such tires, thereby saving rubber resources and promoting green environmental protection. Furthermore, pollution caused by waste tires would be turned into energy. At present, whether in China or in developed countries such as the United States, Japan, and South Korea, most studies focus on tire refurbished industry state, related policy analysis, technology equipment system development of the loading vehicle tire renovation, loading vehicle tire renovation technology, product quality evaluation of the loading vehicle tire renovation, tire tread modification, enhancement technology of the loading vehicle, and other factors (European Rubber Journal GROUP, 2013; Rubber World Group, 2013; Indian/international rubber journal group,

2013). Numerous studies on vehicle tires and retreaded tires have been conducted in those developed countries and in China. However, limited studies have focused on the macro and micro mechanical performance of engineering vehicle retreaded tires. Apart from the results presented by the researchers, published studies are rarely found in recent years. Owing to the lack of basic technology for refurbished engineering tires, tire tread is not wear-resistant during usage, and has other damage forms; for example, it is easy to crash cost block and blast on its appearance, thereby seriously affecting the popularization and application of engineering retreaded tires. To this end, this paper qualitatively and quantitatively described and evaluated the grounding contact pressure characteristics of engineering vehicle retreaded tires by building the computer geometric model, FEA model, and grounding contact pressure characteristic test system. Results provide important theoretical guidance for the study on the performance evaluation and optimization of the renovation technology for engineering vehicle retreaded tires.

2 FEA model of engineering vehicle retreaded tire

The finite element model constructed by ANSYS Workbench software is shown in Fig. 1. The model consists of 19,976 degrees of freedom; 68,377 nodes; and 41,554 units. The pair model construction of contact with the

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ground is shown in Fig. 2. The contact friction coefficient between rigid ground and flexible tire was set to be 0.9 (Fenglin, 2016; Shan and Wei, 2016). The material parameters, such as tread, buffer rubber, tire side, toe mouth rubber, and steel wire ring were measured, as shown in Table 1. The material parameters of the old tire body and belt layers were measured by experiment, as shown in Table 2. Mooney–Rivlin model was applied to simulate the tread, buffer rubber, tire side, and toe mouth rubber. The solid unit was used to simulate the steel wire ring, while the old tire body and belt layers were simulated using a layer unit.

Fig. 1Finite model

Fig. 2 Contact pair model

Table 1 Material parameters of tread

Material	Elasticity modulus (MPa)	Poisson’s ratio	Density (kg/m³)
Tread	7.26	0.48	1790
Buffer rubber	5.94	0.48	1020
Tire side	10.36	0.48	1240
Toe mouth rubber	12.14	0.48	1370
Steel wire ring	2.12 e5	0.29	7850

Table 2 Material parameters of old tire body and belt layer

Material	Elasticity modulus (MPa)			Shear modulus (MPa)			Poisson’s ratio			Density/ kg/m³
	E_1	E_2	E_3	G_{12}	G_{23}	G_{31}	μ_{12}	μ_{23}	μ_{31}	
Old tire body	9.7e4	6.96	6.96	6.04	3.26	3.26	0.398	0.398	0.48	4580
Belt layer	1.58e5	2.62	2.62	9.88	2.58	2.58	0.344	0.344	0.48	6480

3 Finite element numerical simulation of grounding mechanical properties of engineering vehicle retreaded tir

3.1 Analysis of grounding pressure characteris-
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3.1.1 FEA of grounding pressure distribution

The grounding pressure distribution cloud figure of engineering retreaded tire under the tire pressure of 600 kPa and load of 135 kN is shown in Fig. 3. The cloud image of grounding friction stress distribution is shown

in Fig. 4 Figure 3 shows that the pressure distribution of retreaded tires in the grounding area is uneven. The grounding pressure of tire shoulder is 10.503 MPa, while the minimum value is 1.167 MPa in the grounding center area. The minimum value of the pressure increases at a different degree from the grounding center along the width of the tire and the circular rolling direction. Figure 4 shows that the friction distribution in the grounding area of the retreaded tire is not evenly distributed. The contact friction on the shoulder position of the tire reaches the maximum at 8.51 MPa; the friction value of the grounding center area reaches the minimum at 1.94 MPa, and then the friction value increases from the grounding center along the tire rolling and width directions in a different degree.

Fig. 3 Cloud of grounding pressure distribution

Fig. 4 Cloud of grounding friction stress distribution

3.1.2 Test of grounding pressure distribution

The grounding pressure distribution of 26.5R22.5 engineering retreaded tires together with the new tires of the same brand and the same model were tested under the following working conditions: one with constant tire pressure and changeable load, and the other with constant load and changeable tire pressure. In this manner, the grounding pressure distribution rules of engineering retreaded tires were studied and compared with those of the new tire and simulation value.

The composition of the grounding pressure test sys-

tem is shown in Fig.5. The test system installation is shown in Fig. 6. The engineering retreaded tire under the test marked as 4 in Fig. 13 is fixed on the rotation axis marked as 3, and the air compressor marked as 1 is treated with the tire marked as 4. In addition, the tire pressure is calibrated by the tire pressure gauge marked as 5 in Fig. 13, and the force loader marked as 6 moves up and down to implement loading and unloading. Moreover, the loading plate marked as 8 in Fig. 13 simulates the road surface, and the diaphragm-type pressure sensor marked as 9 is distributed in the contact area of the tire tread and ground.

1- Air compressor 2- Support 3- Rotation axle 4- Tire under test 5- Tire pressure gauge 6- Force loader with digital display
7- Platform 8- Loading plate 9- Diaphragm-type pressure sensor 10- Data indicator

Fig. 5 Composition of test system

Fig.6 Test system installation

3.1.3 Analysis of grounding pressure results

According to the simulation and test results, the grounding pressure distribution of the engineering retreaded tires approximately turned out to be a “V” shape, and minimum pressure value was in the tire grounding center area. However, the value increased gradually along the direction of the width and rolling circumference, in which the trend of the increase along the tire width direction was nonlinear, the trend of increase along the direction of the rolling circumference was approximately linear, and the maximum could be reached at the tire shoulder and grounding edge along the rolling direction. The results show that the part of the tire shoulder is more likely to be damaged than other parts of the engineering retreaded tire during usage. When the tire pressure was certain, the grounding pressure along the tire width direction and rolling circumference direction increased as the load increased; when the load was certain, the grounding pressure remained similar under the two types of working condition, of which the tire pressure was $P =$

450 kPa and $P = 500$ kPa. When the tire pressure continued to increase, the grounding pressure gradually increased. The results show that the contact pressure of the shoulder position of the engineering retreaded tire was greater, and the rubber on the tire shoulder position was thicker and arc-shaped, which easily formed the stress concentration. Therefore, the tire shoulder position easily occurred in the form of the tearing failure of dissection from the retreaded tire tread.

3.2 Characteristic analysis of grounding mark and grounding area

3.2.1 Characteristic analysis of grounding mark and side slipping state

When the tire pressure was 600 kPa and the vertical loads were 115, 155, and 185 kN, the grounding mark shape of engineering retreaded tire is shown in Fig. 7, and the cloud of tire sliding distance is shown in Fig. 16.

Fig. 7 Grounding mark shapes of tire

Fig.8 Cloud of tire sliding distance

Fig.7 shows that the grounding mark of the engineering retreaded tire is symmetric geometry, but with the increase of the load, the area of the grounding mark gradually increases, while the shape turns to oval from the original round, and then gradually turns to rectangle. When the load is large, the distribution along the tire circumference direction is in a saddle shape. As shown in Fig. 8, the retreaded tire produces a smaller side-slipping amount along the axial direction, which is 0.08 mm; thus, this condition is ignored in the actual work, which is consistent with the actual situation.

4. Conclusion

(1) Under static grounding working condition, the grounding pressure and grounding friction of the tread center point around the grounding area of the engineering retreaded tire were the smallest; they increased in different degrees along the direction of the tire width and rolling directions.

(2) The landmark shape of the retread tires varies with the increase of load from round to oval, and then near the rectangle, finally resembling a saddle shape.

(3) When the tire pressure is constant, the ground area of the retread tire increases with the increase of load and shows a nonlinear trend.

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