Temperature Rise Characteristic of Engineering Vehicle Refurbished Tire

Qiang Wang, Xiaojie Qi, Yunlong Wang and Guotian Wang
School of Automobile and Traffic Engineering, Heilongjiang Institute of Technology, Hongqi Street, HarBin, China
630702666@qq.com

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Abstract: In order to further clarify the temperature rise characteristic of engineering vehicle refurbished tire, computer geometry models and the finite element analysis modals of the 26.5 R25 engineering vehicle refurbishment tire were built using Pro/E Wildfire and ANSYS Workbench software, the boundary conditions of finite element analysis of steady state temperature field was determined, then the steady-state temperature field test system for the rolling working condition of engineering vehicle refurbished tire was constructed, and last the temperature field distribution characteristics and heat flux distribution characteristics of the tire layer, buffer layer, belt layer, tread body layer, tire side layer and toe mouth rubber layer along the width direction and radial direction of the tire were obtained. The simulation and test results are shown: the two sides of the tread body layer shoulder had the highest temperature, with the lowest temperature on the belt layer, buffer layer, and both sides along the width direction of tread body layer. The interior temperature of the refurbished tire increased with the speed of the running tire, among them, the temperature of the buffer layer and the tire layer increased greatly, and the tread body layer was the second, and the temperature of the belt layer was the smallest. The maximum heat flux was near the shoulder position of the tread body layer.

1 INTRODUCTION

In recent years, with the rapid development of construction, mining and other industries, the usage of tires for engineering machinery vehicles is increasing, but due to its poor working conditions and frequency of usage, the production of engineering vehicle waste tires is increasing sharply. The amount of rubber used for an engineering vehicle tire is about 15% of the total tire consumption, therefore, improving the refurbishment rate of the waste tires of engineering vehicle, which can effectively improve the utilization rate of the waste tires of engineering vehicles, save rubber resources and promote green environment, thus "black pollution" will be effectively changed into "black energy"(Liu Chundao., 2016; Sun Hongyan, 2015). At present, the research on engineering vehicles refurbished tires done by developed countries such as America, Japan, and South Korea and China mainly concentrated in the refurbishment industry conditions and related policy analysis, refurbishment process equipment development, refurbishment process technology, refurbished tire product quality evaluation, etc. There are not many studies on macroscopic and microscopic mechanical properties in the use of engineering refurbished tire, except some results gotten by the author of this paper and the research group in recent years, no results have been published. Due to the lack of basic technology of engineering tires refurbishment, engineering refurbished tires often appear not wear-resisting, easy to collapse cost block, even tread separation, and other damage forms caused by blasting and the blasting in the process of usage, seriously affecting popularization and application (Ma Xiao., 2015; Wang Qiying, 2015). For this purpose, this paper built a computer geometry model, finite element analysis model and temperature rise characteristic test system, qualitatively and quantitatively described and evaluated the temperature rise characteristics of engineering vehicle refurbished tire, thus It provides important theoretical guidance for the researches on the performance evaluation, optimization of the refurbishment process and the using promotion.

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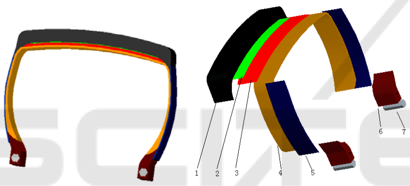
2 THE GEOMETRIC MODEL CONSTRUCTION OF STEADY TEMPERATURE FIELD OF ENGINEERING REFURBISHED TIRE

In this paper, tread layer, buffer layer, belt layer, tire body layer, tire side layer and steel wire ring were respectively established based on the 26.5R25 refurbished radial tire, combining with its material distribution model and using Pro/E Wildfire software, then as shown in fig.1. Virtual assembly was completed by using Pro/E Wildfire software assembly module, and saved as IGES format, and the steady-state temperature field of engineering refurbished tires was analyzed by using ANSYS Workbench finite element software, and imported into ANSYS Workbench software, and the three-dimensional geometry model is shown in fig.2 (Wang Jun, 2016; Wang Guolin, 2016; Qin Tao, 2016) .



1-Tread layer 2- Buffer layer 3-Belt-layer 4-Tire body layer 5-Tire
side layer 6-Toe-mouth rubber layer 7- Steel wirering

Figure 1 3D geometry model and explosion model based on Pro/E Wildfire software

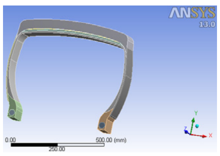


Figure 2 3D geometry model based on ANSYS Workbench software

3 THE FINITE ELEMENT MODEL CONSTRUCTION OF ENGINEERING REFURBISHED TIRE STEADY-STATE TEMPERATURE FIELD

The finite element model was created as shown in fig.3, with 26,762 nodes and 14,333 units. Tread layer, buffer layer, tire side layer and toe-mouth rubber layer were simulated by Mooney Rivlin model, and belt layer and tire body layer were simulated by composite material layer unit, and steel wire ring was simulated by physical unit. The heat conductivity coefficient of each layer is shown in tab.1, and the heat transfer coefficient of each layer at different speeds is shown in tab.2. Initial temperature was set as 20°C, and the measured tire pressure and calculated temperature under different speeds are as shown in tab.3. The speed of free rotation working condition was 40 km/h, and temperature loading model of 95 ° C tire inner cavity temperature is as shown in fig.4 (Wang Ruoyun, 2016; Yan Shan, 2016).

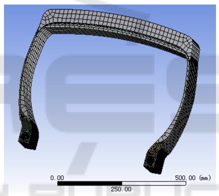


Figure 3 Finite element model

Table 1 Heat conductivity coefficient of each layer

	Tire body layer	Belt layer	Buffer layer	Tread layer	Tire side layer	Toe mouth rubber layer	Tire bead
Heat conductivity coefficient W/m·℃	18.64	34.38	0.24	0.20	0.36	0.28	52.12

Table 2 Heat transfer coefficient of each layer surface at different speeds

Speed km/h	h_w W/(m²·℃)	h_n W/(m²·℃)	h_c W/(m²·℃)	h_q W/(m²·℃)
10	15.22	10.65	10.65	6.09
20	27.25	19.08	19.08	10.90
30	38.30	26.81	26.81	15.32
40	48.77	34.14	34.14	19.51
50	58.82	41.17	41.17	23.53
60	68.56	47.99	47.99	27.42

Table 3 The measured tire pressure and calculated temperature at different turning speeds

Speed km/h	Measured tire pressure kPa	Calculated inner cavity air temperature℃
10	465	30
20	498	51
30	534	75
40	565	95
50	572	99
60	584	107

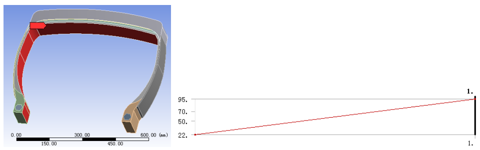


Figure 4 Temperature loading model

4 SOLUTION AND ANALYSIS

Fig.5 shows the distribution cloud graph of the tire temperature field and the temperature distribution of each layer along the radial direction of engineering refurbished tires. The fig. 5 shows that the temperature peak appeared inside tire body layer near the shoulder (95.2°C), the lowest temperature at tire shoulder of tread surface (45.6°C). The simulation results show that the heat transferred from the interior of the engineering refurbished tire to the exterior, the tire body layer was composed of a layer of steel wire curtain, whose heat conductivity was relatively higher than that of rubber and whose shoulder was the thinnest, so the temperature was the highest. The shoulder rubber of tread layer was much thicker and was not conducive to the diffusion of heat, so the temperature was the lowest. In addition, because of the tire side was a layer of steel wire curtain fabric and a thin layer of rubber, thus its temperature was also high.

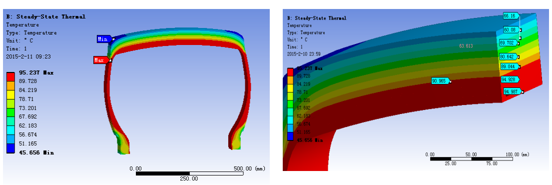
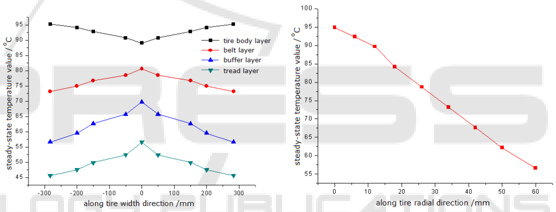


Figure 5 Temperature distribution cloud graph of temperature field and temperature distribution of each layer along radial direction

Fig.6 shows the temperature distribution curve of each layer along the width direction and radial direction. It can be seen from fig.6 and fig.7 that the temperature at the two sides of shoulder of the tread body layer was the highest, and the temperature gradually decreased to the cross section center; the temperature at both sides of the belt layer, buffer layer and tread layer along width direction was the lowest, and the temperature gradually increased to the cross section center, and among them the change degree of the belt layer was not large, and the temperature variation degree of buffer layer and tread layer was larger. Along the radial direction, the temperature gradually decreased from interior of the tire body layer to exterior of the tread layer and change trend was approximately linear. The temperature peak of the tire side layer was at the junction of the tire side layer and the toe mouth rubber layer, and the temperature highest point of the toe mouth rubber layer was at the junction of the toe mouth rubber layer and the steel wire ring, then the highest temperature of the steel wire ring was located at the junction of the steel wire ring and the toe mouth rubber.



(a) (b)

Figure 6 Each layer along width direction（a）and radial direction（b）temperature distribution

Fig.7 shows the temperature variation curve of the center line of the tire cross section along the radial direction at different speeds. It can be seen from fig. 8 that, with the increase of driving speed, the temperature of any point of the refurbished tire increased, and the temperature of the belt layer increased by a minimum, the tire body layer was secondary, and the temperature of the buffer layer and the tread layer increased greatly. The results show that, with the increase of the driving speed of the tire, the heat was quickly introduced to the buffer layer and the tread layer from the tire body layer through the belt layer. Because the heat conductivity of the rubber material in the buffer layer and the tread layer was low, the temperature of this part had risen sharply. If the heat could not be introduced into the atmosphere in time, the adhesive force between the tread layer and the buffer layer, and the buffer layer and the belt layer would be reduced, even due to the high temperature effect, the failure of the tread layer produced.

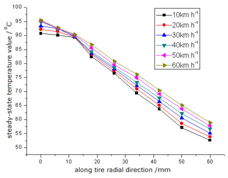
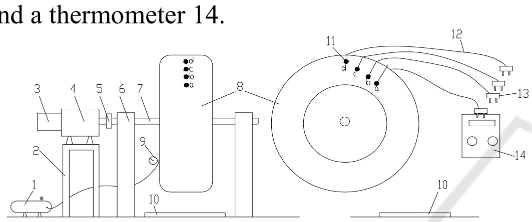


Figure 7 Temperature variation curves of tire radial direction at different speeds

The test system composition is shown in fig.8, and its mainly consists of air compressor 1, bench 2, motor 3, reducer 4, coupling 5, bracket 6, rotation axis 7, tires under test 8, tire pressure gauge 9, platform 10, thermocouple 11, wires 12, plugs 13, and a thermometer 14.



1- Air compressor 2- Bench 3- Motor 4- Reducer 5- Coupling 6- Bracket7- Rotation axis 8- Tire under test 9- Tire pressure gauge 10- Platform 11- Thermocouple 12- Wires 13- Plugs 14- Thermometer

Figure 8 Composition of testing system

The tire pressure of 26.5R25 engineering refurbished tire was 600kPa, the inner cavity stable tire pressure testing results under different rotating speed working conditions are shown in tab.4, the steady-state temperature value of each layer is shown in tab.5, the comparison curve of steady-state temperature measured results and simulation results is shown in fig.9, The measured value was close to the simulation value, which verified the correctness of the simulation model.

Table 4 The inner cavity stable tire pressure of engineering refurbished tires under different rotation speeds

Speed km/h	Running time h	Initial tire pressure kPa	Stable tire pressure kPa
10	2	600	615
20	2	600	648
30	2	600	684
40	2	600	715
50	2	600	748
60	2	600	783

Table 5 The steady-state temperature value of engineering refurbished tires under different rotation speeds

Speed km/h	Temperature of measured point a ℃	Temperature of measured point b ℃	Temperature of measured point c ℃	Temperature of measured point d ℃
10	89.2	81.3	69.3	56.9
20	90.5	81.1	70.7	58.5
30	91.3	82.9	72.1	60.5
40	92.3	83.9	72.9	60.1
50	92.5	85.4	73.9	63.8
60	92.6	86.6	76.0	64.7

Stating: Measured points a,b,c and d respectively represent the central section of tire body layer, the central section of belt layer, the central section of buffer layer, and the central section of tread layer.

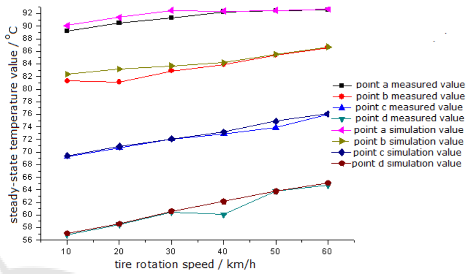


Figure 9 Comparison curve of measured value and simulation value of steady-state temperature distribution at different rotation speeds

5 CONCLUSION

(1)Temperature was higher on both sides of the tire shoulder of tire body layer, which gradually decreased to the center of the cross section, and the lowest temperature was at the both sides of the width direction of belt layer, buffer layer and tread layer, which gradually increased to the center of the cross section, moreover, the changing degree of the belt layer was not large, and the temperature variation degree of buffer layer and tire layer was larger.

(2)With the increase of the running speed, the temperature of any point of interior tire was all increased, among them the temperature increasing degree of the belt layer was the smallest, and the layer of the tire body layer was the second, and the temperature increasing degree of the buffer layer and the tread layer was much larger.

(3)The maximum heat flux of the tire body layer was near the shoulder part, the maximum heat flux was on both sides of the width direction of the belt layer and of the tread layer, the maximum heat flux was on both sides of the width direction of the buffer layer, the maximum heat flux was at the junction of the tire side layer and the tire body layer, the maximum heat flux was at the junction of the toe-mouth rubber layer and the tire body layer, and the heat flux in the middle part of the steel wire ring was the largest.

(4)The heat from engineering refurbished tires would gather at the junction of the shoulder position and the various layers, therefore, it is necessary to pay more attention to the close adhesion between the shoulder position and the buffer layer and the tread rubber. At the same time, the transition of the rubber joint in each layer should be smooth, which reduces the probability of the failure of the shoulder position and each layer.

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