The strength analysis of new W-shape resilient wheel under different working conditions

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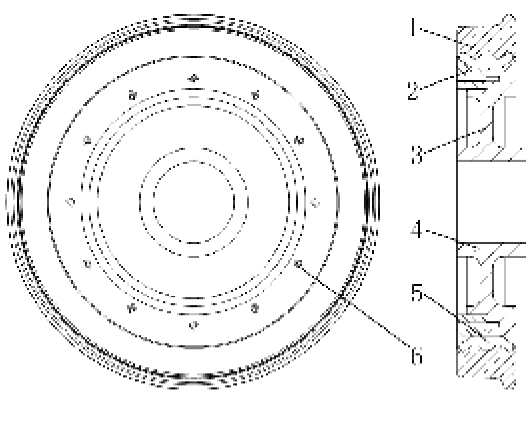
Abstract. This paper presents a new W-shape resilient wheel and bases on "UIC510-5 Technical approval of monolithic wheels (2003)" standard for strength analysis. The calculation results show that in five kinds of working conditions, the elastic components strength of wheel meets the design requirements. New W-shape resilient wheel is proposed, has good application and reference value to the study of resilient wheel.

Introduction

Convenience of subway is more and more get the favour of people, and vigorously develop in the major cities. But at the same time, People pay more attention to the negative impact of noise to the environment caused by the subway operation noise pollution [1, 2]. The design of metro vehicle speed in our country is in commonly 80 km/h. The noise produced by the subway operation is mainly for the rolling noise [3, 4]. As a result, the control of wheel noise, has the vital significance to reduce the noise of the subway operation. Using elastic wheel can significantly reduce the wheel/rail noise and the action of wheel/rail force [5]. From the viewpoint of vehicle dynamics, adding the rubber body between the wheel rim with the wheel center, which can reduce the unsprung mass and reduce the vertical acceleration between wheel/rail, can improve the brim abrasion also.

The structure of W-shape resilient wheel

Base on a certain type of standard wheel, designing a w-shaped resilient wheel model. The resilient wheel model structure is shown in figure 1. A total of 12 pieces of rubber, using the block type is evenly distributed between wheel center with wheel rim. The vehicle load in turn through the axle passed to wheel hub, wheel center and rubber body, wheel rim and rail. Wheel rim, fixed ring, and wheel heart all interference contact with the rubber body. Wheel center and fixed ring connect by bolt. The movement of the wheel rim along the radial is slightly space.



1 wheel rim; 2 fixed ring; 3 wheel center; 4 wheel hub; 5 rubber body; 6 bolt

Fig. 1 W-shape resilient wheel diagram

Fig. 2 Finite element model of resilient wheel

The finite element analysis of elastic wheel

The discrete model of resilient wheel. Simplify elastic wheel model, ignoring the small size geometry characteristic, such as surface chamfer and bolt hole geometry characteristic, which will not affect the calculation. Rubber body adopts tetrahedral mesh, the rest parts use hexahedral grid. The calculation model in total has 165353 elements and 88044 nodes. Finite element model of elastic wheel is shown in figure 2.

The material parameters of resilient wheel. Wheel Rim, fixed ring and wheel center adopt CL60, rubber body use natural rubber and the shore hardness is 70 degrees. The physical properties of the material parameter are shown in table 1.

Tab. 1 The physical properties of the material parameter

	Density (g/cm^3)	Elasticity modulus (MPa)	Poisson's ratio	Ultimate strength (MPa)	Yield strength (MPa)	Allowabl estress (MPa)	C10 (MPa)	C01 (MPa)
CL60	7.8	210000	0.3	1000	600	500		
Natural rubber	1					6	2.9	0.726

Tab. 2 Load value of each working condition

operating conditions	radial (N)	Load (N)	axial (N)	Load (N)
linear condition	F_{z1}	73575		
curve condition	F_{z2}	73575	F_{y2}	41202
turnout	F_{z3}	73575	F_{y3}	24721
exceptional condition	$F_{z\lim}$	148860	$F_{y\lim}$	49240

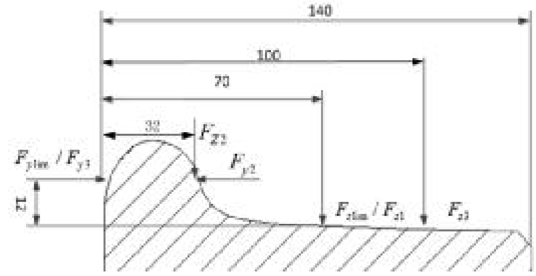


Fig. 3 The calculated load action position

Calculation conditions and boundary conditions

According to “UIC510-5 Technical approval of monolithic wheels (2003)” standard [9], strength calculation is divided into five calculation condition. Considering there is no relative movement between the wheel with the axle, so the fixed constraint is imposed on the surface of wheel hub hole. The calculate load action position as shown in figure 3.The load value as shown in table 2.

The results of calculation and analysis

Using the finite element method analyze the stress distribution on the wheel under different working conditions. The wheel components under different conditions that stress distribution and maximum stress value as shown in table 3.

From table 3 shows, the maximum stress is 213.54 MPa when wheel rim under the working condition of five kinds of computing, safety coefficient is 2.81. The rubber body's maximum stress under the unexceptional condition is 1.65 MPa, safety coefficient is 2.12, and in the exceptional condition, the rubber body’s maximum stress within the scope of the allowable stress. Wheel center in the exceptional condition, the maximum stress is 90.28 MPa, the safety coefficient is 6.65. Fixed ring in the exceptional condition that the maximum stress is 115.52 MPa, safety coefficient is 5.19.

Figure 4 and figure 7 show the rubber body's stress distribution contour when elastic wheel under other conditions. By the figure shown, the maximum stress is 4.939 MPa when rubber body under the exceptional condition. In normal driving conditions, the maximum stress is 2.673 MPa while under turnout, safety factor of 1.31. Therefore, rubber body under various operating conditions, still has larger compression allowance , satisfies the requirement of strength of structure design.

Tab. 3 The results of stress contour of different conditions

Component	operating conditions	maximum Von Mises stress (MPa)	allowable stress (MPa)	maximum stress area
wheel rim	assembly condition	0.79	400	On the interface between rim with the rubber body
	linear condition	130	400	Near the wheel/rail contact point
	curve condition	198.35	400	Near the wheel/rail contact point
	turnout	130.94	400	Near the wheel/rail contact point
	exceptional condition	213.54	600	Near the wheel/rail contact point
rubber body	assembly condition	0.31	3.5	interface between rubber body with wheel rim
	linear condition	1.34	3.5	interface between rubber body with wheel rim
	curve condition	1.65	3.5	interface between rubber body with wheel rim
	turnout	1.34	3.5	interface between rubber body with wheel rim
	exceptional condition	4.94	5	interface between rubber body with wheel rim
wheel center	assembly condition	0.51	400	interface between rubber body with wheel center
	linear condition	6.87	400	interface between rubber body with wheel center
	curve condition	17.91	400	interface between rubber body with wheel center
	turnout	6.87	400	interface between rubber body with wheel center
	exceptional condition	90.28	600	interface between rubber body with wheel center
fixed ring	assembly condition	0.52	400	interface between rubber body with fixed ring
	linear condition	5.16	400	interface between rubber body with fixed ring
	curve condition	4.36	400	interface between rubber body with fixed ring
	turnout	5.16	400	interface between rubber body with fixed ring
	exceptional condition	115.52	600	interface between rubber body with fixed ring

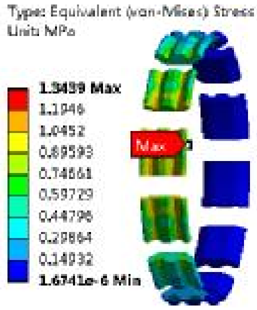


Fig. 4 Stress contour of rubber when wheel under linear condition

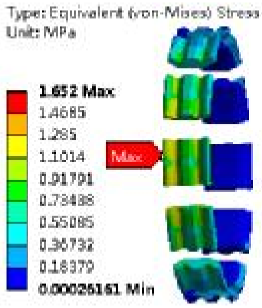


Fig. 5 Stress contour of rubber when wheel under curve condition

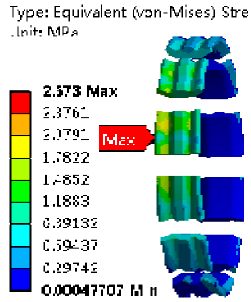


Fig. 6 Stress contour of rubber when wheel under turnout

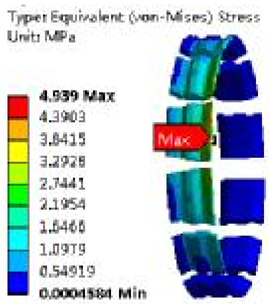


Fig. 7 Stress contour of rubber when wheel under exceptional condition

Conclusion

New W-shape elastic wheel is proposed, which has good application and reference value to the study of elastic wheel. Analysis shows that in the five different conditions, the wheel parts can satisfy the requirement of strength, and have bigger safety coefficient. Under the condition of assembly condition, the maximum stress area in the contact surface between the rubber body with other components, in other conditions, the maximum stress area near the scope of the loading point along the radial.

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