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# Study on Main Factors of Walking Tire Wear in Straddle Type Monorail Vehicle based on ADAMS/Tire

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***Abstract*— Aiming main factors of walking tire wear in straddle type monorail vehicle, this paper made utilization of the multi-body dynamics analysis software Adams to set a "car body-tire- track beam" coupled system model of straddle-type monorail vehicles. simulation analysis of tire wear main factors under the condition of pure braking and cornering, curves are obtained which describes the relations between slip ratio, slip angle, vertical load, the longitudinal force, lateral force and longitudinal and lateral wear abrasion main factor main factor. The mechanical properties of the tire are an important basis to optimize tire design and improve tire performance. Using ADAMS/Tire can simulate a variety of driving conditions of the tire, and then calculate the mechanical parameters of straddle type monorail vehicle tires through mathematical model in all conditions. which can reduce the cost of tire test, and optimize tire design, which can make ca-responding adjustments to tire design and thus improve and optimize the vehic1e With the simulation results of the tire wear main factor model, a reliable quantitative analysis of tire wear under different motion states is provided and played an important role in extending the life of the tire.**

***Keywords*— Component; Tire Wear; Monorail; Walking Tire; Simulation***

## I. INTRODUCTION

With the accelerating process of the city, road congestion, environmental pollution and traffic safety problem are increasingly becoming difficult points which constrain the development of the city. The rail transportation which relies on its great transportation amount, high-speed punctual and economical space and energy etc. has gradually become the mainstream transport system in the city. In urban rail transportation system, straddle type monorail transit is a new type urban rail transit mode, it has unique advantages and characteristics, which takes the electrical machinery as the power supply, and the bogie rides on PC track beam, depends on the friction between the traveling wheel (pneumatic tires) and the top surface of track beam to drive monorail vehicle running along the running surface of the monorail track. Through the contacts between the steering and stabilizing wheels with the side face of track beam to ensure the ability of guidance and steady running. (as shown in Fig.l). But ,on one hand walking wheel, steering the straddle type monorail vehicle running process, it's running system composed of stabilizing wheels which not only ensures the low noise and small radius against derailment, at the same time because "space over closed and static" causes the tire wear speed increases, life circle low, the number of scrap tire is amazing.

Taking the Chongqing straddle type monorail transit line 3 as an example, there are 20 rubber tires on each car, the total number of tires of each train can reaches a total of 80(four cars)— 160 (eight cars), Every year in the whole line of Line 3 can bring more than twenty thousands of waste tires. The rapid consumption of rubber tires will undoubtedly increase the operation cost, restricting the promotion of straddle type monorail transit system in the world.

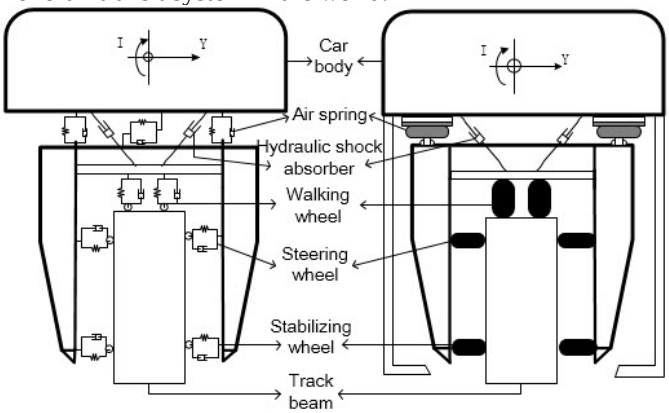


Fig.1. Straddle type monorail vehicle topology diagram

As the main part of the monorail vehicle, tires play a role in supporting the vehicle weight, changing and maintaining the driving direction, transmission power and driving force, and cushioning the impact of the road. The performance of the tires will directly affect the safety of the vehicles.

In the actual application process, there are different degrees of wear and tear in various moving states, and the wear of the tire directly affects the performance of the tire. Therefore, there are more and more researches on the wear of vehicle tires at present.

Tire wear is a very complicated problem. A lot of research on tire wear has been carried out at home and abroad. But the wear mechanism of tires has not been fully explored so far, and the wear prediction is difficult to realize. At present, there is no clear evaluation index and method for the wear degree of tire under different motion conditions. In order to evaluate the effect of vehicle movement on tire wear, by introducing the main factor of longitudinal wear and the main factor of lateral wear, the relationship between the main factor of slip and the side angle of longitudinal wear and side angle

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and the main factor of lateral wear is established, and the effect of the vehicle motion state on tire wear is evaluated by the analysis of the relationship curve.

## II. NUMERICAL ANALYSIS THEORY OF TIRE WEAR OF WALKING WHEEL

The wheel is mainly composed of rubber and steel cord material. The super elasticity and incompressibility of the rubber itself make the mechanical behavior nonlinear, the geometric nonlinearity caused by the large deformation of the tire after the tire is inflated, the contact nonlinearity of the tire and the rail surface, the rim and the rim of the wheel, which must be considered in the finite element modeling and analysis of the wheel rail of the walking wheel. According to the tire rubber experiment data provided by the tire manufacturing company, the accuracy of several commonly used rubber constitutive models is compared by using the data processing function of ABAQUS software. It is found that the constitutive equation model of Mooney-Rivlin materials is the most accurate. Therefore, this paper uses Mooney The constitutive equation model of -Rivlin material is used to describe the mechanical properties of the rubber material. The rubber density of all parts of the walking wheel tire is provided by the tire manufacturing company. The constitutive model parameters can be obtained by fitting the experimental data of the rubber tire. Finally, the specific parameters of each part of the tire are shown in Table 1.

TABLE I. RUBBER MATERIAL PARAMETERS OF WALKING WHEEL TIRE

| Material parameters | $C_{10}$ (MPa) | $C_{01}$ (MPa) | $D_1$ (MPa) | density ($Kg/m^3$) |
|---|---|---|---|---|
| Tread rubber | 0.428 | 0.107 | 0.001 | 1113 |
| sidewall rubber | 0.326 | 0.082 | 0.001 | 1107 |
| Cord rubber | 0.581 | 0.145 | 0.001 | 1168 |
| Trigonometry rubber | 0.401 | 0.102 | 0.001 | 1108 |

The diameter of the walking wheel is 1004mm, the width is 340mm, the ratio of the cross section height to width is 0.85, and the rim diameter is 424mm. The tread is used in the longitudinal grooves. The tread pattern is simple and the bearing capacity is large. There are fourteen kinds of rubber materials which are composed of walking wheels, four kinds of steel cord materials, two dimensional section models and material distribution of running wheels, as shown in Fig.2.

Fig.2. Two dimensional section model of walking wheel tire

In the ABAQUS software, the three-dimensional finite element model of the walking wheel tire is established by rotating two dimensional finite element model, and the key words are *SYMMETRIC MODEL GENERATION, REVOLVE. The unit type of the rotating rubber model body is C3D8H (eight node, linear, hexahedral, complete integral and constant pressure hybrid entity), and the type of body element corresponding to the wire cord is SFM3D4R (four node, reduced integral, tetrahedral surface unit). This paper mainly studies the partial wear of the tread surface and the track surface, so the grid of the part of the contact between the walking wheel and the track surface during rotation is concentrated, and the non contact tire grid is set relatively sparse. The purpose is to calculate the cost under the premise of ensuring the calculation precision. The 3D finite element model of the runner wheel obtained after rotation is shown in Fig. 3.

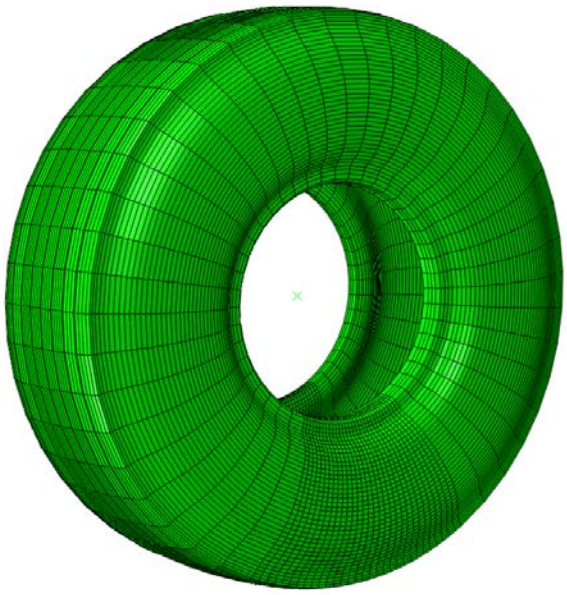

Fig.3.Three dimensional finite element model of walking wheel tire

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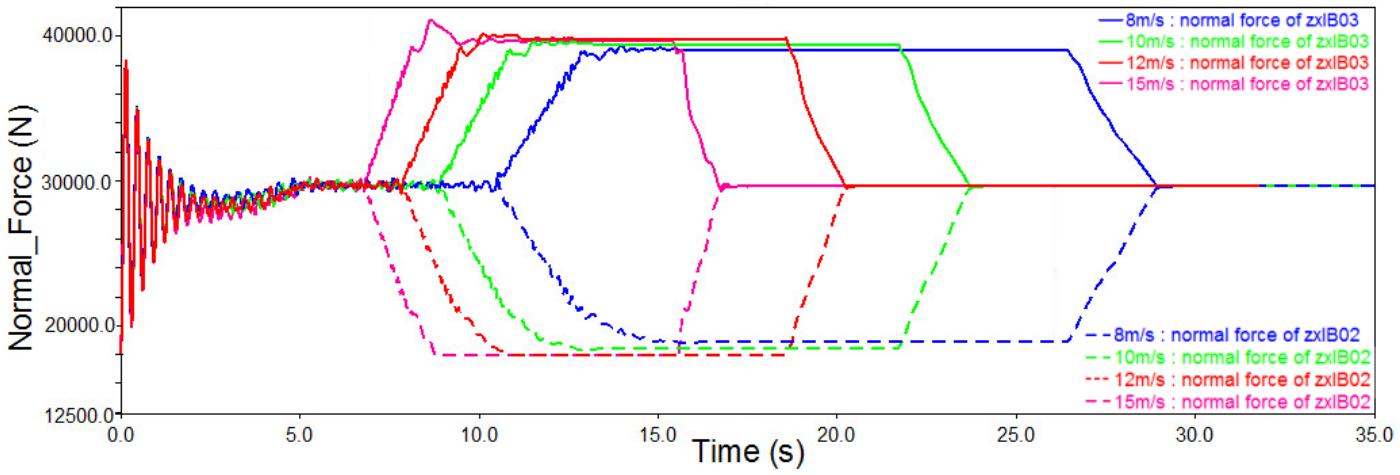
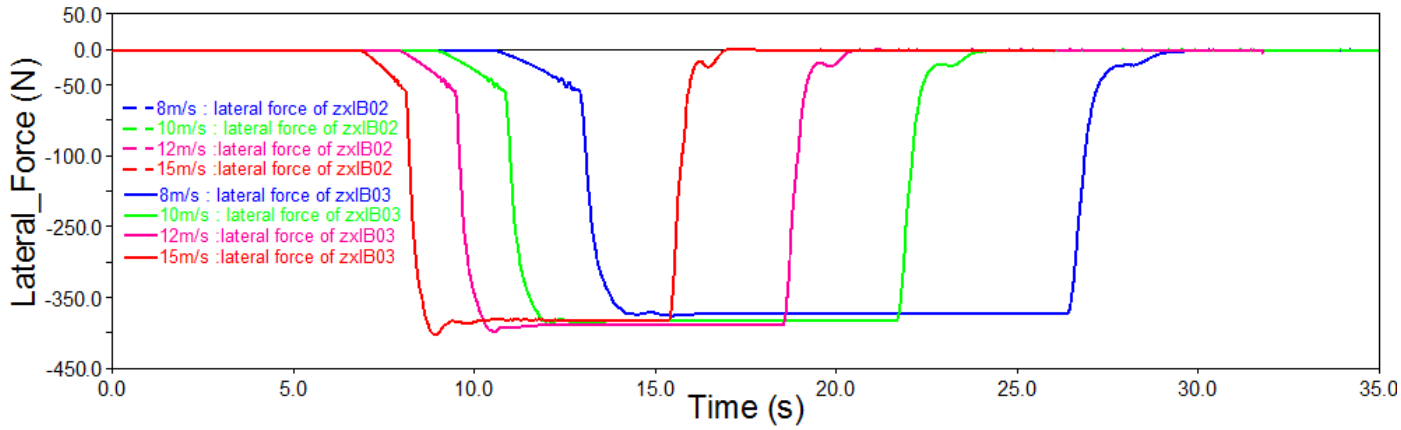
In order to fully investigate the tire wear conditions of the straddle monorail vehicle under different dynamic parameters, the simulation experiment is designed as the following several working conditions.

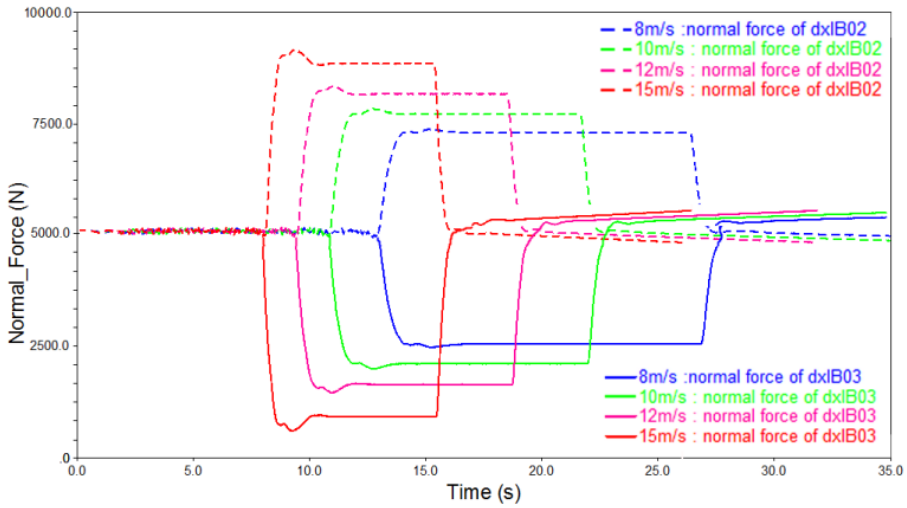
Condition 1: The vehicles pass the test track at different speeds. (Speeds are 8m/s, 10m/s, 12m/s, 15m/s respectively)
The data to be measured include: the history of the vertical force of the front and rear bogies, the left and right running wheels, the history of the left and right running wheels, the history of the lateral deviation of the front and rear bogies, the lateral force of the front and rear bogies, the history of the lateral forces, and the left and right bogies. Trend map

Condition 2: Vehicles pass the test track at a constant speed under different load conditions (loads are 21900kg, 23900kg, and 25900kg, respectively).

The data to be measured include: the left and right bogies left and right running wheels vertical force history diagram, left and right bogies left and right running wheels side slip angle change history diagram, front and rear bogie left and right running wheels lateral force history map, front and rear bogies left and right running wheels Vertical Force History Chart



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## III. ADJUST THE CHASSIS PARAMETERS IMPROVE TIRE WEAR

In order to guarantee that the vehicle has good steering characteristics and driving characteristics, car steering wheel (for front wheel) is provided with a camber angle, toe angle, kingpin inclination and caster angle etc.. Because the positioning angle especially camber angle and toe angle exists, bring bigger impact to the automobile tire wear. Practice shows that, the rapid wear, abnormal wear of automobile tires, tire, except with their quality of wheel dynamic balancing, tire pressure and other factors, another important reason is the camber angle, toe angle and unreasonable matching.

### *A. Right front wheel positioning*

The automobile wheel alignment including dip angle and kingpin camber, toe in, master. The whichever parameter does not meet the technical requirements, will cause the tire abnormal wear, especially the former wheel camber and toe incorrectly wear caused by more serious[2].

Camber is to prevent deformation under load may cause the front axle wheel introverted and setting, its role is to keep the front upright in the car rolling, in order to reduce the running resistance and the tire and the ground friction, tire wear uniform. If the front wheel camber is incorrect, that will increase tire wear. Camber is too large, the outer side of the tire shoulder wear; camber is too small, the inner side of the tire shoulder accelerated wear. When the two front wheel camber unequal, will cause the front wheel outward angle side drag, and front wheel swing, thereby increasing the tire wear.

The main cause is abnormal camber deformation front axle, kingpin loose wheel bearings and the gap is too big. Therefore, unilateral tires wear faster when found, should be corrected promptly check these parts [3].

The main role of the front toe is to balance the negative consequences caused by camber of the front wheels in order to ensure integrity of the scroll and improve the steering stability and reduce wear phenomenon dragging wheel on the ground. If the front toe value adjusted properly, it will make the front side trim slippery conditions occur, causing abnormal tire wear. The current value of the wheel before the beam is too large, the center line of the front wheels tend to travel in outward rolling slip inevitably result of wear of the tread laterally from the outside to the inside, the outside tread wear serious raised inner groove; front toe value is too small, the opposite situation with the toe value is too large, the inside of the tread wear serious lateral groove raised. Incorrect toe value for the front tire wear common feature is very flat tread wear, wear very quickly. According to the survey, a unit B1 2020 off-road vehicles toe is 26mm (standard is 3mm-5mm), the tire only took 2 000 km driving pattern bald[4].

Cause the front wheel toe-value is not the main reason for checking normal adjustment to toe value is not accurate, the front axle and tie rod deformation, and the front wheel bearings and ball straight horizontal rod loosening, it usually should be careful to check these sites and maintenance work[5]. Check the value before the beam, application-specific measuring, at a predetermined measurement position of the original measurement, then the original front toe predetermined value adjusted by a rope eyes and infer way is not guaranteed before the front beam value to meet the requirements.

The caster and camber in the role is to ensure the vehicle stability is moving in a straight line, and the steering portability, reducing tire wear. If the caster angle and inclination angle is too large, too small, will cause the front wheel to produce swing and vibration, the impact load increases, aggravate tire wear. Main reasons causing the dip and inclination change caster is sinking and the front axle spring deformation. Kingpin inclination does not meet the requirements, need to remove the front axle of specialized measurement and correction, and the kingpin caster angle does not meet the requirements, it can be adjusted by adding wedge pad between the front axle leaf spring and the front axle.

### *B. The front axle and rear axle parallel*

Automobile front, rear axle parallel axis through the front, after the bridge at both ends of the distance (CA 1091 to 4050 mm, BJ 2020 to 2300 mm) to measure the. For a new car, the axis, the bridge at both ends of the distance difference should not exceed 5mm [6]. If the former, after the bridge is not parallel through the large, will travel in cars like the toe in value is too large, too small, caused by piping sliding tire side and accelerate the tire wear.

Automobile front, rear axle is not parallel usually has two types: fixed not parallel and mobility is not parallel. The existence of fixed is not parallel, tire deflection angle is always in the lower side slip, so tread wear and toe in value is not normal, flat shaped wear. There is variability is not parallel, tire deflection angle is left, right changing, easy to cause the front wheel swing head, so the characteristics of tire wear is tread corrugation.

Main causes of automobile front, rear axle is not parallel to the leaf spring jumping or elastic one side of a leaf spring is too low, before, after the bridge deformation or frame deformation, leaf spring bushing and lug of serious wear and tear or loose. Therefore, in the use of vehicles, to these areas to strengthen the inspection and maintenance, fault found to promptly eliminate.

### *C. Maintains other chassis part technical condition is good*

There are bad technical condition of some chassis parts will also cause for tire suddenly quickly suddenly slow (not uniform), and generates vibration Britain, accelerate the tire wear; the front wheel steering angle is too large, meet straight rod will scrap tire cornering; carriage, bad fender technical condition, may contact with the tire in the car the tire, scratched, therefore, before driving and traffic should pay attention to check, found that the problem should be promptly removed, prevent to cause early damage of tire"

### *D. Braking characteristics*

The technical position of braking system is not good, often causes applies the brake spontaneously or the individual wheel bubble phenomenon makes the tire mix in the trundle frequently is towing to slide, has the serious attrition. For example: When the gap between brake shoe and brake drum too small or the brake shoe returns to the position to be bad, will create spontaneously automatic; If the brake drum loses the circle, probably causes the wheel in some spot bubble, creates tire periodic delaying, causes the tread protector one has severe wear partially[7]

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*E. Steering mechanism clearance, wheel bearing clearance and rim swing amount to meet the technical requirements*

Steering gear gap is too small, the rotation of the front wheel bearing is difficult, easy to wear, if the gap is too large, easy to make the automobile front wheel swing, accelerate the tire wear. Hub bearing too loose will cause the wheel shimmy and running instability, wave shape caused by tyre wear, serious when can cause the wheel thrown out. Hub bearing too tight will cause the vehicle driving wandering. All wheel bearing too tight, will make the car sliding distance decreased significantly. And the temperature at the hub was significantly increased in the running process, increase tire wear.

Poor technical condition of these parts, not only will affect wheel alignment and can cause abnormal tire wear directly. Steering mechanism and wheel bearings loose, swinging amount exceeds the required standard rotating wheel vehicles (such as CA 1091 automobile wheel cars swing of less than 10 mm), will make the wheels roll, resulting in a wave-shaped tire wear.

## IV. CONCLUSION

Factors that affect tire wear are more drivers driving in the ordinary course of operations to note summarizes the traffic in front of the bus and regularly rotate the tires. During use of the tire, the tread is gradually consumed, but because of the discontinuity with the tires, the tire slip amount of the road type, and the affected road arch, the automobile front and rear, left and right wheels of different wear rate. Some tire wear heavy, some light wear and tear, or even unilateral appear uneven tire wear. In order to extend the life of the tire, the tire must be regularly transposition. Timely transposition can extend tire life by about 20%. Tire rotation is usually conducted among secondary vehicle maintenance, road camber in larger areas or summer, a larger difference in tire wear may be appropriate to increase the number of transposition. There are two methods to change a tire and cross-circulation method. Cross transposition law applicable to the regular on the arch of larger vehicles traveling the road, while the law applicable to the regular cycle of change in the relatively flat road vehicles. Found the problem to be immediately removed to prevent damage caused by tire early.

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