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Research Status of Anti Slip Characteristics of Asphalt Pavement for Vehicle Turning and Braking Stability

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Abstract

The slip resistance of asphalt pavement is an important factor affecting the driving safety of vehicles, and its deficiency will cause the braking distance of vehicles to increase, and even cause traffic accidents. On urban roads, because curves are often accident-prone sections, accidents often occur on urban roads and cause greater losses. The results show that the type of asphalt pavement and the driving condition of the vehicle will have a great influence on the slip resistance of the road surface, which is directly related to the braking stability of the vehicle when cornering. The research progress on the anti-slip performance of asphalt pavement oriented to the stability of automobile steering braking in recent years is reviewed.

Keywords

Asphalt Pavement; Anti-slip Performance; Cornering Braking.

1. Introduction

By the end of 2020, compared with the same period in 2019, the national road mileage increased by 18.56 kilometers, 5.1981 million kilometers. Among them, the mileage of highways of grade 4 and above was 4,944,500 kilometers, an increase of 245,800 kilometers over the same period of the previous year, accounting for 95.1% of the highway mileage; Among them, the number of highways of level 2 and above increased by 702,400 kilometers, an increase of 3.0400 kilometers, accounting for 13.5% of the national expressways; The total length of highways is 161,110 kilometers, and 11,400 kilometers are added. Car ownership in China is on the same rise as the number of drivers. China's highway traffic accidents are frequent, traffic accidents are frequent, traffic accidents are frequent. In recent years, although the Ministry of Communications has carried out a number of "safety projects" across the country and obtained extensive social support, the harm of road traffic accidents is still not well controlled, and the overall traffic safety situation is still not optimistic. The fetal road interaction is an important interaction, and its essence is a tribology, and the contact and relative motion conditions of the two must be considered comprehensively [1], but its mechanism is not clear.

The slip resistance of the road surface is one of the important indicators of road driving safety. Detect the gradation of asphalt mixture, aggregate type, upper load, tire pressure, pattern distribution, geometric size and other factors, and the contact surface between the contact surfaces of the tire road, the pressure of the contact surface, the stress concentration degree of the contact surface and other factors should be taken into account. In addition, the existing asphalt pavement slip resistance assessment mainly adopts pendulum friction meter, lateral force coefficient tester and other means, which is affected by the test temperature, humidity, speed and other factors, the reliability is poor, can not be combined with the actual driving state, and cannot determine the safety limit. When evaluating the anti-slip performance of the road, factors such as tires and road surfaces should be

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considered, and the contact between the tires and the road surface should be considered. According to the theory of vehicle dynamics, the braking performance of the vehicle has a lot to do with driving safety, and if the braking distance is too long, or there is sideslip during emergency braking, it may cause serious traffic accidents [2-3]. Therefore, the braking characteristics of the vehicle play a crucial role in the safe operation of the vehicle.

2. Study on the Mechanical Characteristics of Vehicle Turning Behavior

The automobile brake anti-lock braking system has been extensively studied for a long time and has been successfully applied in automobiles. When the car is steering, tires are required to provide sufficient lateral and longitudinal force for the car to ensure the stability of the steering. When the steering process, when the steering process, the longitudinal force of the tire tends to be saturated, and it cannot provide sufficient lateral force for the vehicle, so that the vehicle is easy to lose its immunity during the steering process, causing the rear axle load to be transmitted forward, so that the vehicle is unstable and easy to deviate in the restricted lane. Therefore, from the perspective of steering stability, it is necessary to consider both the stability of the vehicle itself and the lateral deviation of the vehicle to avoid collision accidents caused by the vehicle crowding into the side lane. At present, the research on the stability of automobile steering brake is still very lacking, and most of them are limited to the force analysis of a single tire, which cannot accurately describe the real automobile steering brake characteristics, and cannot meet the safety needs of automobile steering braking. Therefore, the simple simulation analysis cannot comprehensively explain the braking and steering behavior of the vehicle, and it is necessary to consider the slip resistance of asphalt pavement, construct a vehicle-road coupling analysis model that can simulate the dynamic process of vehicle driving, braking and steering, and carry out the overall stability study of the vehicle, so as to lay a foundation for the evaluation of the steering brake stability of the vehicle under the coupling of multiple working conditions. This project will provide scientific basis for improving braking stability when steering, evaluating road safety, improving vehicle driving safety, and protecting people's lives and property.

3. Research History of Pavement Anti-slip Performance and Tire-pavement Friction Mechanism

The anti-slip properties of asphalt pavement have an important influence on the tyre-road coupling contact characteristics and the stability of the vehicle during braking and cornering. To this end, in order to clarify the contact friction characteristics of the tire road and improve the braking stability of the car when steering, many scholars in the field of road and automotive engineering have carried out the following research.

In the 20s of the 20th century, France, the Netherlands, the United Kingdom and other European and American countries took the lead in carrying out road anti-slip tests to explore the mechanism of its anti-slip force [4-6]. In 1949, under the leadership of the World Road Association (PIARC), the Technical Committee on Pavement Characteristics (TC-1) was established and officially listed road surface anti-skid as an important topic at the International Road Conference [7]. The "Highway Skid Resistance Conference" jointly organized by Charlottesville, USA, and Columbus in the United States extends the research of highway skid resistance to multidisciplinary fields including road surface texture, surface structure, vehicle operating status, traffic safety and economic effects. In the seventies of the twentieth century, the United Kingdom proposed and designed a set of demand indices for asphalt pavement surface aggregates and structural thickness based on road type and driving load [8-9]. In the eighties of the last century, in view of the contradiction between the anti-slip performance and durability of asphalt pavement, the International Road Conference put forward the key points to optimize the anti-slip performance of asphalt pavement: first, we must pay attention to the mineral performance of raw materials, secondly, we must consider the structural structure of the pavement, that is, the type of gradation, and finally, the construction technology in the process of road paving

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[10-11]. In 1992, in the "International Joint Experiment" project in Belgium, Spain and other places, we proposed a new concept, the International Frictions Index, to measure the slip resistance of asphalt pavement [12]. After entering the 21st century, due to the introduction of fractal theory, finite element numerical simulation, machine vision and deep learning, a new round of research on the anti-slip characteristics of asphalt pavement has been carried out and rich results have been achieved [13-16]. At present, the research on the anti-slip of road materials in China is slow and far behind foreign countries. In the 70s of last century, China has not established a complete set of road surface anti-slip performance evaluation system, because of the lack of testing instruments and evaluation standards, we mainly according to the tester to the car brake distance to judge the road surface anti-slip performance, until 1980, China successfully produced the first pendulum tribometer. Since the "Seventh Five-Year Plan", we have carried out special research on the anti-slip characteristics of asphalt pavement, and on this basis, we have gradually formed a domestic anti-slip evaluation system, and issued the "Asphalt Pavement Design Code" in 1987, which proposed the value of the pendulum measurement friction coefficient as the technical index of asphalt pavement anti-slip, and also proposed the value of mineral surface smoothing. In view of the shortcomings that the static load test currently used cannot accurately reflect the dynamic friction characteristics of the tire-pavement, the Academy of Highway Sciences of the Ministry of Communications carried out a special research on asphalt pavement anti-skid from 1992 to 1994, and successfully developed a lateral force-friction factor test vehicle, and in 1997, the "Asphalt Pavement Design Code" included the lateral force-friction factor (SFC) into the evaluation index of asphalt pavement anti-skid dynamics, but the applicability of this index was poor due to the lack of reliable highway data [17]. With the rapid development of national high-grade highway construction, a large number of measured data have been obtained, and the 2006 edition of the Code for the Design of Asphalt Pavement has made corresponding corrections to the thickness of the pavement structural layer (MTD) and the lateral force coefficient (SFC). Today, in the 21st century, with the development of the times and the introduction of various research methods and advanced ideas, Chinese scholars have conducted comprehensive research on the anti-slip performance of asphalt pavement from the aspects of raw material properties, mixture mix ratio, pavement construction technology, media between tire pavement, road engineering and vehicle engineering, computer science and other multidisciplinary interactions. At present, great progress has been made in the study of the slip resistance of asphalt pavement in China [18-19]. With the worldwide study of road anti-slip characteristics, it is widely recognized that there are four factors in the production of road anti-slip characteristics:

1) The cutting effect of the road surface micro-bulge on the rubber: Because the road aggregate is harder than the rubber particles of the tire, when the tire touches the road surface, the micro-bulge of the road surface will be embedded in the rubber particles of the tire, causing stress concentration. In addition, because the contact between the tire and the road is a dynamic process, the shear force caused by the slip of the tire and the road exceeds the shear strength of the rubber, which will form a "furrow" effect on the surface of the tire, thus forming a friction pair. Therefore, the surface structure has a direct impact on the surface slip resistance.

2) Adsorption on the contact surface between the tire layer and the ground: Between two adjacent molecules, a mutual attraction called van der Waals force is formed. Therefore, a similar adsorption effect occurs between the tire and the road aggregate under higher loads. Van der Waals force is a special force field, its size and the temperature of the molecule, the characteristics of the contact material, the medium of the contact interface, etc. have a lot to do. In addition, increasing the area of the contact surface can significantly improve the adsorption capacity.

3) The adhesion effect of tires and roads: When vehicles pass through the road, the contact surface with the road is usually divided into two areas, one is the sliding area far from the road, and the other is the adhesion zone. When the tire is driving, because of its viscoelastic characteristics, when in contact with the road surface, it will inevitably produce strong adhesion, and at the same time, the tire needs to constantly get rid of this adhesion when driving, so as to leave the adhesion zone, and the

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friction generated in this process is "adhesion". It is clear that this friction component is closely related to the size of the adhesion zone and the material of the tire layer itself.

4) Elastic deformation of rubber tires: rubber is a viscoelastic substance that is easy to deform, under the influence of the load above and the internal pressure of the tire, rubber constantly produces and restores the deformation of elasticity, at this time, on the contact surface of the tire and the road, the pressure is constantly recombined, forming a force opposite to the direction of vehicle movement, at the same time, the hysteresis and resistance caused by the hysteresis effect of the tire forms a friction force. The results show that the upper load of the tire, the material characteristics of the rubber and the macrostructure roughness of the pavement are the main factors affecting the stability of asphalt pavement.

4. Stability Study under Vehicle Cornering Braking State

The cause of automobile instability The main manifestation of the car in operation is the nonlinear region of the tire, that is, when the declination angle of the tire increases, its lateral force tends to be saturated. When the front axle is saturated, it is easy to slip, causing the vehicle to deviate from the driver's desired track; When the rear axle is saturated, it is very prone to more dangerous conditions such as tail flicking. When the vehicle brakes, when the difference between the braking force of the left and right wheels or the front and rear wheels is too large, it will cause the brake to deviate, the rear axle slip or the front wheel to lose steering ability, causing the car to lose control and deviate from the original driving direction, resulting in the instability of the car. When the car is steering, in order for the car to complete the intended steering, tires are required to provide the car with sufficient lateral and longitudinal forces. When the friction force is offset by the longitudinal force, the lateral force of the car will approach zero, making the car turn insufficient and unstable. Because the conditions of automobile operation are very complex, there are many factors that lead to unstable car steering, and the main reasons for unstable car steering are summarized as follows:

(1) Under certain operating conditions, the cornering characteristics of the car, such as the lateral and longitudinal acceleration of the car, may cause the car to turn or turn, which in turn leads to the stability of the car.

(2) The longitudinal force of the wheel brake will cause the lateral stiffness of the wheel to decrease, which in turn will lead to sideslip of the front and rear wheel axles, resulting in wheel instability;

(3) The yaw angle speed of the car is usually slower than the driver's steering wheel, and this delay will lead to a larger steering torque of the car during emergency lane changes. When the torque lasts for a certain period of time, it will lead to a large declination angle of the center of mass of the car, and when the declination angle of the center of mass of the car is too large, it will become very difficult for the driver to operate, which will easily lead to the instability of the car.

(4) Since the two tires are under different friction coefficients, the two tires are in different driving conditions, and it is easy to produce large attitude changes. In addition, disturbances such as uneven roads and side winds will cause changes in the attitude of the car, and if these changes lead to a large lateral shift in the center of mass of the car, it will also lead to a decrease in the stability of the car;

(5) In the emergency, the driver made some wrong actions in a state of panic, so that the car is in a non-linear area, at this time, the center of mass of the car has a large lateral tilt, making it difficult for the driver to adjust, resulting in a decrease in the stability of the car.

Chakraborty S et al. [20] used the Kalman filter method to construct an 11-degree-of-freedom vehicle model for estimating the friction factor and longitudinal lateral friction when the vehicle is running. Han K S et al. [21] constructed a 6-degree-of-freedom car model in which the tires and suspension are connected via a Kelvin model. On this basis, the method is combined with the Dugev tire model to realize the real-time estimation of the maximum friction factor of the vehicle. (3) Dynamic simulation and analysis of automotive multibody system: The dynamic simulation of automotive multibody system is the dynamic simulation of automobile multibody system. CarSim is a vehicle

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simulation software developed by Mechanical Simulation Company with the whole body as the core. It is essentially a model library + parameter library + solver + post-processing tools + configuration interface, and it itself comes with a large number of models, so users save the cumbersome process of modeling and parameter adjustment, and only need to adjust the parameters after calling the model, you can simulate. CarSim can animate simulation results, provide the tools needed for real-time simulation, and provide the interface needed for joint simulation, allowing users to integrate CarSim with their own software and hardware platforms. Simulation platforms such as driving simulators can be easily implemented. ADAMS/CAR is a multibody dynamics simulation tool from Mscsoftware[22], its main function is to perform multibody dynamics modeling and simulation. ADAMS has an animation generation function, which can display the results of the simulation in the form of animation, which makes it easier for users to understand complex mechanical structures. It also has a joint simulation interface that can be jointly simulated with other simulation tools. However, the modeling of cars is more complex and the simulation time is relatively long [23]. Cruise is software developed by AVL to drive system simulation. Cruise, like Car Sim, also has a large number of internal modules, which can be called and adjusted parameters, can also be simulated, there is also a joint simulation interface, and it can also be simulated on the real-time simulation platform, but Cruise is a pure "data stream", without any animation effects, only data and curves can be used to observe the simulation effect.

5. Summary

At present, the research on the stability of automobile steering brake is still very lacking, and most of them are limited to the force analysis of a single tire, which cannot accurately describe the real automobile steering brake characteristics, and cannot meet the safety needs of automobile steering braking.

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