Study on the Correction Method for Lateral Force Coefficient Based on Multiple Influencing Factors

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Abstract. The lateral force coefficient of pavement is a critical indicator for assessing the technical condition of road surfaces and a key measure of driving safety. Therefore, enhancing the accuracy of data results by correcting for various influencing factors during the detection process is essential. This study focuses on the correction methods for different influencing factors, including variations in tire manufacturers, different levels of tire wear, distinct trajectories, varying water film thicknesses, different driving speeds, and temperature fluctuations. A comprehensive correction model is proposed, providing a reference framework for systematically correcting detection data.

Keywords: pavement; correction model; skid resistance; lateral force coefficient detection; influencing factors.

1 Introduction

With growing road transportation demand, highway safety has become a critical issue. The Side Force Coefficient (SFC) is a key indicator of skid resistance, directly affecting vehicle stability and road safety, making its accurate measurement essential for safety and maintenance decisions [1].

In recent studies, Fwa [2] investigated asphalt pavement skid resistance using 3D laser scanning technology and pressure-sensitive film, proposing a new tool to improve measurement accuracy, but did not comprehensively consider environmental factors like water film thickness. Zhao et al. [3] analyzed tire abrasion's effect on skid resistance but lacked manufacturer comparisons and water film analysis. Zhan et al. [4] proposed strategies for wear-resistant materials and preventive maintenance but did not address dynamic factors like driving trajectory. Deng et al. [5] examined wear equipment effects but omitted temperature and speed influences. Overall, these studies do not comprehensively analyze multiple influencing factors or their combined effects on SFC.

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To accurately assess the skid resistance of highway pavements, precise detection and analysis of the SFC are essential, but various factors influence detection accuracy. The current Chinese standard, *Field Test Methods of Highway Subgrade and Pavement* (JTG 3450-2019), only addresses correction for speed and temperature, which is insufficient given the diverse factors affecting SFC, such as tire manufacturer, wear level, trajectory position, and water film thickness. These complexities make existing correction methods inadequate for accurate pavement friction assessment. Therefore, this study investigated correction methods considering multiple influencing factors, including speed, tire manufacturer, wear level, temperature, trajectory, and water film thickness. A comprehensive correction model was developed, providing a scientific basis for improving the accuracy of SFC detection. This model expands on existing standards to better address diverse conditions, offering more accurate support for road safety and maintenance.

2 Detection method for lateral force coefficient

Pavement skid resistance, expressed by the friction coefficient, can be tested using two approaches: the direct mechanical model and the indirect geometric method. Advances in technologies like computers, automation, and micro-measurement have led to various skid resistance testing devices. [9]According to Chinese standards (JTG 3450-2019, JTG F80/1-2017, JTG 5210-2018), the SFC is commonly used to evaluate skid resistance in applications like project acceptance and maintenance inspections. This study uses the SCRIM device to analyze factors affecting SFC detection. The SFC is defined as the ratio of lateral frictional resistance, experienced by a smooth test wheel set at an angle, to the vertical load on the wheel. It effectively characterizes both braking performance and skid resistance during lateral sliding. [10]

This equipment uses smooth tires to simulate the worst skid resistance conditions during vehicle operation. The most widely used device in China for this purpose is the SCRIM, originally designed in the UK by WDM Ltd. It operates with the test wheel angled at 20° to the direction of travel under a fixed vertical load, generating lateral frictional resistance detected by pressure sensors. [6] The ratio of this resistance to the vertical load gives the SFC. [8]SCRIM also has a water spray system providing a water film thickness of up to 1 mm during testing.

3 Methodology

3.1 Mechanism of Skid Resistance

The skid resistance of pavement is influenced by three main factors: pavement, vehicle, and environmental. Their combined interaction affects skid resistance through vehicle kinematics, contact mechanics, and fluid mechanics. Pavement factors like asphalt mixtures, which are viscoelastic materials similar to vehicle tires, interact at the tire-road contact surface, involving tire tread patterns (lateral, longitudinal, and block) and pavement texture at various scales, resulting in a complex friction mechanism. Most studies agree that tire-pavement friction primarily originates from two components: adhesion and hysteresis, as shown in Fig. 1. [7] The adhesion component is produced by molecular interactions between the tire and the pavement and is linked to the actual contact area, which can be significantly reduced by a water film. The hysteresis component, resulting from energy losses due to rubber deformation as it encounters pavement irregularities, is the main source of friction on rough surfaces, especially at high sliding speeds, while adhesion dominates at lower speeds.

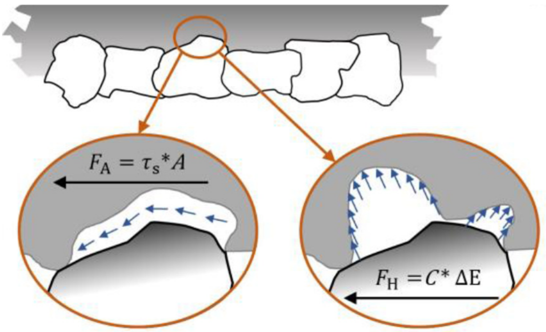

Fig. 1. Key components of tire-road friction

3.2 Analysis of Various Influencing Factors

(1) Test site: To ensure the smooth execution of the experiments, a test site was selected that features low traffic volume, stable friction coefficients, and minimal external interference factors.

(2) Testing equipment and parameters: The experiment utilized a mainstream SFC testing vehicle. The key parameters of the equipment are listed in Table 1.

Table 1. Equipment parameters

Parameter	Value
Pavement friction coefficient	Lateral Force Coefficient (SFC)
Test wheel angle	20 degrees to the direction of travel
Test wheel vertical load	2000 N ± 20 N
Test speed	20~80 km/h

(3) Experimental plan: Due to the numerous factors influencing friction coefficient measurements, a single-variable control method was adopted. The factors were analyzed sequentially in the following order: tire manufacturer, tire wear level, driving trajectory, water film thickness, speed, and temperature. The detailed procedures are as follows: To evaluate the factors affecting SFC, a series of experiments were conducted while holding most parameters constant. First, new tires from different manufacturers were tested at a fixed speed of 60 km/h with controlled water film thickness and temperature to determine the impact of tire manufacturer. Then, tires with different wear

levels (new, 2 mm worn, and 3 mm worn) were tested to assess the influence of tire wear. For the trajectory position, the test wheel's position was adjusted (middle of the wheel path, 1 meter offset, and lane centerline) to analyze differences in SFC. Water film thickness was varied by controlling the valve opening (0% to 100%) to understand its effect on skid resistance. The effect of speed was evaluated by measuring SFC at six different speeds (20-70 km/h), while the influence of temperature was assessed by testing across different ranges (0 °C to 60 °C, in 5 °C intervals).

4 Experimental Results and Correction Model

Based on the experimental results and statistical analysis, a comprehensive correction model for the lateral force coefficient of pavement was developed. The correction model is as follows:

$$SFC = f(SFCc, ti, th, p, hsm, v, t)$$

where *SFCc* is the measured lateral force coefficient; *ti* represents different test tires; *th* indicates the tire wear level; *p* is the trajectory position; *hsm* refers to the water film thickness; *v* is the test speed; *t* is the test temperature.

4.1 Influence of Different Tire Manufacturers

Fig. 2 shows the influence of different tire manufacturers (A, B, C, D) on SFC across four road section levels. At levels 1, 2, and 3, manufacturers A, B, and D have similar values, while C deviates. At level 4, A, B, and C align more closely, but D differs significantly. A marked drop in SFC is seen from level 3 to level 4, indicating reduced friction with increased road section level. Despite overall trends, differences remain under demanding conditions. Therefore, verifying tire consistency and correlating with standard values are crucial for reliable results.

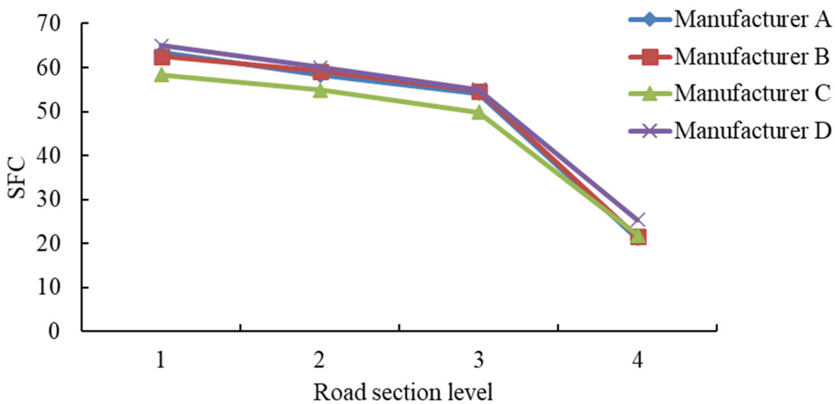

Fig. 2. Influence of tire manufacturer

4.2 Influence of Tire Wear Level

Fig. 3 shows the influence of tire wear level on SFC. When the tire wear level is 0 mm or 2 mm, the SFC remains constant at 41, indicating that minor wear (up to 2 mm) does not significantly affect friction. However, at 3 mm, the SFC drops to 38, showing a noticeable decrease in skid resistance. This suggests that tire wear beyond 2 mm negatively impacts SFC, emphasizing the importance of monitoring tire condition to maintain road safety.

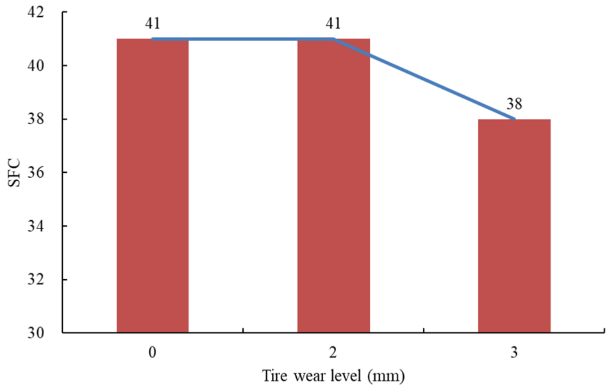

Fig. 3. Influence of tire wear level

4.3 Influence of Trajectory Position

Fig. 4 illustrates the influence of trajectory position on SFC values. When the testing trajectory deviates by 1 meter from the normal wheel track, the SFC value is significantly higher (48) compared to the normal trajectory (40). This indicates that trajectory deviation substantially impacts SFC, highlighting the need to carefully control the test trajectory to ensure reliable results and accurate skid resistance assessments.

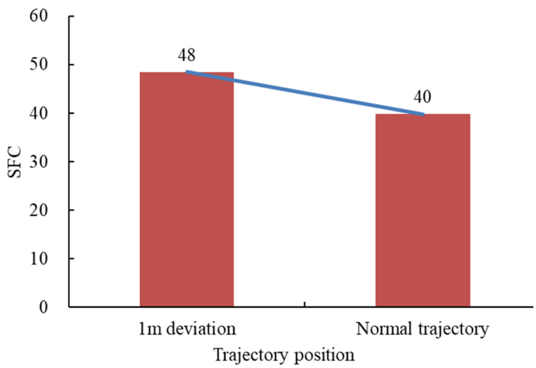

Fig. 4. Influence of trajectory position

4.4 Influence of Water Film Thickness

Fig. 5 shows that SFC measurements without water (78) are significantly higher than those with water, indicating that a water film greatly reduces skid resistance. When the water film thickness reaches 0.5 mm, SFC drops sharply to 53, but further increases (0.7 mm, 1 mm, 1.5 mm) have minimal effect, stabilizing around 52-53. This highlights the significant impact of a small water layer, beyond which additional water has little influence.

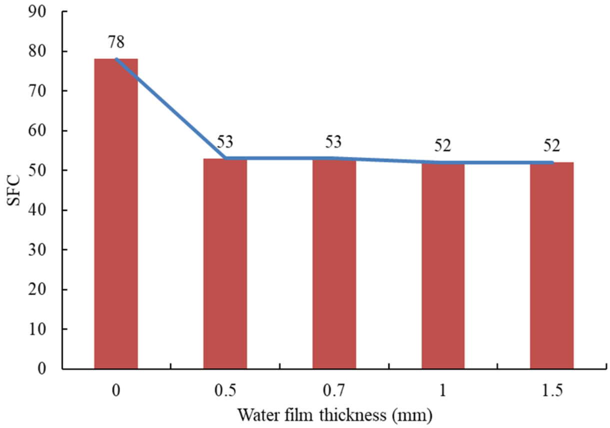

Fig. 5. Influence of water film thickness

4.5 Influence of SPEEd

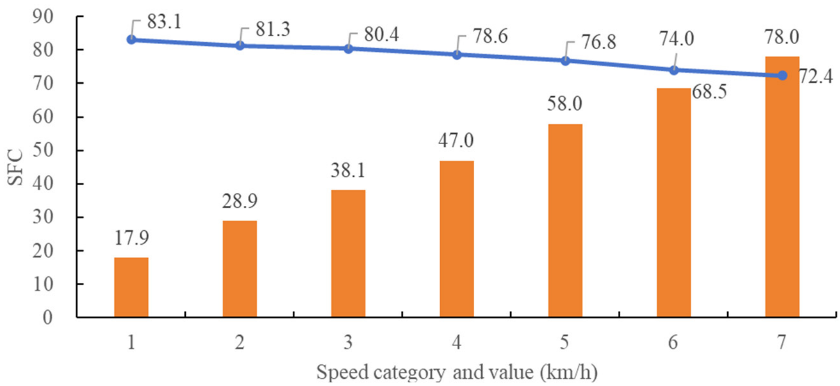

Fig. 6. Influence of speed

Fig. 6 shows that as speed increases, SFC values exhibit a decreasing trend, consistent with correction standards. For example, at a low speed of 17.9 km/h, the SFC is 83.1, but it gradually decreases to 72.4 at 78 km/h. This demonstrates that higher driving speeds lead to reduced friction between the tire and road surface, indicating a decline in skid resistance. The consistent reduction across speed categories highlights the importance of speed as a key factor affecting skid resistance and supports the need for speed-related corrections to ensure accurate pavement evaluation.

4.6 Influence of Temperature

Fig. 7 shows the influence of temperature on SFC measurements. As temperature increases from 10° C to 60° C, SFC values decrease from 76.8 to 66.4, indicating reduced friction. Beyond 55° C, the decrease becomes less pronounced, suggesting a saturation effect. This trend underscores the need to consider temperature effects in practical applications and supports temperature-based corrections for accurate skid resistance evaluation.

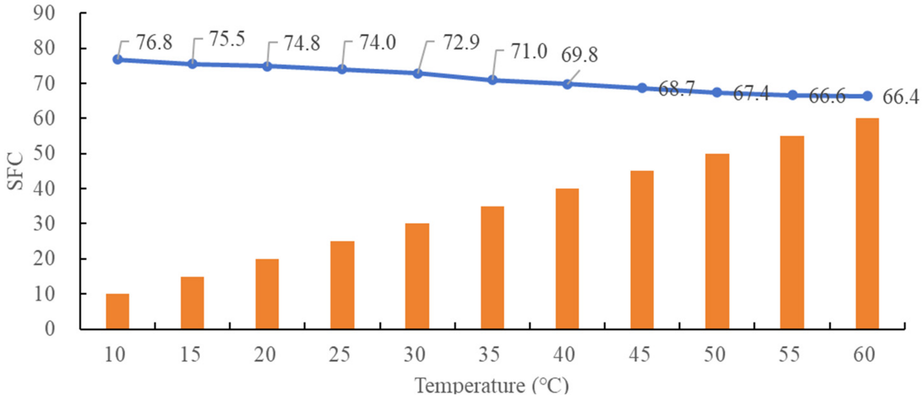

Fig. 7. Influence of temperature

5 Conclusions

This study analyzed six key factors—tire manufacturer, tire wear, trajectory position, water film thickness, speed, and temperature—on SFC, revealing their significant influence on skid resistance. The findings form the basis for a comprehensive correction model that enhances current standards, improving the accuracy and reliability of skid resistance measurements for highway maintenance and safety evaluations. In real-world applications, this model can be instrumental in supporting decision-making for road safety assessments, optimizing maintenance schedules, and ensuring consistent pavement conditions. However, the model may face limitations under complex geological conditions or extreme climate environments that were not considered in this study. For instance, factors like rapidly changing weather, mixed road surfaces, or heavy traffic could affect the model's performance. To address these challenges, future research should extend and refine the model, incorporating additional variables to enhance its adaptability and robustness in various challenging scenarios.

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