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The Effect of Roughness on the Wet Skid Resistance of Tire Tread Compounds

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The Effect of Roughness on the Wet Skid Resistance of Tire Tread Compounds

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Abstract. The wet skid resistance is the main performance of automobile tires, and the excellent wet skid resistance can ensure the safety of the car. In this paper, 60 mesh sandpaper, 400 mesh sandpaper, 1000 mesh sandpaper and 2000 mesh sandpaper were used to pre-grind the sample, which changed the surface roughness of the sample; measured the dry and wet friction coefficient of the sample, and the measured friction pair was smooth Glass surface, rough glass surface and 180 grit sandpaper surface. The experimental results show that the rougher the surface of the sample and the surface of the friction pair, the greater the wet friction coefficient and the better the wet skid resistance.

Keywords: Tire Tread Compounds, Wet Grip Resistance, Roughness, Coefficient Of Friction

1. Introduction

With the advancement of modernization and the rapid development of the world's automobile industry, automobiles have become an indispensable means of transportation in people's lives. The wet skid resistance is the main driving performance of the tire [1-3]. On wet and slippery roads, the friction coefficient between tires and the ground is reduced, and the grip performance is significantly reduced. Vehicles are prone to sideslip and loss of control. Traffic accidents occur from time to time, which directly affects driving safety [4-6].

Moore D F [7] applied the hydrodynamic lubrication theory to the analysis of tire contact with the ground, and proposed the "three-zone concept" (see Figure 1). The lubrication mechanism of the three zones is different. In order to improve the wet skid resistance of the tire, the treatment methods for the three zones are also different, as follows [8,9]:

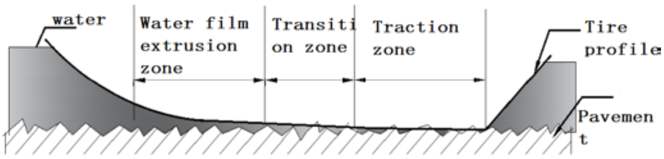

Fig 1. Schematic diagram of the three zones where the tire is in contact with the watery road

1.1. Shorten the Water Film Extrusion Zone

The water film extrusion zone is located at the front of the junction area. According to the research of Moore DF, the main mechanism of action at this time is hydrodynamic lubrication and elastohydrodynamic lubrication. The friction generated in this area is very small, so this area should be shortened to improve the wet skid resistance. The time t_{sf} required for water film extrusion is:

$$t_{sf} = \frac{L_{sf}}{V} = \frac{K_{sf}}{W} \times \frac{\eta A^2}{f(\omega/h) h_i^2} [1 - \frac{h_f^{\ 2}}{h_i^2}] \tag{1}$$

In the formula, Lsf is the length of the water film extrusion zone; V is the vehicle speed; W is the normal load of the tread groove block; η is the viscosity of water; A is the tread groove block area; hi is water The initial thickness of the film; hf is the final thickness of the water film; K_{sf} is a constant related to the shape of the tread groove pattern; $f(\omega/h)$ is a dimensionless surface roughness parameter, expressed by the following polynomial:

$$f(\omega/h) = C_0 + C_1(\varepsilon/h) + C_2(\varepsilon/h)^2 + \cdots \tag{2}$$

In the formula, ε is the average height of the raised peak-to-valley on the rough surface; h is the thickness of the water film; C_i *(i=0, 1, 2, etc.)* is a constant related to the geometry of the specific road surface.

According to formula 2, under the premise of certain road conditions, load, water viscosity and road structure, the water film extrusion speed depends on the water film thickness and the tread groove pattern structure. According to the water film thickness formula, the tread rubber Performance can affect the thickness of the water film. Therefore, reasonable tread rubber performance and tread rubber pattern structure in this area are the main means to improve the wet skid resistance of the tire.

1.2. Shorten the Transition Zone and Increase the Proportion of Interface Lubrication

In the transition zone, the tire part dynamically covers the road surface, and the water film is gradually destroyed, and its thickness also decreases, eventually reducing to the thickness of several layers of water molecules. Therefore, in this area and containing hydrodynamic lubrication and interfacial lubrication, it is a mixed zone of different lubrication mechanisms. In this area, the friction coefficient of the tire changes from the minimum value of the viscous water slip at the front of the transition zone to the maximum value when the interface is lubricated at the rear end of the zone, and the effective friction coefficient varies greatly.

When the water film extrusion speed is given, reducing the transition zone can improve the wet skid resistance of the traction zone. The size of the transition zone depends on the time t_d required in the process of rubber sinking and covering the road surface. t_d can be expressed by formula (3):

$$t_d = \frac{L_d}{V} = [\frac{\rho d}{g}]^{1/2} \times [\frac{A}{E^*}] \times [R \cdot P_i]^{-1/t} \tag{3}$$

In the formula, Ld is the length of the transition zone; ρ is the density of the tread groove block, d is the crown thickness; g is the gravity; R is the road convex radius; Pi is the tire pressure; E^* is the tread rubber compound mold the amount.

This formula shows that, in addition to other external conditions (road surface, tire pressure), the structure of the tire itself and the compound modulus of the tread rubber play an important role in the transition zone time.

1.3. Increase the Traction Area

The water film in the traction zone has been completely or basically eliminated. At this time, the interfacial lubrication mechanism is the mainstay in the zone, and almost all the traction is produced in this zone. Increasing the traction in the traction zone can greatly improve the tire's wet skid resistance. performance. The lubrication of the traction zone is interfacial lubrication. Under this lubrication condition, the deformation factor of friction (hysteresis friction) plays a major role. Therefore, the dynamic performance of the tread rubber is very important to resist the influence of wet slip.

In summary, it can be seen that the roughness of the tread rubber and the road surface has a great influence on the wet skid resistance of the tire. Therefore, the influence of the roughness on the wet skid resistance of the tread rubber has great research value [10].

2. Experimental

2.1. Materials

The materials and material ratios used in the test are shown in Table 1.

Table 1. Proportion of materials required for samples

Material name	Butadiene rubber (BR9000)	carbon black(N110)	ZnO	Stearic acid	Sulfur	Accelerator (TBBS)	Accelerator(TMTD)	Anti-scorching agent (ctp)	Anti-aging agent(4010NA)
Component content (phr)	100	30	3	1	1.8	1.5	0.3	0.1	1

2.2. Preparation of the Compoundsr

2.2.1. Sample preparation. According to the formula, first add raw rubber (NR, BR, SBR) into a small rubber-plastic experimental internal mixer with a capacity of 1 L, the rotor speed is 60 r/min, the temperature is 140 ℃, and the pressure is stirred for 180 s, and then the carbon black is added. And white carbon black (if the total amount of the two is more than 50 parts, add in two times, double the time), temperature 150 ℃, rotating speed 60 r/min, stirring for 180 s, finally add other materials except sulfur, temperature 150 ℃ , Rotating speed 60 r/min, stirring for 240 s, then discharge the glue, park for 8-12 h, add sulfur to the mill, add sulfur at 80 ℃, load the film, park for 8-12 h, put it in the corresponding mold, press for 10 MPa, heat vulcanization at 150 ℃. The sample is cylindrical with a diameter of 16mm±0.2 mm and a height of 6-15 mm.

2.2.2. Sample surface treatment. In order to make the surface roughness of the tread rubber samples different, the samples were pre-ground with 60 mesh sandpaper, 400 mesh sandpaper, 1000 mesh sandpaper and 2000 mesh sandpaper before the test. In the sandpaper pre-grinding process, it is necessary to ensure that the roughness of the surface of each sample is basically the same to avoid errors in the measurement, and to ensure that the sample is flat to ensure that the force is balanced.

2.2.3. Roughness measurement. In this paper, in order to better quantify the surface roughness of the sample, the main parameter to evaluate the surface roughness, the arithmetic mean deviation of the profile, Ra, is introduced. The arithmetic mean of the absolute value of the contour deviation within the sampling length L is the contour arithmetic mean deviation, as shown in formulas 4 and 5:

$$Ra = \frac{1}{L}\int_0^1 |y(x)| dx \tag{4}$$

It can also be approximated as:

$$Ra = \frac{1}{n}\sum_{i=1}^{n} y_i \tag{5}$$

In the formula, y is the contour offset, which refers to the distance between the contour point and the reference line in the measurement direction. The reference line is the least squares midline O of the contour. This line divides the contour and minimizes the sum of squares of the contour deviation from this line within the sampling length. The parameter profile arithmetic mean deviation Ra commonly used in countries all over the world is used to evaluate the surface roughness of the sample. Because its parameters contain most of the information on the microscopic unevenness, it can fully characterize the surface roughness performance. But because the roughness of the sample is slightly different at different places, its value is not stable, and the measurement results at different places contain some measurement errors.

Figure 2 is the parameter value of the arithmetic mean deviation Ra of the sample surface morphology and roughness profile after pre-grinding measured by the surface performance tester. The roughness parameter value of the sample pre-ground with 2000 grit sandpaper is measured Ra=2.78, the roughness parameter value of the sample pre-ground with 1000 grit sandpaper is measured Ra=9.18, and the sample is pre-ground with 400 grit sandpaper The roughness parameter value of the piece is Ra=45.52, and the roughness parameter value of the sample after pre-grinding with 60 grit sandpaper is measured Ra=98.69.

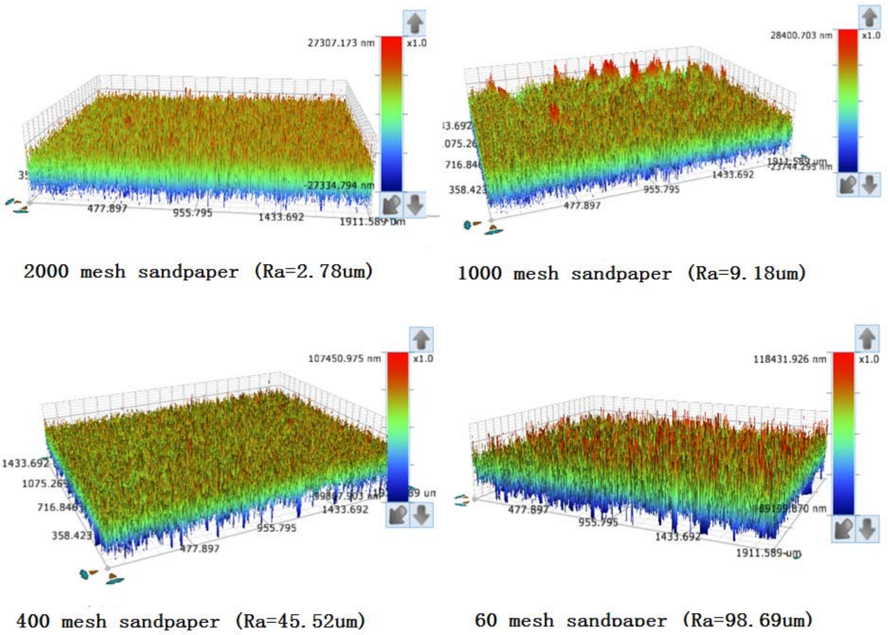

Fig 2. Three-dimensional surface topography of the samples after pre-grinding

2.2.4. Wet and dry sliding friction tests. Wet friction and dry friction were measured using a friction and wear tester under the average force of 30 N, sliding path of 50 mm and speed of 30 mm/s. The tests were carried out in a water tank to ensure the water depth of 3-4 mm and the test temperature of 20 ± 2 °C. The pretreatment was done within 3 days of testing. Ground glass, smooth glass and Sandpaper (180 mesh) were used as wet and dry friction surfaces respectively for all the samples. The parameters of relevant materials are shown in Table 2. Prior to the wet grip test, the samples were immersed in water for 10 min so as to ensure the consistency of the experimental environment. The test device is shown in Figure 3.

Table 2 Relevant material performance parameters

Materials	Mohs hardness	Roughness
Smooth glass	5.9±0.2	0.40 ±0.05 nm
Ground glass	5.9±0.2	3.03±0.05 um
Sandpaper (180 mesh)	10±0.2	30±5um

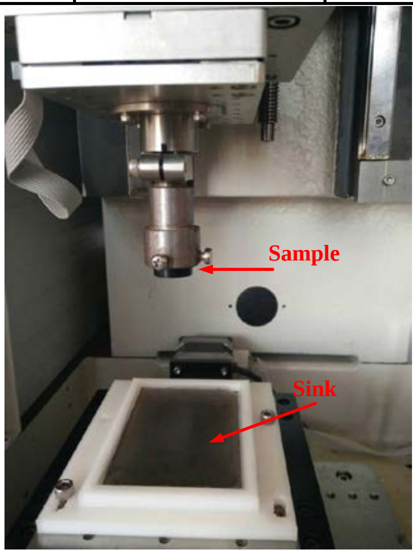

Fig 3. The wet and dry sliding friction test device

3. Results and Discussion

The measurement result obtained in Fig. 4 is the dry and wet friction coefficient data measured when a positive pressure of 30N is applied to the sample and the sliding speed is 30 mm/s. Roughness 1, 2, 3, and 4 are expressed as roughness parameter value Ra=2.78, roughness parameter value Ra=9.18, roughness parameter value Ra=45.52, roughness parameter value Ra=98.69. That is, from 1 to 4, the surface of the sample is getting rougher. It can be seen from the figure that as the roughness increases, the coefficient of dry friction becomes smaller and the coefficient of wet friction becomes larger. The main reason is that the coefficient of dry friction is related to the contact area between the friction pairs. The greater the friction coefficient, the greater. The wet friction coefficient is the opposite of the dry friction coefficient. The wet friction coefficient increases with the increase of the roughness of the sample, indicating that the rougher the surface of the sample, the better the wet skid resistance. The main reason is the rough sample. The surface is easier to pierce the water film to form a good grip, resulting in improved wet skid resistance.

In terms of dry friction, when the sample slides on the smooth glass surface and the frosted glass surface, the adhesion friction is relatively large, and the adhesion friction is related to the effective contact area. The larger the contact area, the greater the friction. The coefficient of dry friction of the glass surface is smaller than that of a smooth glass surface. But on the rougher sandpaper surface, the dry friction coefficient of the sample is the largest, which is inconsistent with the theory of effective contact area. The main reason is that although the sandpaper surface has been pre-ground, the sand on the surface is still sharper. This makes the adhesive friction force decrease when the sample slides on its surface, while the hysteresis friction force increases. The result of the joint action is that the overall friction force increases and the friction coefficient increases [11].

It can be seen from Figure 4 that the rougher the surface, the greater the wet friction coefficient and the better the wet skid resistance. This is because the rougher the pavement structure, the thinner the water film between the pavement and the sample surface, making the sample The easier it is to touch the road to form a grip, the better the wet skid resistance.

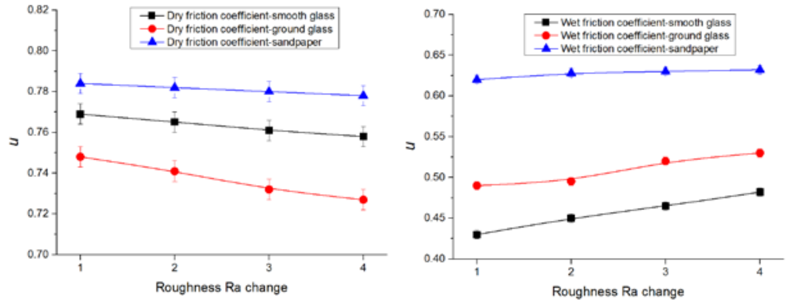

Fig 4. Variation curve of friction coefficient with sample surface roughness

4. Conclusion

This paper studies the dry and wet friction coefficients of the specimens sliding on surfaces with different roughnesses and the dry and wet friction coefficients of the specimens with different roughnesses; the test results are as follows:

(1) The smoother the sample surface, the larger the coefficient of dry friction of the sample; the smoother the surface of the sample, the larger the coefficient of dry friction;

(2) The rougher the surface of the sample, the larger the coefficient of wet friction of the sample; the rougher the surface of the sample, the larger the coefficient of dry friction;

Therefore, the rougher the surface of the tread rubber and the rougher the road surface, the higher the wet skid resistance of the tire.

Acknowledgements

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