A Study on Testing of Rubber Friction Coefficient and Its Wear Surface by UMT-2

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Abstract. For some products as tire, shoes and other wear parts products, friction performance is a very important performance index. A series of theories had been put forward to study the friction properties. With the development of science, the method of rubber friction was more and more abundant, from the friction wear properties to the microstructure, as well as the simulation, all the friction performance of the study provided a reliable basis. UMT - 2 multifunctional friction and wear testing machine, friction properties of the rubber material to make relatively objective evaluation, can provide reliable basis for research on the properties of friction. Due to many factors influencing the rubber materials, rubber friction behaviour of the friction and wear mechanism of exploration would still need a lot of research work.

1. Introduction

Friction performance is one of the most important indicators of rubber [1]. According to statistics, friction and wear are wide spread in nature and it has already consumed more than 50% of all primary energy sources in the world [2]. In the process of friction, the deformation by the shear stress happens not only on the rubber surface, but also inside the material under the surface at the same time [3]. It could cause some energy loss when resisting the friction on surface and viscoelastic characterization internal. The study is becoming more and more important on friction behavior between the surface of rubber products and its dual plane, between rubber macromolecule and packing on microcosmic morphology. Then, it could reduce the abrasion, cut down heat of rubber material and improve its fatigue life. And then it could bring considerable economic benefit and social benefit on saving energy, materials, lubricants and other aspects. [4, 5]

By studing the change of the friction coefficient of rubber under different conditions, we could calculate the friction behavior of rubber products under actual-use conditions. We researched the friction behavior of SSBR, and fond the corresponding laws of friction by different sliding velocity, pressure and different dry and wet conditions. On the whole, it provides important reference basis for the performance of rubber research.
2. Experiments

2.1. Materials
SSBR RC2564S, vinyl content of 65.5%, PetroChina Natural Gas Co. Ltd., Dushanzi Branch; NR SCRWF, China Hainan Rubber Industry Group Co., Ltd.; Precipitated silica: Luodiya Silica White (Qingdao) Co., Ltd.; CB N330: Degussa (QD)Co., Ltd.; ZnO: C.P., Tianjin Bodi Chemical Co., Ltd.

2.2. Blend recipe
SSBR 80, NR 20, N330 50 (Silica 50, Si69 2), ZnO 4, SA 1, NS 2.2, S 1.5, NOBS 0.8, 4010NA 2.

2.3. Sample preparation
CB or Silica were blended to the SSBR matrix on the mixer manufactured and other assistants were added in turn at about 130 ℃. The blends were taken out of the mixer and processed at room temperature with S and NS on an SK-160B two-roll mill, finally being molded into sheets in a VC-150T-FTMO-3RT vacuum press manufactured at 151 ℃ for 20 min.

2.4. Main measurements
The friction coefficients were tested at room temperature (23 ℃) at different conditions of different pressures and different sliding velocities on a Multi-functional friction and wear tester UMT-2 (as shown in fig.1), Center for Tribology Inc. USA.

Microscope of surface after frictional wear was studied by stereoscopic microscope SMZ1500, Nikon Company, Japan.

SEM of surface after frictional wear was observed using a JEOL-JSM-7500F, JEOL Company, Japan, coated with Pt-Pd.

DMA was carried out using a Netzsch DMA 242 Dynamic Mechanical Analyzer, Netzsch, Germany, from -80 ℃ to 80 ℃, 3 K/min, 1 Hz.

![Figure 1. Friction and wear tester UMT-2](image)

3. Results and discussion

3.1. Friction factors
The experiments were implemented with the steel ball, diameter of 4 mm, at 23 ℃, the relative speed of 15.9mm/s, loading load of 5 N, and different reinforcing agent respectively of CB and Silica.

As shown in figure 2, the different friction factors were tested when the load are respectively 1N, 2N, 5N, 10N, and 20N, at 23 ℃ and the friction velocity is 15.9mm/s. It shown the relationship between the friction coefficient, when the load was small, the friction coefficient was large, which fully explained that most of the rubber friction gave priority to hysteresis friction. When the load was increased gradually, the friction coefficient became small since most of the rubber friction gave priority to sticky friction, and then the pressure recover limited deformation of rubber macromolecules.
There were two kinds of data listed under the condition of wet and dry friction. It was shown in figure 3 that under water lubricant condition, rubber friction coefficient greatly reduced, and the friction coefficients of CB reinforcing SSBR vulcanizates were lower than that of silica.

![Figure 2](image2.png)

**Figure 2.** The effect of friction coefficient by different friction pressure with steel ball

![Figure 3](image3.png)

A: CB  B: Silicon  d: Dry  w: Water wet

**Figure 3.** The effect of friction coefficient by water wet condition with steel ball

With other conditions unchanged, the friction velocity was changed to 3.2 mm/s, 6.4 mm/s, 15.9 mm/s, 31.8 mm/s, 79.4 mm/s, in order to get a different friction velocity, as shown in figure 4.

![Figure 4](image4.png)

**Figure 4.** The effect of friction coefficient by different friction speeds with steel ball
Obtained from the experimental data, the friction coefficient increased with the sliding velocity when the steel ball bearing on the rubber. And under the condition of hysteresis friction was the main factor, when the relative speed increased, the steel ball forced the greater deformation of rubber and produced the greater friction resistance. As a result, the friction coefficient increased.

![Image of different friction conditions]

Note: The arrows stand for the direction of friction, 15.8 mm/s

**Figure 5.** The photographs of different load on the steel to the SSBR (100X)

### 3.2. Friction surface Microanalysis

A certain degree of wear and tear occurred on the surface of SSBR after the steel ball sliding on the rubber surface with a constant pressure and speed. Different damage surfaces of SSBR were observed by stereoscopic microscope, as shown in fig.5.

Stereoscopic microscope photos in figure 5 shown that when the load was small, the steel ball slid on the rubber surface and the friction mainly acted as sticky friction, and it would be gradually torn the rubber to scratch. As the friction and pressure increased, the friction acted as adhesive friction and hysteresis friction at the same time, when the steel ball more partial pressure gradually into the rubber, reciprocatingly, then the rubber stack occurred.

![Image of different friction speeds]

Note: The arrow for the direction of friction, 5N

**Fig. 6** The Photoshop of different velocity of friction behavior on the SSBR (100X)

Also, fig. 6 shows that through the process of friction between steel ball and rubber materials, there were wear stripes, groove, and the larger of abrasive, volume, etc. On the rubber surface, even the fatigue spalling and adhesion occurred. At the same time, fast friction speed was easier to make stack occur on the rubber surface, thus accelerated rubber scratching damage.

When the friction happened with water lubrication, we found a different result on rubber with different fillers under the same pressure and the relative friction velocity.

With lubricants, the friction coefficient is greatly reduced, then the friction and wear is also changed, as shown in fig.7 for the carbon black reinforcing SSBR with white carbon black reinforcing of SSBR in dry friction and water lubrication friction surface of wet friction conditions.
Taking the friction experiment lubricated with water, we found that the friction behavior was significantly different from that without water. And it was also different from the one reinforcing by carbon black and white carbon black, on dry or wet conditions. When the friction took with carbon black reinforcing of SSBR under dry condition, the rubber surface became coarse, with curly phenomenon, while under the condition of water lubricated surface scratches, it was relatively smooth. While the surface became rough after white carbon black reinforcing SSBR friction under dry condition, part surfaces of rubber cracked when water lubricated. Comparison with these two kinds of reinforcing SSBR under the same condition of friction, the wear resistance of white carbon black reinforcing was better than that of carbon black reinforcing SSBR.

Scanning electron microscopy (SEM) analysis was carried out on the friction and wear surface above to show the microstructures (figure 8). Under the condition of dry friction or wet rubbing, different microstructures of friction and wear of surface of carbon black reinforcing SSBR and white carbon black reinforcing SSBR were presented.

After magnified 5000 times and 20000 times respectively, we could see that friction surface under different friction conditions are obviously different. The microstructure of friction surface was stacked and curled on carbon black reinforcing of SSBR under dry condition, while tiny crack occurred under the condition of wet rubbing. While the microstructure of friction surface was curly, but it was appear cracked under the condition of wet friction. From the microstructure, the friction failure mechanisms of these two kinds of reinforcing system of SSBR vulcanizates were similar. Curled up, and the generation of cracks or cracked would accelerate torsion for rubber material to damage.

Under the different conditions of the friction above, the situations of friction and damage on the rubber by steel ball were not the same. Broadly speaking, four kinds of mechanisms were obtained from SEM analysis: curl, josephalbert, crack and piling, which could accelerate the rubber to flexible damage, and then the abrasion performance was degraded.
4. Conclusion
Obviously, the rubber friction behavior was influenced by the rubber itself inherent nature, in addition to the rubber components. Material hardness and Young's modulus had a great relationship with the relative motion. And the pressure and speed of the friction pair of the relative velocity, the greater the deformation of the rubber to restore, hardness of rubber itself, or flexibility. As a result, the friction wear was generated increasingly.

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