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# Experimental study on preparation of short fiber and rubber composites using top ram pressure

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**Abstract:** Top ram pressure is one of the important factors, which impacts the mixing process and top ram pressure of SFRC greatly. The effects of different top ram pressure on mixing process of SFRC have been researched by experiments. In the paper, the top ram pressure was changed from 0.3MPa to 0.6MPa respectively. And also the addition of short fibers was about 0phr~6phr. The experimental results indicated that SFRC had better physical and mechanical properties as top ram pressure was about 0.6MPa, and the addition of short fibers was about 3phr.

## 1. Introduction

Short fiber-rubber composite material (SFRC) is a kind of composites, which could be manufactured by the way of mixing rubber, short fibers and other fillers such as N330, SiO2, 4010NA. Because SFRC has good performances, it has been used in almost all kinds of rubber products in recent years [1~10]. Especially, SFRC has been applying to all parts of tires, such as antiseismic engineering.. While mixing is the first step and one of the most important steps of manufacturing SFRC, because mixing quality influences the coming process and products performances directly. Due to top ram pressure is an important factor which influences the mixing quality and physical and mechanical properties of SFRC, so the effects of top ram pressure on mixing process and physical and mechanical properties has been researched by experiments in this paper.

## 2. Experiments

### *2.1. Materials and Formulation (unit: phr).*

The materials and formulation for manufacturing SFRC are shown as following, Natural Rubber (NR),100.0, Polyester Short Fibers (3~5mm, slenderness ratio 120), 0~6.0, Carbon Black (N330),38.5, White Carbon Black (SiO2),15.0, Antioxidant (4010NA),2.0, Zinc Oxide (ZnO),3.5, Stearic Acid (SA),2.0 Coupling Agent (CA)，3.0, N-Oxidiethylene-2-Benzothiazolyl Sulfonamide (NOBS)，1.5, Sulfur (S),1.0.

### *2.2. Equipments.*

X(S)M-1.7 Internal Mixer, X(S)K-160 Open Mixer, QLB-D400×400×2 Flat Vulcanizing Machine, XD-1 Electronic Microscope, TS2005b Testing Machine, QP-16 Slicing Machine, KS-DR-S Plasticity

Testing Machine, LX-A Rubber Durometer, MM4130C Vulka Meter without Rotors and DG1000NT Carbon Dispersion Testing Machine.

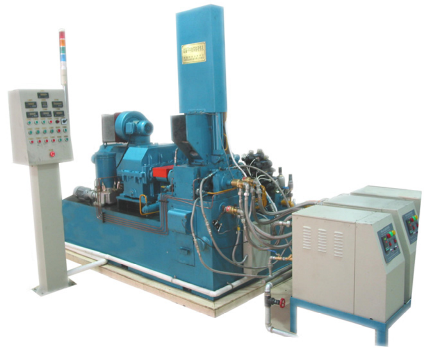

Figure 1. X(S)M-1.7 Mixer

*2.3. Experimental conditions.*
Addition of short fiber is 0phr~6phr, top ram pressure is 0.3MPa~0.6MPa, fill factor is 0.6, cooling water temperature is 40±1℃, vulcanization condition is 150℃×25（min）×10MPa(oil pressure), testing speed for physical and mechanical properties is 50mm/min, rotor speed is 70rpm.

*2.4. Orientation of short fiber.*
The way of making short fibers get orientation is tablet forming the mixed rubber of SFRC on the open mixer. The method is setting the open mixer roller space to 4mm, making the mixed rubber pass through the roller space for 5~10 times at the same direction in order to make short fibers orientated at a certain direction. Afterwards, the roller space of the open mixer was set to 2mm, through which making the mixed rubber pass at the same direction, also about 5~10 times. As a result, short fibers would get orientation.

*2.5. Testing samples.*
The samples for performances testing were made in the following way. Pay attention to the orientation of short fibers during the vulcanization process of mixed rubber, then the samples should be made along the orientation of short fibers as shown in the Figuer2 and Figure 3.

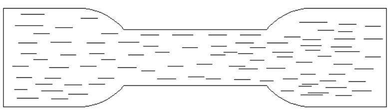

Figure 2. Sample for tensile-strength testing

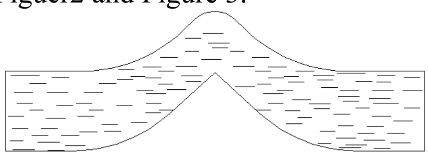

Figure 3. Sample for tearing strength testing

**3. Results and Discussion**
The top ram pressure was changed as 0.3MPa, 0.4MPa, 0.5MPa and 0.6MPa for researching the effects of top ram pressure on the mixing process and physical and mechanical properties of SFRC. Also, the addition of short fibers was changed as 0phr, 1phr, 3phr, 5phr and 6phr in the experiments. And the other experimental conditions were not changed.

The experimental results have been shown in Figure4 and Figure 5, in which, ● top ram pressure was 0.3MPa, ▼top ram pressure was 0.4MPa, ▲top ram pressure was 0.5MPa, ■top ram pressure was 0.6MPa.

### *3.1. Mixing Process*

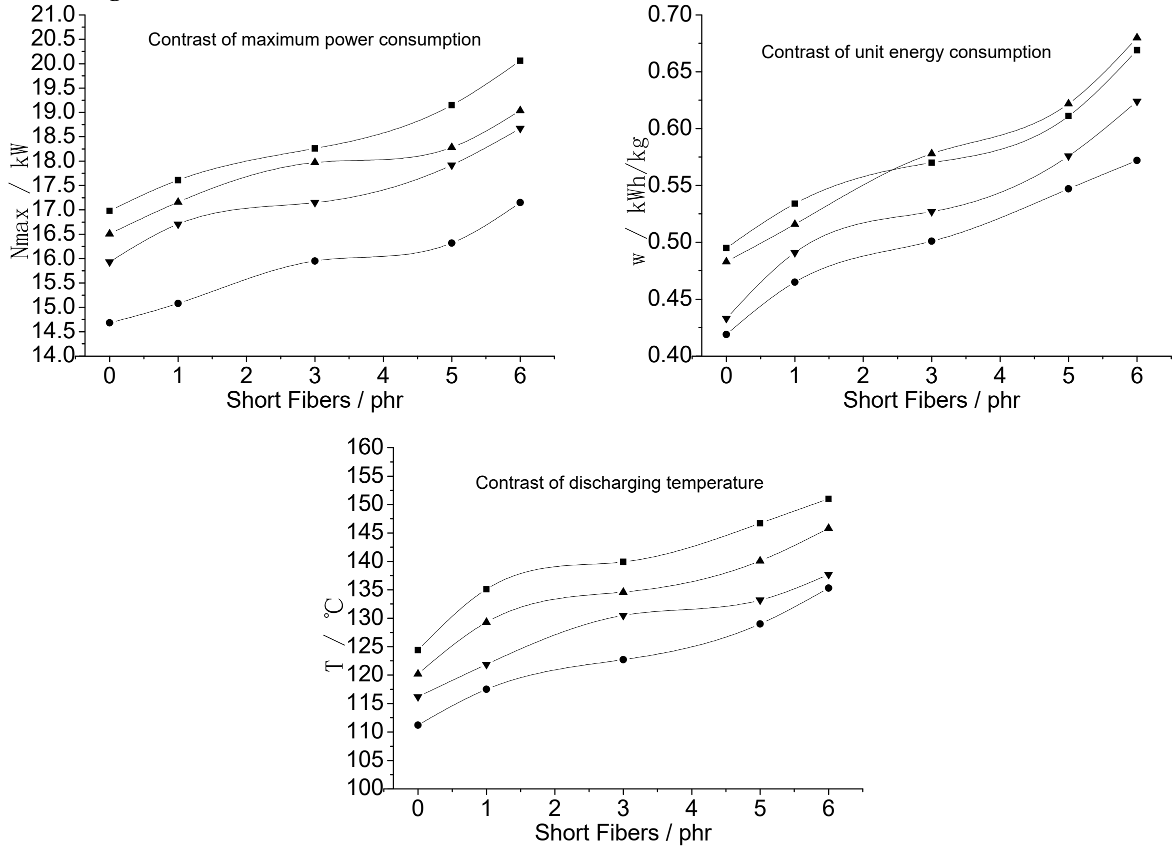


Figure 4. Experimental results for mixing process

#### *3.1.1. The effects of top ram pressure on mixing process*

The top ram pressure is helpful for the rubber materials be pulled into the mixing room. As shown in the Figure 4, if top ram pressure increased, then the maximum energy consumption, unit energy consumption and the discharging temperature would increase with the condition which was the short fibers addition was the same. The reason is that, increasing the top ram pressure, the rubber material above the mixer rotors would be pulled into the mixing room strongly. As a result, the rubber together with other fillers such as carbon black, short fiber, etc, would bear a stronger shearing force in the clearance between the two rotors and between the rotor and mixing room. Therefore, the maximum energy consumption and unit energy consumption would increase. Also, along with the rubber materials bearing a strong shearing force, the temperature would get higher and higher, which leaded to a higher discharging temperature.

#### *3.1.2. The effects of fibers addition on mixing process*

As what has been shown in the Figure 4, during the mixing process of SFRC, the maximum energy consumption, unit energy consumption and the discharging temperature would increase along with increasing of short fibers addition. The reason is that, the flow ability of the mixed rubber with short fibers would get worse due to the short fibers modulus was larger than that of rubber matrix. As a result, the frication between the surfaces of mixer rotors and mixing room would increase, leading to more energy needed for mixer rotors turning, also more quantity of heat would be generated because of higher shearing force. So the maximum energy consumption, unit energy consumption and the discharging temperature would increase.

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### *3.2. Physical and mechanical properties*

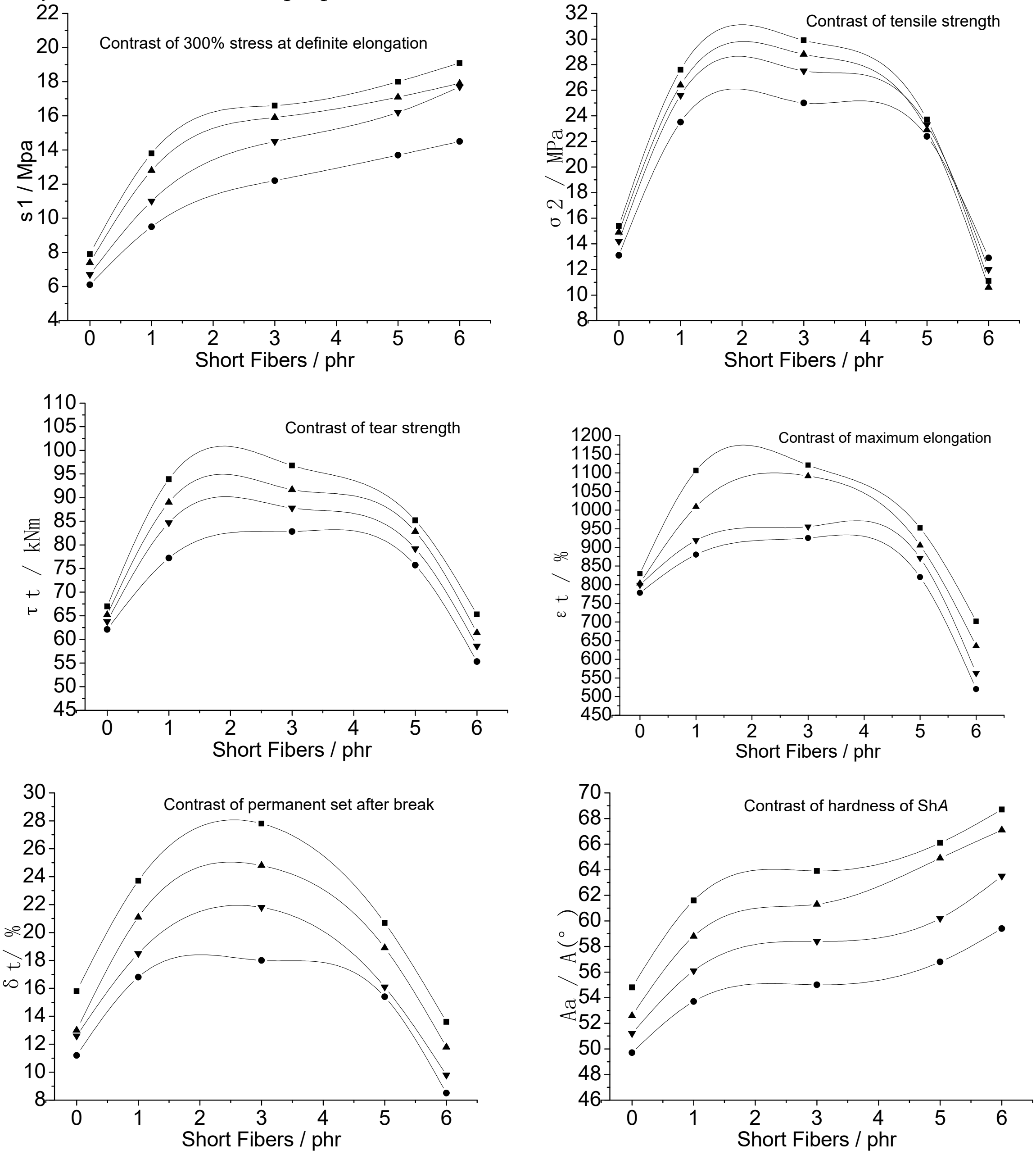


Figure 5. Experimental results for physical and mechanical properties

#### *3.2.1. The effects of top ram pressure on physical and mechanical properties*

As vividly shown in the Figure 5, on the condition of same adding amount of the short fiber, the physical and mechanical properties including strength at 300% elongation, tensile strength, tear resistance, maximum elongation, permanent set at break and hardness of the mixed SFRC increase first and then decrease with the increasing of top ram pressure. And if the top ram pressure was 0.6MPa (shown as ■), the physical and mechanical properties of the SFRC would be best. The reason is that, if the top ram pressure was low, then the mixer rotors would pull rubber materials into the mixing room hardly, which would result to a weak mixing process for SFRC, the mixing quality would be bad. But if the top ram pressure was high, it was good to enhance the mixing process of

SFRC, due to the mixer rotors would pull rubber materials into the mixing room easily, it would make the electromotor with a high load status. As a result, it would decrease using life of the electromotor. Therefore, this means the top ram pressure is not the higher, the better. As what has been shown in the Figure 5, the proper top ram pressure was 0.6MPa.

*3.2.2. The effects of fibers addition on physical and mechanical properties*

As what has been vividly shown in the Figure 5, comparing the mixed rubber without short fibers and SFRC, the physical and mechanical properties of SFRC including strength at 300% elongation, tensile strength, tear resistance, maximum elongation, permanent set at break and hardness were better, which mean the short fibers had played a role in the reinforcing action. But if the short fibers addition was more than 3phr, the tensile strength, tear resistance, maximum elongation, permanent set at break would get worse, while strength at 300% elongation and hardness would get better and better. The reason is that, if more short fibers were added, due to modulus of short fibers was lager than that of rubber matrix, on one hand the flow ability of the mixed rubber would get worse, on the other hand, more short fibers couldn't disperse well in rubber matrix. So in general, it is not the more short fibers added, the physical and mechanical properties of SFRC are better. Therefore, according to the experimental results, the proper addition of short fibers is 3phr.

## 4. Conclusions

Top ram pressure impacts the mixing process and quality of mixed rubber greatly. During the mixing process, the maximum energy consumption, unit energy consumption and the discharging temperature would increase if top ram pressure increased or of short fibers addition increased. While the physical and mechanical properties would get better if the top ram pressure or the short fibers addition was proper. Therefore, according to the experimental results, the proper top ram pressure is 0.6MPa and addition of short fibers is 3phr.

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