AEMCME 2018 IOP Publishing
IOP Conf. Series: Materials Science and Engineering 439 (2018) 042075 doi:10.1088/1757-899X/439/4/042075

Research Of Mixer Rotors Speed On Mixing Process Of Short Fiber-rubber Composites

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Abstract: Mixer rotor speed is one of the important factors which effects the mixing process and mixer rotor speed of SFRC greatly. The effects of different mixer rotor speed on mixing process of SFRC have been researched by experiments. In the paper, the mixer rotor speed was changed from 50rpm to 80rpm 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 mixer rotor speed was about 70rpm, 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 etc. Because SFRC has good performances, it has been used in almost all kinds of rubber products in recent years [1~4]. Especially, SFRC has been applying to all parts of tires, such as tire tread, tire shoulder, tire wall [5~10], etc. 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 mixer rotor speed is an important factor which influences the mixing quality and physical and mechanical properties of SFRC, so the effects of mixer rotor speed on mixing process and physical and mechanical properties have 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.

2.3 Experimental conditions.
Addition of short fiber is 0phr~6phr, mixer rotor speed is 50rpm~80rpm, fill factor is 0.6, top ram pressure is 0.6MPa, cooling water temperature is 40℃, vulcanization condition is 150℃×25 (min) ×10MPa, testing speed for physical and mechanical properties is 50mm/min.,

2.4 Orientation of short fibers.
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, and 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 Figure2 and Figure 3.

3. Results and discussion
In order to research the effects of mixer rotor speed on the mixing process and physical and mechanical properties of SFRC, the mixer rotor speed was changed as 50rpm, 60rpm, 70rpm and 80rpm. Also, the addition of short fibers was changed as 0phr, 1phr, 3phr, 5phr and 6phr in the experiments. And other experimental conditions were not changed.

The experimental results have been shown in Figure4 and Figure 5, in which, ● mixer rotor speed was 50rpm, ▲ mixer rotor speed 60rpm, ■ mixer rotor speed 70rpm, ▼ mixer rotor speed 80rpm.

3.1 Mixing Process
3.1.1 The effects of mixer rotor speed on mixing process

Mixer Rotor speed is a key parameter for mixing process of SFRC. As shown in the Figure 4, if the mixer rotor speed 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, with the increasing of mixer rotor speed, the rate of shear which generated by mixer rotor’s turn would also increase. So the shearing force would get higher, leading to the rubber materials got a stronger mixing process, as well there would be more quantity of heat. As a result, the maximum energy consumption, unit energy consumption and discharging temperature would increase.

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 friction 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.

3.2 Physical and mechanical properties
3.2.1 The effects of mixer rotor speed on physical and mechanical properties

As what has been 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 mixer rotor speed. And if the mixer rotor speed was 70rpm (shown as ■), the physical and mechanical properties of the SFRC would be best. The reason is that, if increasing the mixer rotor speed, the rubber materials would bear a higher rate of shear and a stronger shearing force, also, all the materials including rubber, carbon black, short fibers, etc, would bear more shearing times during the same time comparing with a lower mixer rotor speed, which would make all materials get well mixed during the mixing process. As a result, the psychical and mechanical properties of SFRC were getting better and better along with the increasing of mixer rotor speed.
speed. But if the mixer rotor speed got higher, the rate of shear and a shearing force would get higher, which would destroy the short fibers’ length and make short fibers lost reinforced ability. Moreover, the higher mixer rotor speed would make the mixed material generate more quantity of heat, so the rubber viscosity got lowered and made the fillers materials disperse in rubber matrix worse. Therefore, the physical and mechanical properties of the SFRC got worse. So, as what has been shown in the Figure5, the proper mixer rotor speed was70rpm.

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 larger 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

Mixer rotor speed 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 mixer rotor speed increased or of short fibers addition increased. While the physical and mechanical properties would get better if the mixer rotor speed or the short fibers addition was proper. Therefore, according to the experimental results, the proper mixer rotor speed was70rpm and addition of short fibers is 3phr.

Acknowledgements

The authors would like to thank the National Natural Science Foundation of China (NO. 50775116), Project of Shandong Province Science and Technology Development Program (NO. 2013TD16006) , Project of Shandong Province Higher Educational Science and Technology Program (J15LB73) for finance support.

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