Effects of Cooling Water Temperature on Physical and Mechanical Properties of SFRC

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Abstract: Cooling water temperature is one of the important factors which effects the mixing process and cooling water temperature of SFRC greatly. The effects of different cooling water temperature on mixing process of SFRC have been researched by experiments. In the paper, the cooling water temperature was changed from 20\textdegree{}C to 50\textdegree{}C 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 cooling water temperature was about 40\textdegree{}C, 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, SiO\textsubscript{2}, 4010NA etc. 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. Because mixing is the first step and one of the most important steps of manufacturing SFRC, so mixing quality influences the coming process and products performances directly. Due to cooling water temperature is an important factor which influences the mixing quality and physical and mechanical properties of SFRC, so the effects of cooling water temperature 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 (SiO\textsubscript{2}),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, cooling water temperature is 20°C~50°C, fill factor is 0.6, top ram pressure is 0.6MPa, vulcanization condition is 150°C×25(min)×10MPa(oil pressure), testing speed for physical and mechanical properties is 50mm/min, and rotor speed is 70rpm.

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 could be set to 2mm, and making the mixed rubber pass through the roller spacing at the last 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 Fig.1 and Fig. 3.

![Fig. 1. Sample for tensile-strength and tearing strength](image)

3. Results and discussion
In order to research the effects of cooling water temperature on the mixing process and physical and mechanical properties of SFRC, the cooling water temperature was changed as 20°C, 30°C, 40°C and 50°C. 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 Fig.3, in which, ● cooling water temperature was 20°C, ▲cooling water temperature was 30°C, ■cooling water temperature was 40°C, ▼cooling water temperature was 50°C.
3.1 The effects of cooling water temperature on physical and mechanical properties
As vividly shown in the Fig.2, 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 of the mixed SFRC would be best if the cooling water temperature was 40℃ (shown as ■). The reason is that, if cooling water temperature was lower, the rubber materials would slide on the surfaces of mixer rotors or mixing room, resulting in the rubber materials could not be mixed well with fillers such as carbon black, short fibers etc. Therefore, the physical and mechanical properties of the SFRC would be worse. But if the cooling water temperature was higher, the viscosity of rubber would get lower, which also made rubber materials could not be mixed well with fillers. Moreover, short fibers could not combine with rubber matrix well, so, the physical and mechanical properties of the SFRC would also be worse. As what has been shown in the Fig.2, the proper cooling water temperature was 40℃.

3.2 The effects of fibers addition on physical and mechanical properties
As what has been vividly shown in the Fig.2, 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 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 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
Cooling water temperature 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 cooling water temperature increased or of short fibers addition increased. While the physical and mechanical properties would get better if the cooling water temperature or the short fibers addition was proper. Therefore, according to the experimental results, the proper cooling water temperature was 40°C and addition of short fibers is 3phr.

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