

Research of Physical and Mechanical Properties of SFRC by Top Ram Pressure

Bo Shen^{1,2}, Dewei Zhang^{1,2*}, Yiren Pan^{1,2}, Lin Zhu^{1,2}, Xiaolong Tian^{1,2}, Shaoming Li^{1,2} and Chuansheng Wang^{1,2}

¹Shandong Provincial Key Laboratory of Polymer Material Advanced Manufacturing Technology, Qingdao, 266061, Shandong, China

²College of Electromechanical Engineering, Qingdao University of Science & Technology, Qingdao, 266061, Shandong, China

*Corresponding author: zhangdewei1421@163.com

Abstract: 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 etc. Because SFRC has good performances, it has been used in almost all kinds of rubber products in recent years [1~3]. Especially, SFRC has been applying to all parts of tires, such as tire tread, tire shoulder, tire wall [4~9], etc. 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.

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 $40\pm 1^\circ\text{C}$, vulcanization condition is $150^\circ\text{C}\times 25(\text{min})\times 10\text{MPa}$ (oil pressure), testing speed for physical and mechanical properties is 50mm/min, and rotor speed is 70rpm.

2.4 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.

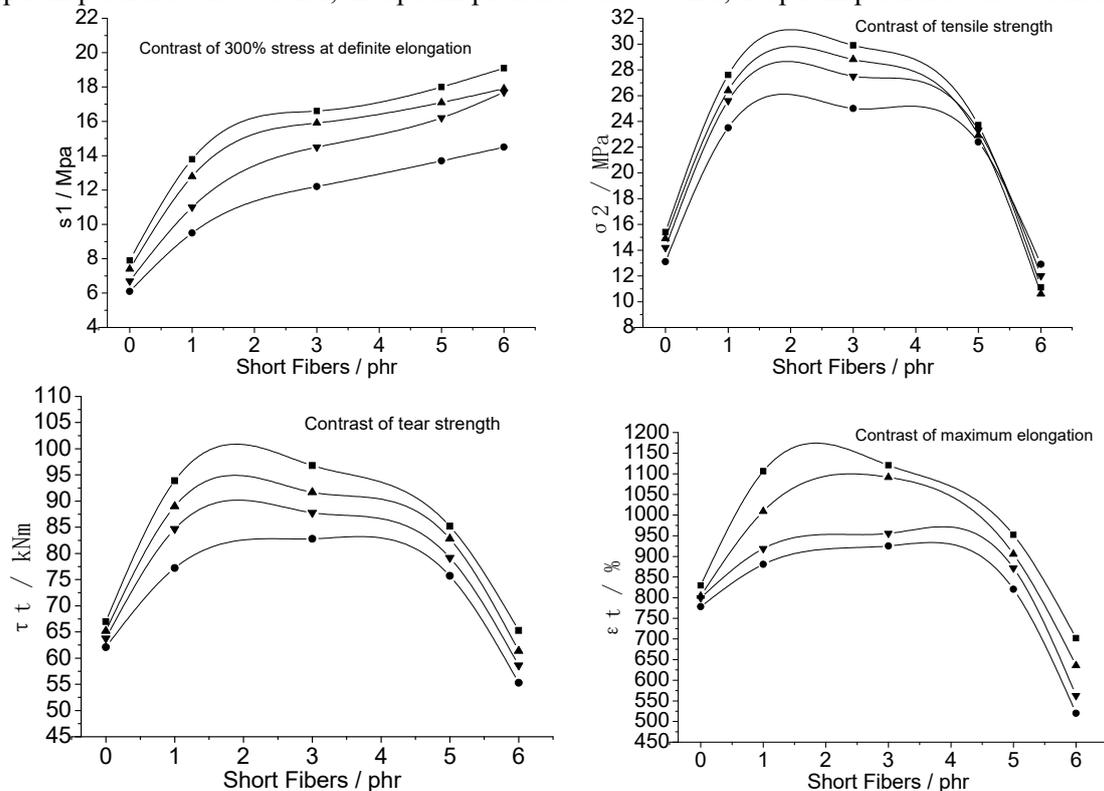


Fig.1. Sample for tensile-strength and tearing strength testing

3. Results and Discussion

In order to research the effects of top ram pressure on the mixing process and physical and mechanical properties of SFRC, the top ram pressure was changed as 0.3MPa, 0.4MPa, 0.5MPa and 0.6MPa. 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.2, 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.



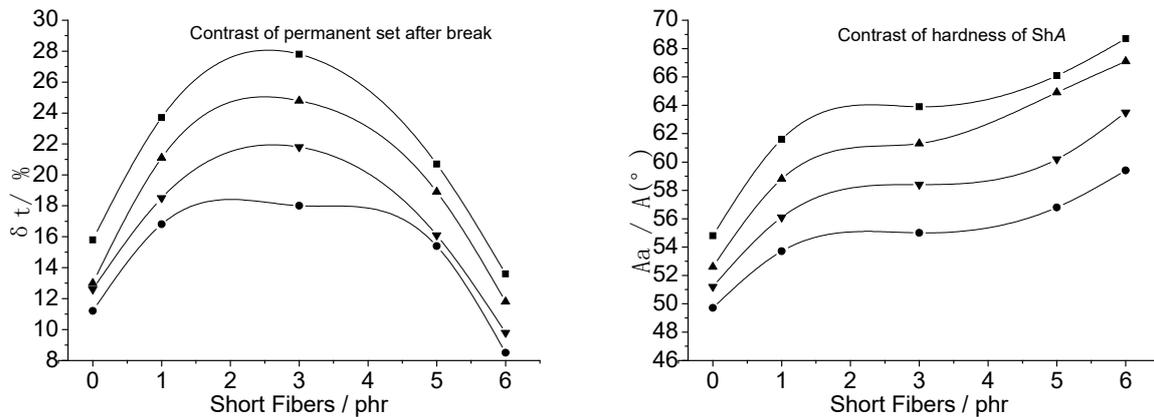


Fig.2. Experimental results for physical and mechanical properties

3.1 The effects of top ram pressure 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 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, and 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 Fig.2, the proper top ram pressure was 0.6MPa.

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 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 was 0.6MPa 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.

References

- [1] Li H T. Development of Short Fiber-rubber Composite Material[J]. *Modern Rubber Technology*, 2006, 32(4):5-12
- [2] Wang C S, Liu C J, Bian H G. Radial Orientation Mechanism and Experimental Research of Short Fiber in Tread Compound[J]. *Journal of Donghua University*, 2009, 26(6):666-672.
- [3] Wang C S, Zhang D W, Bian H G. Effects of Mixing Parameters on Properties of Short Fiber and Rubber Composite Material[J]. *Journal of Functional Materials*, 2011, 42(8): 1448-1452.
- [4] Nuttapon H, Sombat T and Taweechai A. Improving the mechanical properties of short pineapple leaf fiber reinforced natural rubber by blending with acrylonitrile butadiene rubber[J]. *Polymer Testing*, 2017, 57:94-100
- [5] Pitchapa P, Sombat T and Taweechai A Comparative study of natural rubber and acrylonitrile rubber reinforced with aligned short aramid fiber[J]. *Polymer Testing*, 2017, 64:109-116
- [6] Zhang D W, Wang C S, Lin G Y. Effects of Rotor Speed on Manufacturing Process of Short Fiber-rubber Composite Material[J]. *Advanced Materials Research*, 2011, 211(1): 350-355.
- [7] Zhang D W, Wang C S, Lin G Y, etc. Effect of Die Structure on Radial Orientation of Short Fiber in Tire Tread and its Performance[J]. *Key Engineering Materials*, 2012, 501(1): 247-252.
- [8] Li Li, Wang Chuansheng, Zhang Dewei, Effects of Radial-Orientation-Die Structure Parameters on Properties of Short Fiber and Rubber Composite Material, *Journal of Donghua University (Eng. Ed)*, 2014, 31(3): 249-255
- [9] L. Liu, L.Q. Zhang, Z.X. Feng, Development of Green Tires, *J. China Rubber Industry*. 46(1999)245-248.
- [10] C.S. Wang, C.J. Liu, H.G. Bian, Radial Orientation Mechanism and Experimental Research of Short Fiber in Tread Compound, *J. Journal of Donghua University*. 6(2009)666-672.