A study on natural rubber composites reinforced by carbon fiber

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Abstract. The carbon fiber was used to reinforce the natural rubber. The mechanical property, thermal property, morphology and thermal conducting property of the rubber composites were researched. The carbon fiber is dispersed well in the rubber matrix according to the scanning electron microscope images. The strength increased with the increase of the carbon fiber content and the strength reached the maximum value 20.9MPa when the content of carbon fiber is 2%. The addition of carbon fiber improves the aging resistance of rubber and maintain the property of rubber matrix. The addition of carbon fiber can improve the decomposition temperature effectively and enhance the heat-conducting property.

1. Introduction

Many kinds of particulate filler are commonly used to improve the composite properties for rubber material composites. Some inorganic fillers are employed to reinforce rubber materials such as carbon black, silica and zinc oxide which have well effect on high strength and hardness in traditionally [1-3]. Amin Khodadadi et al investigate the impact properties of the composite consisting of plain-woven kevlar fabric and rubber matrix [4]. Aramid fiber displays better reinforcement efficiency at temperature below the glass transition of the matrix rubber and low fiber contents of 2 and 5 phrs [5].

As a most widely used universal rubber, the production of Natural rubber (NR) is increasing due to its eco-friendly characteristics. NR composite shows consequential advancement and increases the life of the final rubber products for their applications compared with the original rubber [6-7].

As a widely used filler, carbon fiber are also being tried to blend with rubber. Rubber composites formed by carbon fiber and rubber materials constitute a current area of interest in composites research [8-9]. Carbon fiber has intrinsic low density, outstanding chemical density, excellent thermal and electrical conductivity as well as the high specific mechanical properties, which possess great potential as a filler for specific applications [10]. The composite of silicon rubber and chopped carbon fiber in a ratio of 7:3 has better conductibility than silicon rubber [11].

In this paper, the carbon fiber were used to reinforce the natural rubber. The mechanical properties, thermal properties, morphology and thermal conducting property of the rubber composites were researched.

2. Experimental

2.1. Sample composite
NR 85phr, butadiene rubber 15phr, paraffin 1 phr, stearic acid 2phr, CZ accelerator 1.5 phr, tetra methyl thiuram disulfide (TMTD) 2phr, antioxidant 1phr, zinc oxide (ZnO) 5phr, carbon black(CB) 50phr, aromatic oil 4phr, sulphur 2phr. Above all, the basic rubber composites were prepared.

Carbon fiber (1,2,4,6 phr) were grafted on the surface by silane coupling agent(KH550) , and added into the basic rubber composites separately.

2.2. Mixing and vulcanisation
All the components were thrown into open rubber mixing machine at 45℃.Then the mixer was put on the vulcanizing press for 20 min at 140℃ with the load of 15T. The resulting rubber vulcanisates were kept at room temperature for 24 h before testing.

2.3. Mechanical properties
The rubber composites fleet were cutting into the standard size according GB/T 528-2009, samples for tensile were got from that. The mechanical properties were tested by electronic universal testing machine.

2.4. Thermal aging test
Some samples of tensile test were put into temperature and humidity regulator at 70℃ for 72h, then kept at room temperature for 24 h before testing.

2.5. Surface morphology
The morphology of the samples were sprayed by gold powder, and observed with a scanning electron microscope(SEM).

2.6. Thermal analysis
The thermal properties were tested by thermal gravimetric analyzer from 50℃ to 1000℃.

2.7. Heat-conducting property
Heat-conducting property was tested by laser thermal conductivity analyzer. The sample was made into a circular sheet with a thickness of 2mm and a diameter of 12.7mm. The test temperature was set at 90℃.

3. Discussion

3.1. Mechanical properties

![Figure 1. The mechanical properties of rubber composites with different content of carbon fiber](image)

The mechanical properties in room temperature and after 70℃ for 72h were shown in figure1. The
strength of the carbon fiber/natural rubber composites increased first and then decreased with the increase of carbon fiber content. The results showed that the carbon fiber treated with coupling agent has a certain strengthening effect on the natural rubber. The strength decreased with the increase of the CF content when the strength reached the maximum value 20.9MPa. That maybe induced by the poor bonding degree between the carbon fiber and the rubber matrix. Carbon fiber is easy to break away from the rubber matrix which high in carbon fiber during stretching process, and that maybe resulting in the strength decline.

It can be seen that the tensile strength and elongation at break of the rubber composites have a decreasing tendency after air aging in 70°C for 72h. The variation range of tensile strength and elongation after breaking decreases gradually with the increase of the content of carbon fiber. It can be infer that the addition of carbon fiber improve the aging resistance of rubber and maintain the property of rubber matrix. That maybe because carbon fiber distributed in rubber matrix evenly, which prevent free radicals from destroying the double bond in rubber and then reduce the aging process of rubber.
3.2. Morphology

![Figure 2](image_url)

Figure 2. The microstructure of rubber composites with different content of carbon fiber, (a)0),(b)1%,,(c)2%,,(d)4%,,(e)6%,,(f)the adhesion of fiber and matrix

It can be seen from figure 2, carbon fiber distribute in rubber matrix evenly, and oriente along the tensile direction during stretching process(d)(e), and can strengthening the property of rubber matrix. However, fibers are arranged closely between each other which resulting in interstitial space as the content of carbon fiber, then the rubber matrix got damage from the space. It can be seen from (f), carbon fiber unites with rubber matrix firmly. When the fiber breaks away from the rubber, it will also take away part of the rubber.
3.3. Thermal property
The thermal property of the rubber composites are shown in figure 3. The initial temperature of weight loss of rubber composites increase obviously with the addition of carbon fiber. The temperature rise from 344°C (original rubber composite) to 357°C with the content of CF 2% when the weight loss is 5%, which prove that heat can be transferred to the matrix through the carbon fiber quickly when the rubber composites is heated gradually. The heat inside the rubber composites is uniform because the carbon fiber is dispersed well, then the decomposition temperature of composites have different degrees of improvement in the process of weight loss.

![Figure 3. The thermal properties of rubber composites with different content of carbon fiber](image)

3.4. Thermal conducting property

The effect of different content of carbon fiber on the heat conducting of rubber is shown in figure 4. The heat conducting property of rubber composites increases gradually with the increase of carbon fiber content. Carbon fiber is a good heat conductor which can transfer heat well, and it can dispersed in the rubber matrix evenly and overlaps with each other to form a heat conduction channel. In addition, the good combination between carbon fiber and rubber matrix can also transfer heat well. The heat conducting coefficient of rubber composites increased from 0.23 W/(m•K) to 0.32 W/(m•K) which have an increase of 21.7% when the content of carbon fiber is 6%.

![Figure 4. The heat conducting coefficient of rubber composites with different content of carbon fiber](image)
4. Conclusions

The carbon fiber is dispersed well in the rubber matrix according the scanning electron microscope images. The addition of carbon fiber improves the mechanical properties of rubber composites significantly. The strength decreased with the increase of the CF content when the strength reached the maximum value 20.9MPa. The addition of carbon fiber improve the aging resistance of rubber and maintain the property of rubber matrix.

The addition of carbon fiber can improve the decomposition temperature effectively and enhance the heat-conducting property.

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