Study of nylon textile-reinforced natural rubber composite

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Abstract. This study focuses on the production of nylon-reinforced natural rubber composites. In general, technical textiles serve as reinforcement and strength materials for a wide range of applications in rubber/textile composites. The adhesion between rubber and nylon is the most important factor affecting the assembly process and the strength of the finished product. The results showed that natural rubber reinforced with nylon textiles can be efficiently prepared by splicing a single layer of nylon fabric between two layers of rubber. The nylon textile-reinforced natural rubber composite was characterized by tensile testing machines and rubber curing characteristics, etc. The main result showed that the mechanical properties of rubber/nylon composites were higher than those of pure rubber. From the experimental results, it was found that nylon fabric can strengthen the natural rubber composite material for use with car tires.

1. Introduction

Natural rubber (NR) is a very helpful rubber which represents low hysteresis, high green strength, high resilience, and high tear properties, etc [1-2]. Nowadays, the use of synthetic fibre as reinforcement for polymer matrix composites has received a lot of interest [3]. The rubber application is used by some fibre-reinforcing materials inserted during the rubber layers, or the elastomer matrix is directly mixed with reinforcing fillers. The main objective of a reinforcing filler is to enhance the mechanical properties of the rubber composite [4], whilst fibre-based materials provide an additional goal of providing acceptable functional properties to the product [5]. The technical textile can be served as a reinforcing and strength-enhancer in the rubber/textile composite. The adhesion between rubber and textile is the most important factor in influencing the assembly process and finished product performance in rubber/textile composites [6]. The rubber matrix can be compounded with either reinforcing fillers or reinforcing fibre assembly. Technical textiles have received a lot of attentions and are widely used to apply to industrial applications such as tires, conveyors, and so on. In the fibre-reinforcing composite industry, the original of fibre are quite different, for example, glass fibre, carbon fibre, nylon, polyester, and aramide, etc [7].

Recently, the fabrics are applied to reinforce the elastomer in order to improve of the mechanical properties of the composite [8]. The objective of this work is to study the properties of reinforced nylon fabrics in NR composites, especially in the state of crosslinked rubber. Therefore, nylon fabric can be used as a reinforcing material for NR composite materials due to its high mechanical strength. It is
expected that developed composite samples with nylon fabrics can be used to reinforce NR composites for use in tire applications.

2. Experimental
2.1 Materials
NR was STR20 grade (Standard Thai Rubber) by Sintongthai Rubber Co., Ltd., carbon black (N330) was supplied by Bridgestone Carbon black (Thailand) Co., Ltd., zinc oxide (ZnO) was supplied by Global chemical Co., Ltd., stearic acid was supplied by Chemmin Co., Ltd., sulphur was supplied by Utids Enterprise Co., Ltd., N-cyclohexyl-2-benzothiazole sulfenamide (CBS) was supplied by Shandong Sunsine Chemical Co., Ltd., and nylon textile had warp yarn of 20 lines/square inch and weft yarn of 3 lines/square inch coated with resorcinol formaldehyde latex (RFL) was supplied by Haiyang Technology Co., Ltd.

2.2 Preparation of NR sample
NR compound was prepared by a two-roll mill front rotor speed: rear rotor was 20:24.1 rpm at a temperature of 60°C (Shanghai Rubber-Machine, China). Firstly, the NR was masticated for 2 min to make the rubber softer. Then, the chemical ingredients were mixed in a conventional order, namely ZnO and stearic acid followed by carbon black (N330) and CBS before sulphur was added in the last chemical for the total mixing time about 24 min, the compound formulation is shown in Table 1. After cooling to room temperature, the rubber compounds were ready to prepare the composite.

Table 1. Compound formulation for the investigation in this study (parts per hundred of rubber: phr).

| Ingredient  | Rubber compound (phr) |
|-------------|-----------------------|
| STR20       | 100                   |
| N330        | 40                    |
| ZnO         | 3                     |
| Stearic acid| 1                     |
| Sulphur     | 2                     |
| CBS         | 1                     |

2.3 Preparation of NR/nylon composite
One layer of reinforcement nylon textile weight 2 grams was sandwiched between two rubber sheets (the rubber weight 25 grams per sheet). Then, the sandwich sample was compressed at 160°C for 4 min to receive a 1 mm thick composite sheet.

2.4 Characterizations of the Composite
The rubber composite was characterized by various techniques such as the curing characteristics of the NR compounds were determined at a temperature of 160°C following ISO 6502:1991 by using a Moving Die Rheometer (Gotech, M-3000A). This machine provides information on the curing behaviour of rubber compound.

The tensile tests were performed based on the ASTM D412 standard using a universal testing machine (Gotech, AI-7005) with a dumbbell type sample. The crosshead speed was 500 mm/min and a 500 N load cell was used.
The H-Test following ISO 4647 standard, using a universal testing machine (Gotech, AI-7005) was used to determine the adhesion between textile cord and vulcanized rubber. This method is applied by cords made from either natural or synthetic fibre.

3. Results and discussion

3.1 Curing characteristics of the rubber compound

The curing characteristics of NR compounds are shown in Table 2, it can be revealed the scorch time (ts2) and cure time (tc90) of the NR compound. The scorch time (ts2) generally defines the measure of the time at which vulcanization of the rubber compound begins and thus represents the time limit available for processing. The cure time (tc90) is the estimated time for 90% vulcanization of the rubber compound which should be an optimum time [2]. From the previous work, a rubber formulation exhibited scorch time at 1 min 17 sec and cure time at 2 min 22 sec due to almost twice amounts of zinc oxide (ZnO) and stearic acid compared to our formulation. The result of literature increased kinetic of vulcanization and then reduced scorch time (ts2) and cure time (tc90) almost twice compared to our result [9].

| Table 2. Curing characteristic parameters of the rubber compound. |
|---------------------------------------------------------------|
| **Formulation** | **ts2 (min)** | **tc90 (min)** |
| Rubber compound | 2 | 4 |

3.2 Mechanical properties of NR/nylon composite

The use of reinforced nylon textile in NR composites represent the improvement of mechanical properties of materials. Table 3 shows the tensile strength and elongation at break of crosslinked NR/nylon composite. We found that the tensile strength of NR/nylon composite is almost twice higher than that of NR alone form literature review, indicating the compatibility of nylon fabric with NR in the composite [1]. The nylon fabric better resists to the external force, thus it can reinforce the NR. The resorcinol formaldehyde latex (RFL) was used to coat on the surface of nylon fabric, the resorcinol can react with the nylon fabric whereas the latex can react with NR during vulcanization. So, the nylon fabric with RFL adheres well on the NR surface, becoming the good NR/nylon fabric composite. The H test method was used to assess the adhesion between rubber and fabrics. Therefore, the rubber industry prefers to offer nylon textiles to reinforce tire production.

| Table 3. The mechanical Properties of rubber/nylon composite. |
|---------------------------------------------------------------|
| **Sample** | **Tensile strength (MPa)** | **Elongation at break (%)** | **H-test (N)** |
| Rubber/nylon composite | 14.07 | 29.83 | 46.29 |

4. Conclusions

In this work, two layers of crosslinked NR was successfully reinforced by one layer of RFL-coated nylon fabric to become the NR/nylon sandwich composite. The results showed that the NR compound was prepared in a good manner and then exhibited the optimum cure time compared to the literature review. The nylon fabric with RFL adhesive adhered well on the NR compound and then became the NR/nylon composite after vulcanization. The H-test showed the compatibility at the interface between...
NR and RFL-coated nylon fabric. The tensile strength of crosslinked NR/nylon composite was higher than that of crosslinked NR alone. For rubber/nylon woven composites, moreover, this research is useful technical information for applications in the composite industry.

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