Rubberwood sawdust filled natural rubber composites: effects of filler loading and zinc oxide content

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Abstract. The aim of this work is to investigate the effects of rubberwood sawdust (RWS) and zinc oxide contents on mechanical properties of natural rubber (NR)/RWS composites. The curing characteristics of the composites were determined and the composites were vulcanized at 150°C for 10 min and a pressure of 1000 psi using a hot press machine. The properties of the composites such as tension, hardness and morphology were characterized. The increasing additions of RWS in range of 20-100 phr increased the minimum torque (ML), maximum torque (MH) and hardness of NR/RWS composites, but tensile strength and elongation at break of the composites decreased. Further, an increment of zinc oxide contents in range of 3-5 phr into the composites slightly affected the ML, MH, hardness and tensile properties. Therefore, the addition of zinc oxide 3 phr is recommended to achieve the properties of NR/RWS composites as well as saving cost.

1. Introduction
Nowadays, children’s toys were usually manufactured from wood and plastic materials because of their high strength and stiffness as well as difficult to break. However, another material that has the potential for producing the toys in Thailand is natural rubber (NR) that is harvested from rubber trees. The NR is an important unique biopolymer in many of its most significant applications, which cannot be replaced by synthetic alternatives [1]. The featured properties of the NR are high resilience (elasticity), high tensile resistance and hard tear.

The NR is a very soft and flexible material that safes for children’s play. However, it is not appropriate for producing the toys that desire high shape stability, the addition of high filler content in rubber matrix is a solution. Ninyong et al. [2] found that the addition of wood particle 20 phr into NR composites increased the surface hardness and dimensional stability. Datta and Wloch [3] suggested that increasing fibrous filler content resulted in increasing of tensile moduli 100% of elongation and hardness, and decreasing of rebound resilience and abrasion resistance of prepared jute/natural rubber composites. Thus, rubberwood sawdust (RWS) waste from processing the wooden toy is a filler that is interesting.

The development of NR composite materials, to response the children’s toy purposes, needs a better understanding in influence from the material components [4]. Hence, the effects of RWS and zinc oxide
contents on mechanical properties of the NR composites are needed to be further investigated. The overall results of the current work facilitate the development of NR/RWS composites for producing the children’s toys.

2. Experimental

2.1. Materials

NR of STR 5L grade (Standard Thai Rubber 5 L) was purchased from GSP Product Co. Ltd., Thailand. Zinc oxide (ZnO) was purchased from Thai-Lysaght Co. Ltd., Thailand. Stearic acid was purchased from Palm-Oleo Sdn. Bhd., Malaysia. Wingstay-L was purchased from OMNOVA Solutions Inc., USA. CBS was supplied from Chemistry Corporation Co. Ltd., Thailand. Sulfur was purchased from Miwon Chemicals Co. Ltd., South Korea. RWS was supported by Plan Creations Co., Ltd., Thailand.

2.2. Preparation of NR composites

Before blending, the RWS was sieved through a standard sieve of 40 mesh, and then was dried in an oven at 110°C for 8 h to remove moisture. NR was masticated in a two-roll mill with a rotating speed of friction ratio 1:1.11 at room temperature. To prepare pre-vulcanized NR/RWS blends, all chemicals for curing NR including zinc oxide 3/5 phr, stearic acid, Wingstay-L, RWS 0/20/40/60/80/100 phr, CBS and sulfur were added sequentially into the premixed NR/RWS blends for 15 min. All NR/RWS blends were compression-molded at 150°C for 10 min at pressure of 1,000 psi to prepare the sample specimens for testing the physical and mechanical properties.

2.3. Physical and mechanical measurements

The cure characteristics like minimum torque (ML) and maximum torque (MH) were measured on an oscillating disk rheometer (rheoTE H OD+) at 150°C. Morphological analysis of the NR/RWS composites was carried out using a scanning electron microscope (Model FEI Quanta 400 from FEI Company, USA). The fractured surface of the specimen was coated with gold in order to eliminate electron charging during the imaging. They were imaged with magnifications of 1000x at an accelerating voltage of 20 kV. Hardness (shore A) of different NR/RWS composite samples was measured by a Hirosima hardness tester according to ASTM D 2240. A mechanical universal testing machine was used to investigate tensile properties according to ASTM D 412. The tensile test was conducted under ambient condition with a crosshead speed of 500 mm/min.

3. Results and discussion

3.1. Cure characteristics

The minimum and maximum torques of NR/RWS composites are showed in Figure 1. The values of minimum and maximum torques of NR composites increased clearly with an increment of RWS content. This is attributed to the increase in the stiffness of NR composites with filler content [5]. Ismail and Shaari [6] revealed that the addition of filler restricts the mobility of the NR chains, resulting the maximum torque value of NR/RWS composites increased. Furthermore, Figure 1 also displayed the effect of zinc oxide content on the minimum and maximum torque values of NR/RWS composites. It can be seen that zinc oxide content slightly affected the minimum and maximum torque values of NR/RWS composites.

3.2. Hardness property

The hardness of the NR composites with different RWS and zinc oxide contents is represented in Figure 2. It was found that the hardness of the NR/RWS composites linearly increased as rubberwood sawdust content increases in the NR composites. Because the rubberwood has higher hardness than that of the weak rubber matrix while the addition of wood sawdust into NR phases reduces the elasticity or flexibility of rubber chains, resulting in more rigid NR/RWS composites [7-9]. Further, an increment of zinc oxide contents in range of 3 to 5 phr insignificantly affected the hardness of the NR/RWS composites.
3.3. Tensile properties
The effects of RWS and zinc oxide contents on tensile strength and elongation at break for NR/RWS composites are shown in Figure 3. The tensile strength and elongation at break of the NR/RWS composites were clearly decreased with the increasing content of RWS. This was mainly due to poor dispersion of the filler in the rubber matrix and weak adhesion between wood sawdust and rubber, which in turn leads to reduce the tensile strength and elongation at break of the composite materials [9]. These results could be proved with SEM images as shown in Figure 4. The NR composites reinforced with RWS 40 phr (Figure 4(a)) showed less porosities and smaller gaps between the wood sawdust and the rubber matrix than reinforced with RWS 100 phr (Figure 4(b)).

In fact, the mechanical properties of wood-polymer composites were closely related to the efficacy of interfacial adhesion between wood and polymer matrix. The increasing addition of RWS content in the NR composites increased the dispersing difficulty of the wood sawdust and their tendency to form strong...
agglomeration [8, 10]. Further, the addition of RWS in range of 60-100 phr insignificantly influenced the tensile strength of the NR/RWS composites. Likewise, the effects of zinc oxide content on the tensile strength and elongation at break for NR/RWS composites exhibited a similar behaviour to the maximum torque and hardness: the zinc oxide content lightly affected.

Figure 4. SEM images of NR composites reinforced with RWS (a) 40 phr and (b) 100 phr.

4. Conclusions
This research revealed the effects of RWS and zinc oxide contents on mechanical properties of NR/RWS composites. The minimum and maximum torques and hardness of the NR composites linearly increased with an increment of RWS content, but tensile strength and elongation at break of the composites decreased. Further, the addition of RWS in range of 60-100 phr insignificantly affected the tensile strength of the NR/RWS composites. Besides, the increasing addition of zinc oxide in range of 3-5 phr into the NR/RWS composites slightly affected the minimum and maximum torques, hardness, tensile strength and elongation at break. Therefore, the additions of zinc oxide 3 phr and RWS 100 phr are recommended to achieve the properties of NR/RWS composites for producing the children’s toys as well as saving cost and safe to user.

5. References
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