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Development, Manufacturing and Characterization of a New Composite Prepared from *Cyperus corymbosus* Rotth and Poly(Vinyl Chloride)

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Abstract. This research was focused on the study of the synthesis process, and the physical and mechanical properties, of the composite material prepared from Poly(vinyl chloride) (PVC) and natural fiber extracted from reed, scientific namely Cyperus corymbosus Rotth, leading to the development of a new type of low cost material for the furniture function. Reed is chosen to be a source of natural fiber due to its ease of finding and ease of growth along water reservoir which can provide a cheap material for composite production. In the study, the samples were divided into four groups based on the addition of reed powder loading, ranged from a weight ratio of 0%, 20, 40 to 50%, respectively. The composite materials were pre-mixed, using white oil as coupling agent, by the single screw extruder, and the wood plastic was produced by compression molding method. The flat plate panels were tested by several standard techniques, including impact testing, bending testing and tensile testing. Morphology of the fracture surfaces and the dispersion of filler particles were observed by using scanning electron microscopy (SEM). The testing measurement revealed the decreasing of impact strength, tensile strength and flexural strength in all WPCs in comparison with pure PVC. This negative effect may be ascribed to the poor compatibility between the fibers and polymer matrix.

Introduction

Poly(vinyl chloride) or PVC is one of the most important polymers used these days, since it has many applications in medical equipments, pipes as well as some machine elements [1]. Its versatility for accepting numerous additives, extraordinary stability to weathering, and competitive price, are the reasons for the success of PVC. Rigid particle fillers have been extensively used in creating polymer composites with good modulus, strength and rigidity. Therefore, researchers are constantly investigating ways to produce the polymer composites with balanced mechanical properties at a reasonable production cost. As for PVC, low-cost fillers, such as natural fillers, were extensively investigated to incorporate into the PVC matrix [2].

Reed is a common name for several tall, grass-like plants of wetlands. It is botanically classified in the genus of herbaceous plants, monocots of the family Cyperaceae. Scientific Cyperus corymbosus Rotth [3] trunk is round, 1-2 meters tall, dark green. In Thailand, it grows well in a flooding area. In particular, though, it would not be classified as an important crop in the country, Thailand is known for bringing reeds as woven mats centuries ago. Reeds flour is a potential candidate for the development of new composites because of their high strength and modulus properties [4].

Compression molding is the main method used by the plastic industry due to its high efficiency and low cost [5]. However, the combination of compression techniques and natural fiber, especially reed fiber, for furniture function has not been sufficiently investigated. As far as these issues are concerned, a balance between performance and technological applications of composite material might be achieved through proper methodology. The objective of this study was to investigate the potential of a raw material from the reed trunk to be used to fabricate WPC. The effects of the mixture reed flour on the mechanical and physical properties of WPC panels were investigated and discussed.

Experimental Procedure

Poly(vinyl chloride) (PVC) suspension powder was purchased from the Thai Plastic Co. Ltd. Reed was procured from the wetlands in Nakorn Nayok province (Thailand) and was first thoroughly cleaned with water to remove of dirt and impurities and subsequently dried in sunlight for few days. The fiber bundles were chopped and chipped to about 1 cm in length. In order to remove the moisture and organic matter, reed has been heated to 120°C for 1 hr. The oven-dry reed wastes were grounded to a powder form and thoroughly sieved screen to 400-500 um uniform particle size.

The samples were divided into four groups based on the addition of reed powder loading, which ranged from a weight ratio of 0%, 20, 40 to 50%, respectively. Composite materials made from PVC and reed fiber (RF) with white oil as coupling agent were obtained using a single screw extruder with an extrusion temperature at the die of 180°C and a rotational speed of 40 rpm. Blends comprising of reinforcing material were extruded, cooled down in water and granulated. The granular compounds were dried in Hopper drier at 60°C for 2 hrs. The compounds were, then, molded and subsequently compressed in an electrically heated hydraulic into sheet of 20 x 20 cm^2 continuously pressed under a pressure at 1,000 psi at 180°C for 9 minutes (3 minutes preheat + 2 minutes venting + 4 minutes full pressing). The sheet was cooled between two plates of a cold press at 2,100 psi for 6 minute.

The specimens were tested under several standard methods. For evaluating the toughness, the impact test was evaluated and tested according to ASTM-D256 (A) using Gotech Izod impact tester, model GT-7045. Mechanical properties were evaluated by performing tensile and flexural test using a standard material testing machine, HOUNSFIELD model H50KS, according to ASTM-D638. Five Specimens were tested in each condition to obtain a reliable average value. The fracture surfaces of the specimens were characterized with scanning electron microscopy (SEM) model JSM-5410LV.

Results and Discussion

The impact test is a method for evaluation of the toughness and the notch sensitivity of engineering materials. The test results are reported in Fig. 1. The impact strength of composite decreased significantly when mixed to 20% filler in comparison with the pure PVC, but, when the filler mixer further increased, it was gradually increased. The results indicate that introduction of reed powder negatively affects to the impact properties. The decreasing of the impact strength of composite by addition of natural fibers is possible, depending on the nature of fibers [6]. This negative effect may be ascribed to a poor compatibility and a weak linkage between the fiber and polymer matrix [6].

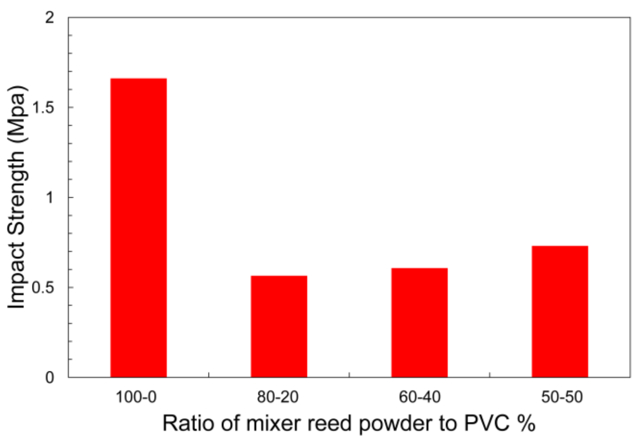
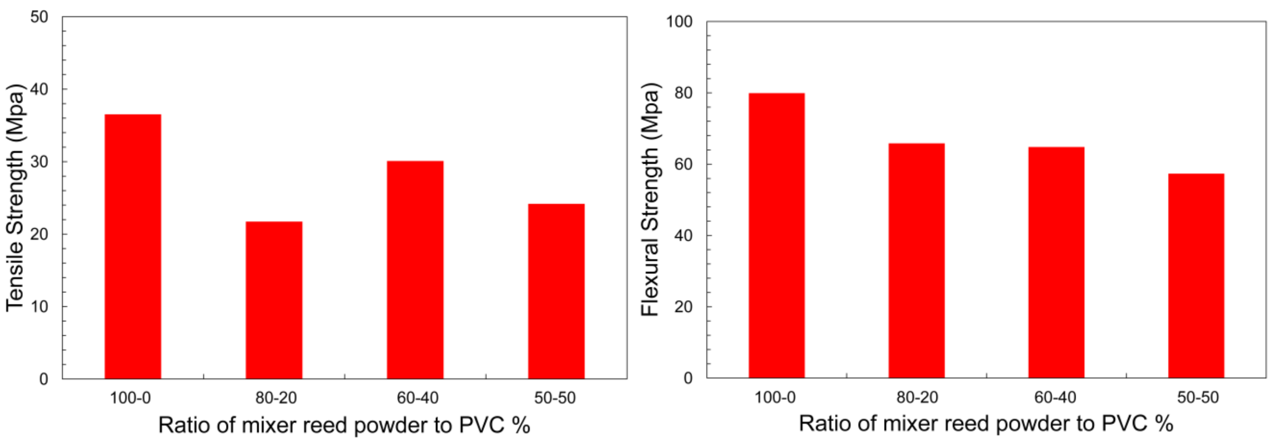


Fig. 1. Effects of mixture reed powder content on the impact strength of composites.

The influence of the mixture reed powder content on the tensile strength of composites is shown in Fig. 2 (a). It is seen that the tensile strength of composites at all compositions is lower than the pure PVC. The tensile strength decreased significantly when mixed to 20% filler. However, it slightly increased when mixed to 40% filler and decrease again when mixed to 50% filler. Tensile testing in the specimen is an index for an assessment of the internal linkages among the fibers and the quality of the connectivity between its various components. Several factors affect the strength of composites, such as, strengths of fibers and matrix, fiber content and the interfacial bonding between fibers and matrix [7]. Good tensile strength depends strongly on effective and uniform stress distribution [8]. This rather poor strength might be attributed to the inability of the filler to support stresses transferred from the polymer matrix.

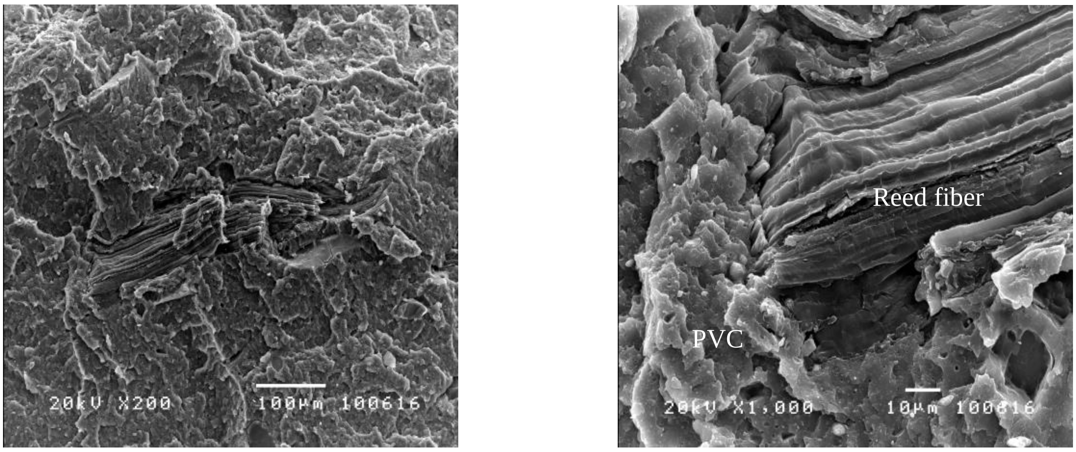
The flexural properties of composites affected by reed powder are shown in Fig. 2 (b). It is seen that the flexural strength of composites gradually decrease with the increasing of reed content. Flexural strength is defined as the stress in a material just before it yields in a flexure test and it represents the highest stress experienced within the material at its moment of rupture [9]. The flexural and the tensile strengths would be the same if the material were homogeneous. In fact, most materials have small or large defects in them which act to concentrate the stresses locally, resulting in a localized weakness. When a material is bent, only the extreme fibers are at the largest stress, so the flexural strength will be controlled by the strength of those intact fibers [9]. When the same material was subjected to tensile forces, all the fibers in the material are at the same stress and failure will initiate when the weakest fiber reaches its limiting tensile stress [9]. Reflecting from the facts that flexural strength was higher than the tensile, our composites seem to withstand the bending better than the stretching. Also, contradiction of the tensile and bending trends of the specimen filled with 20% filler implies that the filler quantity might be too low to be uniformly distributed over the matrix.



(a) (b)

Fig. 2. Effects of mixture reed powder content on; (a) the tensile strength; and (b) the flexural strength of composites.

Fig. 3 (a) and (b) show SEM images of the fracture surface of specimen filled with 20 wt. % reed flour. Although, the filler seems to be strongly embedded in the matrix, there are slightly gaps between reed flour and PVC matrix, indicating the poor interface bonding. Basically, natural fillers have higher strength and stiffness than the weak polymer matrix, thus the proper miscibility between them is a key role for composites [10]. In fact, some natural fibers may acts as reinforcing materials while others only act as filler, which contribute less to mechanical strength improvement [6]. The addition of compatibilizer should improve the level of miscibility. However, the decreasing of tensile, flexural and impact strengths with filler loading implies to the decrease of the stressed transfer area as a results of poor interface and fillers dispersion. Even though there were no earlier report on the role of the white oil, a liquid by-product of the distillation of petroleum to produce gasoline and other petroleum-based products from crude oil, as coupling agent, it was verified by our study that it does not seem to have a significant influence for coupling of reeds flour and PVC matrix. Nonetheless, natural fibers give positive outcome to the stiffness of the composites while decreasing the density, to reap the overall benefits, the reed fiber content should be ~40 wt. % at which compromise in the impact property is well compensated for by enhancement in other properties.



(a) (b)

Fig. 3. Scanning electron microscope (SEM) images of the fracture surface of the PVC composite filled with 20 wt. % reed flour to the magnification of; (a) x200; and (b) x1000, respectively.

Summary

In this work, wood plastic composites (WPCs) were produced from a mixture of reed powder and Poly(vinyl chloride) (PVC). The composites were premixed using single screw extruder by increasing reed powder content 10, 20, 40 and 50 wt% to PVC powder using white oil as coupling agent. A square compression mold, dimension 20 x 20 cm^2, was used for manufacturing. The effects of changing material compositions to the physical and mechanical properties of WPCs panels composed of this plant fiber were determined and evaluated. The testing measurement revealed the decreasing of impact strength, tensile strength and flexural strength in all WPCs in comparison with pure PVC. It seems that white oil does not have a significant influence for coupling of reeds flour and PVC matrix.

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