

Vacuum Effect on Improvement of Mechanical Properties of Natural Fiber Reinforced Composite

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ABSTRACT

Vacuum effect has applied to produce the natural fiber reinforced composite in this recent study. There were two kinds of fiber type used in the work as reinforcement of material, namely coir and empty fruit bunch fiber. Such fiber was manually mixed in resin at room temperature with volume fraction of fiber in resin of about 6%. The mixing were vacuumed by using vacuum apparatus by vacuum variations of -300 mmHg, -400 mmHg and -500 mmHg. As control, the composite was also made under condition of 760 mmHg (1 atm) pressure. The results show that the highest tensile strength of composite was recorded for the highest vacuum. Meanwhile the tensile strength of composite prepared on 760 mmHg was only obtained in lowest level. From the fracture surface of the composite, it was observed that many fibers of composite processed by 1 atmosphere were pull out from matrix without availability of residual resin sticky on fiber surface. On the contrary, many resins stuck strongly on fiber surface of the composite made under vacuum were found.

KEYWORDS: Fracture surface; vacuum; natural fibers; composite.

1. Introduction

Until now the investigation of natural fibers applied for reinforcement of the composite has still became an interest topic to be done. The natural fiber has several advantages in improvement the composite strength such as low cost process, abundant. Natural fibers from coconut plant and empty fruit bunch are cheap resources which can be applied as reinforcement material in composite to be a useful product. The material utilized to be mixed with natural fibers is usually of polymer such as resin. Strength of composite depends strongly on interfacial bonding between fiber surface and matrix []. However, some previous report revealed that natural fibers have poor bonding to resin matrix due to different behaviors []. The natural fiber is a hydrophilic material and resin material is a hydrophobic one. As hydrophilic material, natural fiber has high hydrogen bonding on the surface compared to the hydrophobic one. Many studies have reported improvement of interfacial bonding between natural fiber and resin as matrix material []. The usual method to improve the interfacial bonding between both materials is alkali treatment (called mercerization) by using sodium hydroxide []. The alkali treatment has encouraged a big effect on improvement of strength of natural fiber reinforced composite.

Reinforcement material used for this study was taken from fiber of coconut coir and empty fruit bunch. These fibers grow extensively in tropical countries like Indonesia and mostly became waste material. Such fibers belong to the natural fiber that has lignocelluloses and has several advantages like a cheap fiber, even cheaper than sisal and jute [3], are not as brittle as glass fibers, are amenable to chemical modification. However, the fiber performance of coir and empty fruit bunch as reinforcement in polymer composites is unsatisfactory and not comparable even with other natural fibers. This inferior performance of coir is due to various factors such as its low cellulose content, high lignin content. Various treatments have been used to improve the properties of the natural fibers [4]. The results obtained with the untreated fibers show clear signs of the presence of a weak interface—long pulled-out fibers without any resin adhered to the fibers—and low mechanical properties were obtained. The present work is to observe the fracture surface of coir/resin composite manufactured by vacuum variations. Big attention was given to coir fibers that were pulled out and stuck strongly by resin.

In producing composite, the usual method used is by mixing fiber and matrix manually. During mixing both materials, some bubbles from air may be trapped in the matrix. The bubbles trapped in the fiber surface have a big

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effect on the composite strength. The strength of composite will reduce due to a poor compatibility between resin and fiber surface [1]. Some efforts have been done to reduce the trapped air bubble in resin matrix [2]. However, the previous studies focused on the effect of vacuum variation on improvement of the composite strength were very limited to be founded in references [3]. The aim of the recent study is to report the vacuum effect on the natural fiber reinforced resin matrix composite.

2. Material and Method

2.1. Material resources

In this research, two kinds of natural fiber were used for reinforcement of composite, namely fibers from coconut and empty fruit bunch. The fibers resources were obtained from local region, Padang, Indonesia. The fibers were cut in 4 mm length and were treated by 5% sodium hydroxide in 1 liter distilled water for 2 hours and finally rinsed by water to remove the residual alkali solution. Treated fibers were dried by using low humidity air (relative humidity about 40%) in length of 12 hours. The matrix that used to fabricate the fiber specimen is bright resin of density 1.1 g/ml is mixed with hardener of density 1.13 g/ml. The volume ratio of mixing bright resin with hardener is 3:1.

2.2. Preparation of composite samples

The matrix used to fabricate the composite specimen was bright resin of density 1.1 g/ml and its hardener of density was 1.13 g/ml. Resin as matrix was heated at 100°C for 10 minutes in order to improve its fluidity before mixing with fibers. Heated resin weight of 160 gram was mixed within hardener of 5 ml. The mixing solution was poured in chamber in which the fibers of 20 gram were available. The chamber was, then, entered in vacuum machine in order to vacuum the coir/resin composite. Each composite sample was vacuumed under variations of -300, -400 and -500 mmHg. The composite samples also were prepared by 760 mmHg. The kind of vacuum machine used in the study was explained in detail in Final Report of Iswandi Imra [5]. After fully drying of composite sample, it was separated from the moulds and cut to make a specimen of tensile testing with dimension of specimen (length x width x thickness; 60 x 6 x 4) mm. In order to make the sample of tensile testing, the steel mold was used as presented in Fig. 1a. Meanwhile, Fig. 1b exhibits the composite sample ready to be tested by using tensile machine.

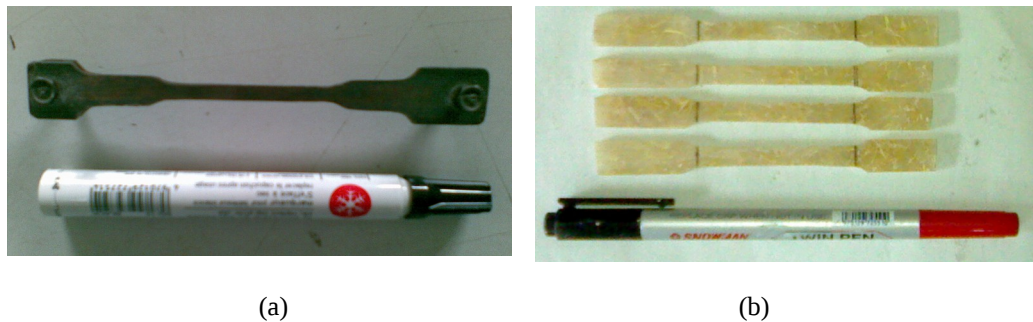


Fig. 1. a) Steel mould for making the tensile testing sample, b) Coir fiber reinforced composite in form of tensile testing sample

2.3. Tensile testing

Tensile testing of MS fibers was carried out using tensile machine of Com-Ten Industries product made in United State of America. The applied load was measured using a micro-load cell of 1200 kg attached to the machine. Tensile testing was carried out by room temperature under the constant cross-head speed 10 mm/min. The apparatus was equipped with data acquisition software developed under the ANSI C programming language in order to create the stress-strain diagram. It was already installed in an integrated computer, thereby both a force-deflection curve and a stress versus strain diagram can be obtained automatically and precisely from the apparatus.

2.4. Fracture surface

Fracture surface of composite sample was observed by using the light microscope. The attention was given to fibers pulled out from the matrix and enclosed by matrix.

3.3. Result and Discussion

3.1 Tensile Strength

Fig. 1 presents the stress-strain graph of the natural fibers composite manufactured by condition of vacuum and non vacuum. It is clear to see that the tensile strength of both composite is quite different. The vacuumed samples revealed the highest value compared to the non vacuumed ones. The increasing of strength after vacuum process is affected by improvement of interlocking between fiber surface and resin as matrix. Effect of the vacuum variation on the tensile strength of coir fiber reinforced composite has been investigated. Fig. 1 shows difference of tensile strength form of two composite samples in different treatment. Tensile strength of natural fiber composite processed by vacuum was higher than that of sample treated by non vacuum.

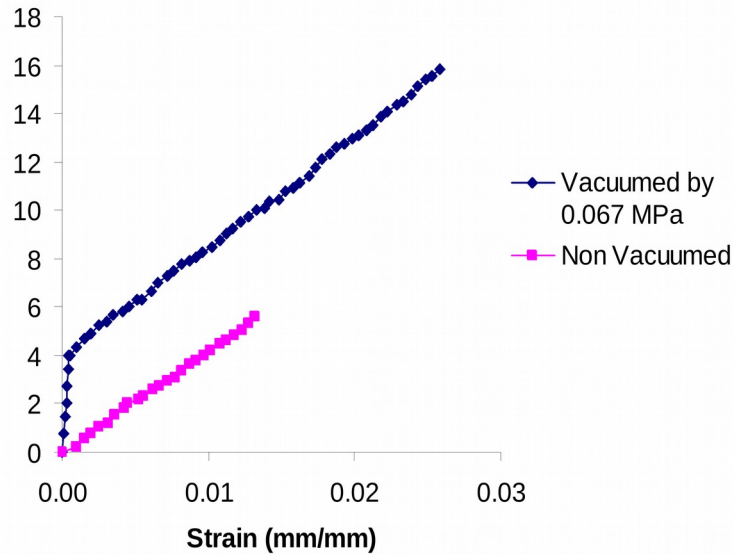


Figure 1. Stress vs strain of coir fiber reinforced resin composite on vacuum by -500 MPa compared with non vacuum. Testing was carried out by room temperature and tensile speed 10 mm/min.

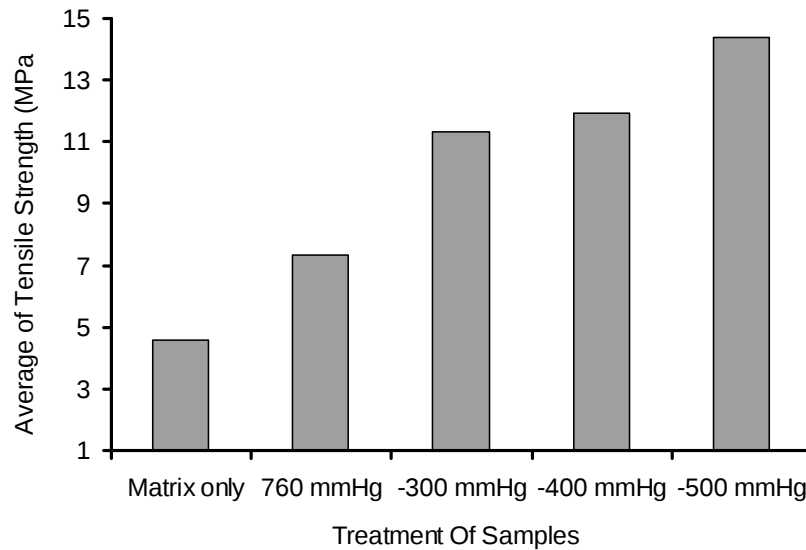


Figure 2. Average of tensile strength of samples under different treatments

The Fig. 2 shows average of the ultimate tensile strength from two samples manufactured by different conditions. Tensile testing was carried out by room temperature on constant tensile speed. For comparison, the tensile strength of resin sample was also measured without fibers. From Fig. 2 can be seen that the tensile properties of sample

tend to increase as vacuum was also improved. It can be affected by improvement of interfacial bonding between resin and coir fiber surface [3,4,5]. Many the fibers of composite manufactured by vacuum were stuck strongly with resin. Meanwhile, fracture surface of composite without vacuum, exhibits many fibers pull out from resin and thereby the tensile strength of non vacuumed composite will decrease [3].

3.2. Fracture surface

Most polymers such as resin are a hydrophobic materials and natural fiber like coconut coir fibers are a hydrophilic materials. Due to these different characteristic, the interface bonding between both of the materials is rather poor [6,7]. Therefore, much investigations have been conducted to improve the interfacial bonding of the material surfaces [8,9]. The alkali treatment of cellulosic fibers is an usual method used to increase the interface bonding. The chemical processing directly influences the cellulosic fine structure of plant fiber. Alkali treatment improves the fiber–matrix adhesion due to the removal of natural and artificial impurities from the fiber surface as well as it change the crystal structure of the cellulose and thereby the mechanical properties of composite will increase. Improvement of the mechanical properties is because of increasing the interlocking of resin on the fiber surface. Other method that can improve the interlocking is vacuum process that will be studied in the research. Figure 3 shows two different fracture surface conditions of coir fiber reinforced composite after tensile testing. Figure 3a exhibits fracture surface of resin/coir composite manufactured under 760 mmHg condition. Meanwhile the fractures surface of coir composite processed by vacuum is shown in Figure 3b. It is clear to see that the fracture surface of resin/coir composite showed much pull out fibers. On the contrary, the fracture surface of composite manufactured by -400 mmHg has many resins stuck strongly on fiber surface of the composite. Due to strong sticking of resin on coir fiber surface, the tensile strength of composite processed by vacuum process is higher than that of resin/coir composite manufactured by 760 mmHg. From tensile testing, the ultimate strength of resin/coir composite manufactured by -400 mmHg was obtained 10.7 MPa, meanwhile the tensile strength of resin/coir composite processed by 760 mmHg was measured 5.8 MPa.

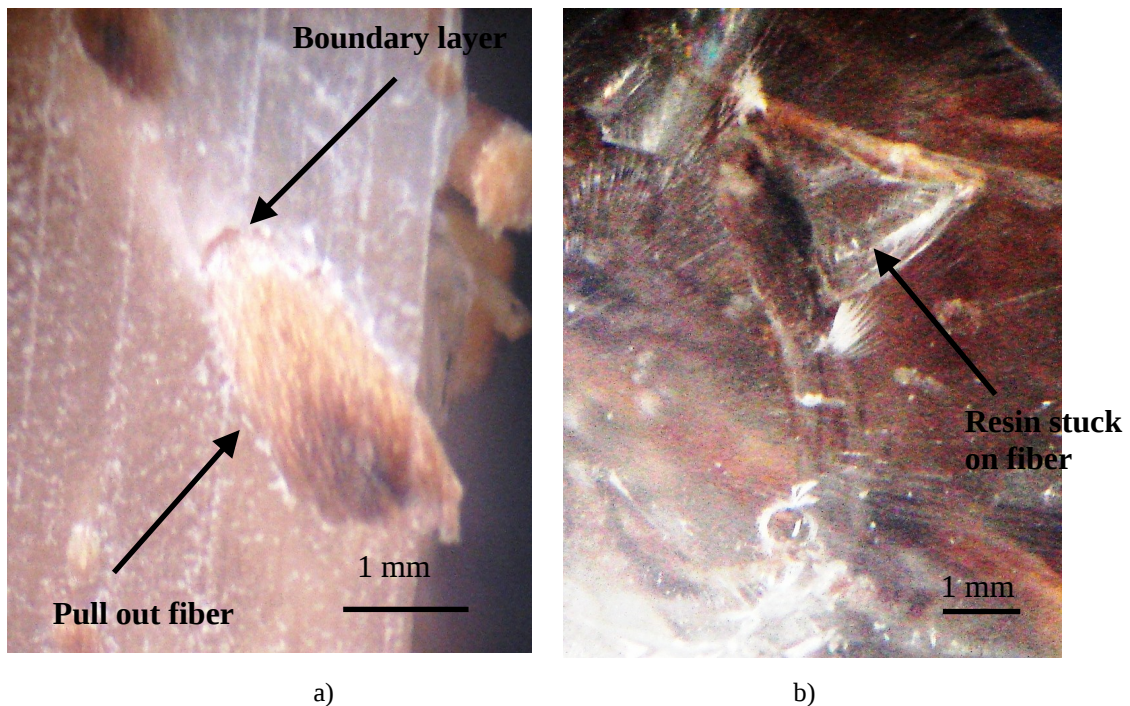


Fig. 3. Fracture surface of coir/resin composite manufactured by a) 760 mmHg, b) -400 mmHg

Conclusion

The results of the present study show that the tensile strength of coir fibers reinforced composite that was manufactured by vacuum was higher than that of resin/coir composite processed by 760 mmHg. It can be related to improvement of interlocking of resin on the coir fiber surface. The investigation shows the result that many fibers of composite processed by 1 atmosphere were pull out from matrix without availability of residual resin

sticky on fiber surface. On the contrary, many resins stuck strongly on fiber surface of the composite made under vacuum were found.

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