Tensile properties of bacterial cellulose nanofibers - polyester composites

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Abstract. The paper shows tensile properties of bacterial cellulose (BC) nanofibers and polyester (PO) matrix composites. Tensile properties including tensile strength (TS), modulus elasticity (ME), and elongation (EL) were observed respectively. BC nanofibers exist in the form of a sheet that was then varied in matrix PO. The BC sheet was mounted by one, three, five and seven pieces respectively in the matrix PO. The tensile strength of the composites was conducted by using the tensile equipment. The results showed that the tensile strength of the composite with a single sheet of BC was lower than that of pure PO. The ST value achieved maximum level in the number of layers of BC three pieces, but then it decreased for the composites reinforced five and seven pieces of BC nanofiber, respectively. Scanning Electron Microscope (SEM) observation exhibits bad interface bonding between BC nanofibers and PO matrix.

1. Introduction

BC has been studied extensively for application a commercial product such as for the speaker diaphragm, diet food, high-grade paper [1, 2]. Other using that was very spectacular is that BC is applied in the health field for wound dressing materials [3]. Right now many researchers are interested in conducting research BC due to its unique properties. BC contains a pure cellulose, mostly crystallinity, and the nano-sized fibers [4].

Mechanical properties of BC nanofiber are very excellent. Due to the low density, the specific strength of BC is higher than that of steel. Therefore, it is very interesting to apply BC nanofibers to develop military products that require strong and lightweight. Such product is like body armour, helmet having high strength and toughness.

Polyester is one of kind of the polymer owning interesting properties, such as high tensile strength, rapid drying, low density. Because of the advantage properties, polyester is popularly used as a matrix in the composite. However, polyester is brittle due to thermosetting material and so easy to fracture into pieces due to the impact. Therefore, it is necessary to reduce the brittleness of polyester by using reinforcement. The aim of this study is to see the characteristics of BC nanofibers composite mixed with polyester. In this paper, results of tensile strength, modulus of elasticity, and strain, respectively are reported.
2. Methods

2.1. Preparation of BC nanofibers

The BC nanofiber used in this study came from local food product as a dessert. The product that consists of nanofiber was in the form of a sheet. Nanofiber sheet that contains a lot of water was compressed so that water out. Then the fiber is soaked with 5% NaOH solution over 120 minutes aiming to eliminate impurities to bind to the polyester better. Subsequently, the fiber is washed with water to remove NaOH solution. Then the fiber was dried by the sun, and lastly by using a hair dryer until constant weight is reached.

2.2. Manufacture of composites

The dried fibers are mixed with unsaturated polyester resin. The composite sample was varied in one, three, five and seven layers, respectively, of BC nanofibers as the matrix. Composites were made by hand lay-up method. Standard of the samples used for tensile testing was based on ASTM D638.

2.3. Tensile Testing

The tensile strength of composite sample were measured by using equipment Com-Ten testing machine of 95T Series with testing speed of 3 mm/minute at room temperature.

2.4. SEM observation

A kind of SEM equipment used for observation fracture surface of BC nanofibers PO matrix composite was Hitachi 3400 N series.

3. Results and Analysis

3.1. Tensile Strength

The tensile strength of the composites reinforced by different BC sheets in PO matrix is displayed in figure 1. TS value of pure PO is 38.3 MPa that is a little bit lower than other TS of PO from referees [5]. As shown in the figure 1 that strength of pure PO matrix is higher than that of all composite strength after being mixed by BC sheets of nanofibers. Decreases in TS may be due to defects in the composites appearing during the manufacturing the sample such as porosities from air trapped in PO matrix. Another defect in lowering of TS is a bad interface bonding between BC sheet and PO matrix.

![Figure 1. Tensile strength versus number of sheets.](image-url)
Average TS value of the composite for one sheet BC was 20.5 MPa. Then, it increased for three sheets BC in the PO matrix composite. Average TS of three BC reinforced composites was 26.7 MPa. The increment of TS values may be due to the fact that the BC sheet was effective to reinforce the applied load.

3.2. Modulus of Elasticity

Figure 2 shows modulus of elasticity not only for pure PO but also all composites. The ME value of pure PO was 576.7 MPa, and it was lower compared to last report [6]. As increasing the sheets in PO matrix, the ME of composite increased, especially for one and three sheets. The ME of the composite for one and three BC sheets was 630.8, 669.4 MPa, respectively. However, it decreased as increases in the number of BC sheet in PO matrix. The ME for five and seven sheets of BC was 604.5, 482.6 MPa, respectively. The decreasing may be due to the fact that the sample was so fast fractured due to many defects like porosities and micro crack in PO matrix occurring in manufacturing composites. Also, a bad interface bonding between BC sheet and PO matrix provided lowering of ME [7].

![Figure 2. Tensile strength versus number of sheets.](image1)

![Figure 3. Tensile strength versus number of sheets.](image2)
3.3. Maximum Strain
Characterization of the composite strain of each different BC sheet was displayed in figure 3. The strain of pure polyester was 14% and the highest of whole strains of the composites. At the beginning of the composites for one sheet of BC, the elongation was still high. However, EL of the composites decreased continuously for further BC sheets in the PO matrix. This decreasing of the EL values may be due to increasing the number of defects in samples.

3.4. SEM photographs
Fracture surface of composites in SEM observation was displayed in figure 4. As shown in the figure 4 that micro crevice was observed on the fracture surface. Clearly, BC sheet was not bonded well with PO matrix resulting crevice between matrix and BC sheet. The difficulties of the BC bonding with PO matrix may be due to the fact that different characterisation of both materials. The behaviour of PO matrix is hydrophobic and the BC hydrophilic.

![SEM fracture surface of tensile sample reinforced by one sheet of BC nanofibers.](image)

Figure 4. SEM fracture surface of tensile sample reinforced by one sheet of BC nanofibers.

4. Conclusion
The tensile properties of BC nanofibers polyester composite were presented in this paper. Some conclusions can be drawn as follows:
- TS value of pure PO matrix was higher than that of BC sheets reinforced composites. The maximal TS was achieved on 26.7 MPa by three layers of BC in the PO matrix.
- ME of the composites were increased as an increment of BC sheets in PO matrix. The maximum value of ME was 669.4 MPa obtained on number of 3 sheets.
- Fracture strain of the composites decreases continuously as number of sheets increases.
- SEM fracture surface revealed bad interfacial bonding between PO matrix and BC sheets due to different characterisation.

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