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The Effect of Fumigation and Alkalization on Dimensional Changes of Cantula Fiber Reinforced Unsaturated Polyester Composites Under Immersion

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This study aims to investigate effect of fumigation and alkaline treatment on dimensional change in cantula fibers reinforced UPRs composite under immersion test in aqueous environment. Composites were fabricated using compression moulding method with cantula fiber content of 30% vt with the addition of 5% microcrystalline cellulose. Composite specimens were immersed under aquades for 2 months at room temperature. The dimensional changes of cantula fiber reinforced UPRs in different solutions were found to follow a Fickian behavior, where the dimensional change of composites in solution shows the saturation point after several weeks of immersion. Fumigation treated fibers and alkali treated fiber composites after immersion has lower results both in dimensional changes and its slope than untreated fiber composites.

1 Introduction

In the industrial field, the materials needed are high quality materials such as high mechanical properties in accordance with their usefulness, competitive material and manufacturing prices, and ease of materials to recycle [1]. One alternative that can meet the material criteria is to use biocomposites. Biocomposite is a composite whose constituents consist of at least one natural material either fiber or matric [2]. The use of biocomposites has a good impact on the environment because it is able to be renewed. In addition, natural fibers have good mechanical properties, low density, require low energy during production, and are easy to recycle [3]. Cantula fiber is one of the natural fibers that has been developed in Indonesia. One of these agave plant species has strong, hard, and capable of growing in dry weather [4].

Unsaturated polyester has high mechanical strength supported by low price and easy to fabricate. It has been widely applied to automotive and construction [5]. In the manufacture of natural fiber composites, one of the problems is the lack of distribution of natural fiber cellulose. One of the efforts to overcome that is by reducing particles of natural fiber cellulose compounds, to increase the spread in the composite using microcrystalline cellulose (MCC) [6]. Microcrystalline celullose (MMC) is pure cellulose isolated from

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alpha cellulose using mineral acids with the advantages of renewable, inexpensive, non-toxins, high mechanical properties, and biocompatibility [7].

In polymer composites fiber amplifiers have mechanical properties that are influenced by the adhesion bond between fibers and matrices. Fumigation is a method that aims to make the moisture content of fibers decrease so that it causes the surface of the fiber to become rough which results in the mechanical properties of the composite will increase [8]. previous research on the alkaline treatment of natural fibers to the tensile strength of composites obtained as a result of alkaline treatment can make the bonds between fibers and matrices increase by eliminating lignin and hemicellulose in natural fibers [9].

Previous research explained that the exposure of natural fibre/thermoset composites under room temperature immersion significantly decreased the mechanical properties [10]. The water immersion might directly affect the dimensional [11].

To complementary the analysis of immersion behaviour, the research about the dimensional change of cantula fibers reinforced UPRs composite in aqueous environments needs to be done. The testings were conducted to complete the analysis of research, namely, thickness dimension change and surface macrograph observation.

2 Experimental Methods

2.1 Materials

Unsaturated polyester has specific gravity of 1.04-1.46, tenacity value of 1%-5%, and tensile strength value of 89.63 Mpa which is the highest value compared to other thermoset resins [12]. Cantula fiber is a natural fiber derived from the extraction of the leaves of the plant Agave Cantula Roxb. Agave Cantula Roxb plant is widely grown in Kulonprogo, DIY to Temanggung, Central Java. Based on Research and Industrial Development of the Ministry of Industry Yogyakarta cantula fiber has a cellulose content of about 64.23%, so it has the potential as a composite reinforcing fiber [13]. The content of cantula fiber consists of 64.23% cellulose, moisture 13.13%, ash 4.98%, lignin 5.91%, and extractive 1.1% [14]. Microcrystalline cellulose (MCC) is pure cellulose derived from alpha cellulose. MCC is obtained from various natural sources, such as woody plants, cotton bark, straw, and cane pulp isolated by delignification method using alkaline solution, bleaching, and α-cellulose hydrolysis using a high temperature acid solution [15].

2.2 Fiber Treatment

Cantula fiber fumigation process is one of the chemical treatments to affect surface roughness in a composite. The fumigation process is carried out for 10 hours using smoke from the burning of coconut fibers. The temperature used in the fumigation process is between 40^{o}C to 60^{o}C in order to produce a lot of smoke and not to heat the cantula fibers. The alkali treatment was applied by immersing canrtula fiber in a NaOH solution for 6 hours. To remove any traces after treatment, cantula fiber were washed in a 1% CH3COOH solution.

2.3 Fabrication

Composite manufacturing process using compression moulding method with pressure of 10 MPa with a duration of 12 hours and room temperature. Then, the composite is inserted into the oven for a 2-hour post cure process with a temperature of 60^{o}C.

2.4 Water Immersion

The specimens were immersed in distilled water (aquades). The dimensional changes were recorded by periodic removal of the specimen from the water bath and using an electronic balance accurate to 10^{-4} g to monitor the mass during the aging process. The samples were weighed until the weight of water content reached equilibrium. The dimensional change graphs were calculated from its thickness before, h_0 and after, h_t as follows

$$h_{max} = 100\% \times \left(\frac{h_t - h_0}{h_0}\right) \tag{1}$$

The slope of dimensional change (S) was calculated from the difference of thickness versus the square root of time by:

$$S = \frac{h_t - h_0}{t_t - t_0} \tag{2}$$

3. Result and Discussion

Observation of dimension changes in immersion testing in this study using percentage of dimension change (h_{max}) shown in equation (1). The curve of dimensional change in immersion test in aquades water shown in Figure 1. Curve of dimensional change is the result of the average percentage of dimension change (h_{max}) all specimens. At the start of the observations, dimensional changes in solution increases rapidly, until after a few weeks it reached the saturation point. The phenomenon indicates that curve of dimensional change follow Fickian behaviour, where the dimensional change of composites in solution shows the saturation point after several weeks of immersion.[16].

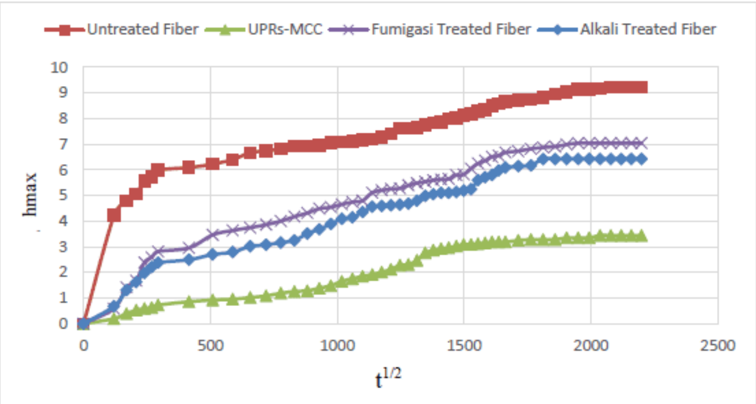


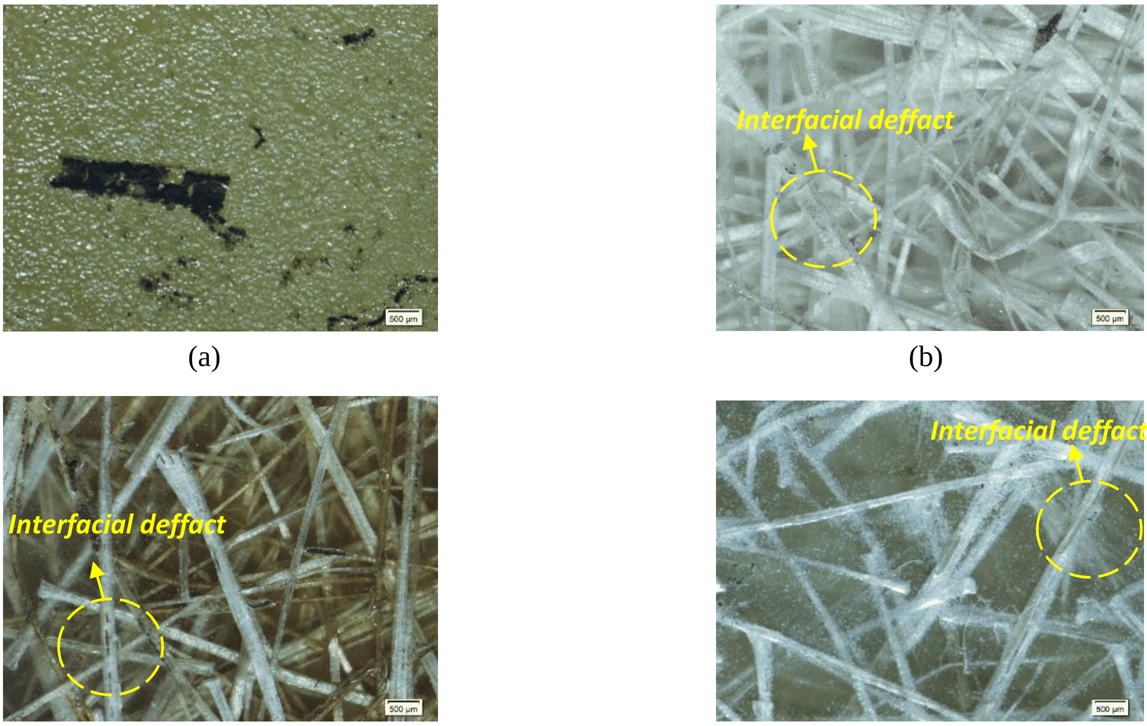
Figure 1. Curve of dimensional change of composites in solution of aquades

In specimens of untreated cantula fiber composite shown in Figure 1 there is the largest water absorption phenomena in aquades fluid. This phenomenon occurs because the result of fumigation and alkaline treatment of fibers affects the absorption of water. In a previous study by Ariawan which explained the alkaline treatment of fibers reduced the rate of water absorption associated with the elimination of hemicellulose and lignin [17]. Hemicellulose absorbs water more easily compared to cellulose crystals [17]. In specimens with fumigation fiber treatment applies also the phenomenon, because fumigation treatment is able to reduce the content of hemicellulose in fibers [17], [18].

Slope of dimensional change (S) and maximum dimensional change (h_{max}) in Table 1. are sequentially each type of specimen untreated cantula fiber composite > specimens of fumigation treated cantula fiber composite > specimens of alkaline treated cantula fiber composite > UPRs-MCC specimens. In Table 4.1 the value of Slope of dimensional change (S) and maximum dimensional change (h_{max}) is directly proportional to the greater the value of Slope of dimensional change (S), the greater the value of maximum dimensional change (h_{max}). The phenomenon is influenced by immersion that lasts for 60 days which leads to reduced strength of adhesion bonds between fibers and matriks. It also causes microscopic cracks or voids in the composite.

Table 1. Slope of dimensional change (S) and maximum dimensional change (h_{max}) in aquades

Fluid Type	**Aquades**			
Specimen	**UPRs-MCC**	**Untreated fiber**	**Fumigasi treated fiber**	**Alkali treated fiber**
S(%/h)	0.008	0.018	0.013	0.013
Hmax(%)	4.239	9.212	7.218	7.091



(a) (b) (c) (d)

Figure 2. Macro surface image of specimen after immersion on aquades: a) UPRs-MCC, b) Untreated cantula fiber composite, c) Alkali treated cantula fiber composite, d) Fumigation treated cantula fiber composite

Phenomena occurring in Figure 2. (a, b, c, d) indicate the onset of gaps between fibers and matrices that tend to be more numerous. In Figure 2. (b, c, d) show slits and cracks tend to be more due to swelling of the fibers occurring on the composite surface of the cantula-fiber UPRs without fiber treatment, with fumigation fiber treatment, and with alkaline fiber treatment after immersion when compared to UPRs-MCC specimens. This phenomenon is supported by Najafi et al that the amount of fiber used as a matrix reinforce is directly proportional to the composite ability to water absorption[19]. Cracks that occur in specimens as a result of the disconnection of interface bonds between fibers and matrices that start from fiber bending, in addition to the phenomenon occurs also fiber damage.

4. Conclusion

Cantula Fiber reinforced unsaturated polyester composites were successfully created using process compression moulding. Specimens with 30% vt of cantula fiber content have revealed that dimensional change patterns were found to follow Fickian behavior. Slope of dimensional change (S) and maximum dimensional change (h_{max}) on untreated cantula fiber composite are higher than fumigation cantula fiber composite, alkaline treated cantula fiber composite and UPRs-MCC. In addition, fumigation and alkaline treatments in cantula fiber slightly reduces changes in composite dimensions. So that phenomenon can be concluded that composite uprs-fiber cantula without treatment absorb the most fluid compared to other composite specimens in aquades with a value of S = 0,018%/h and h_{max} = 9,212%. The phenomenon is supported by observation of macro surface image on specimens.

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