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The Effect of Filler Particle Size on the Mechanical Properties of Waste Styrofoam Filled Sawdust Composite

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Abstract-The effects of filler particle size on the mechanical properties of waste Styrofoam filled sawdust were investigated. The composite contained 70 wt.% of Styrofoam, whereas the sawdust loading was remained constant at 30 wt.%. 6 wt.% from total composite weight of maleic anhydride was also used as compatibilizer. Sawdust was prepared in several particle sizes viz. 300, 180, 150 and 140 micron. Results indicated that the incorporation of 150 micron have increased the mechanical properties of the composite such as tensile strength, flexural strength and impact strength. However, on the addition of smaller particle size of sawdust (140 micron the properties have decreased. Scanning electron microscopy (SEM) micrographs showed of sawdust in Styrofoam matrix (150 micron) resulted in good distribution and reduce the amount of the voids present in the composite.

Keywords*- Styrofoam, Sawdust, Tensile Strengh, Flexural Strength, Impact Strength*

I. INTRODUCTION

Plastic waste management is one of the main problems in developing countries like Indonesia. Utilizing wasted Styrofoam could become an excellent solution to minimize plastic waste as it is a non-biodegradable material. However, the recycled product of wasted Styrofoam would contribute to poor mechanical properties material. Therefore, addition of reinforcements is compulsory in order to improve its properties

Environmental concern has become one of the most convincing reasons to develop replacement of synthetic fibers with natural fibers. However, the fact if the natural fibers reinforced composites provide lower mechanical properties and poorer water resistance when compared to synthetic fibers (such as glass fibers) cannot be neglected. The development of composite technology has been starting to experience a shift from the synthetic fillers into natural fillers composite materials. Natural fillers are considered one of the environmentally friendly materials which have good properties compared to synthetic fiber. Some natural fibers as fillers researches have been done [1-9]. Wood is one of Indonesia's natural resource. Each timber processing into semi-finished materials (e.g., in the form of boards or beams) or finished goods (furniture) always produces byproducts that form sawdust.

The sawdust contains high cellulose content of 69%. Besides, sawdust contains high levels of hemicellulose in general, also contains lignin in an amount of about 15-30% by weight. Therefore, when added to the mixed composite as filler, it will absorb the matrix and provide additional tensile strength between the filler due to adhesion properties and dispersion. Moreover, the matrix will be encapsulated the filler as well as inhibit the diffusion of water in the material due to the nature of matrix hydrophob. However, as combining polar materials like sawdust particle and non-polar materials like wasted Styrofoam would result in incompatibility of matrix and fillers, chemical modification could be applied to the sawdust as it might reduce its polarity [10]. Chemically modified fillers would also have its water absorption diminished in extent [11]. Compatabilizer, such as maleic anhydride (MAH) could also be applied to improve the compatibility of the matrix with the reinforcement.

This paper reports a study of the effect of filler particle size of wasted Styrofoam filled with sawdust on tensile strength, flexural strength, and impact strength of the composite.

II. METHODS

A. Material

Styrofoam was collected from wasted food container. Sawdust was obtained from carpenter. The chemicals such as sodium hydroxide (NaOH), maleic anhydride (MAH), and toluene were supplied by MERCK and used as received.

B. Modification Sawdust

Sawdust was soaked with 5% of sodium hydroxide (NaOH) for 4 hours at room temperature. Hereafter washed with water and dried with oven temperature 110 ^{o}C. Sawdust particles were screened with the sizes of 300, 180, 150, and 140 micron.

C. Composite Manufacturing Process

25 g of Styrofoam (1.5 x 1.5 cm) was diluted in toluene 20% with the addition of 6% maleic anhydride. Diluted Styrofoam was mixed with sawdust with a composition ratio of 70 : 30 (wt.). The mixture was poured into a metal mold which has been formed according to the standard of tensile strength, flexural, and impact strength tests. Samples were then pressed by using a hot press with a pressure of 125 psi, preheat for 5

minutes and continue with compression for 8 minutes with temperature of 130°C.

D. *Characterisations*

1. Tensile Properties. Tensile strength and elongation at break were investigated by the standard of ASTM D 638 - 10 Type IV using Instron Machine.

2. Flexural Strength. Flexural test was performed in accordance to ASTM D790 by using Instron Machine. A cross-head speed of 5 mm/min was used.

3. Impact Strength. Impact strength was investigated by the standard of ASTM D 4812 – 11 with Unnotched Izod method using Impact Testing Machine.

4. Scanning Electron Microscopy. Scanning electron microscopy was employed for microscopic structure of composites fracture from impact test. The instrument used for morphology observation was SEM Evo MA 10 Zeiss.

III. Results and Discussion

A. *Tensile Properties*

Figure 1 shows the results of tensile strength a well as elongation at break of Styrofoam filled with sawdust composites.

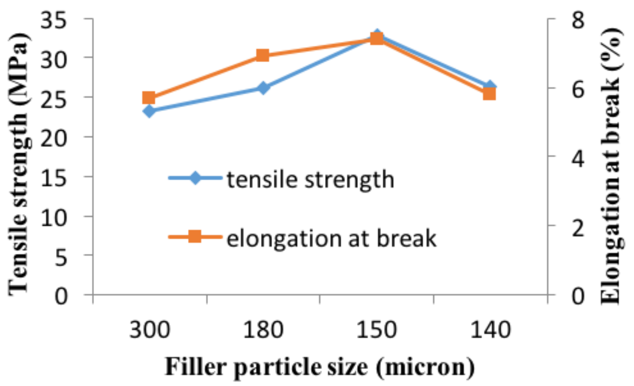


Figure 1. The effect of particle size of filler on tensile strength and elongation at break of Styrofoam filled with sawdust composites

The particle sizes of sawdust were varied from 300 to 140 micron. The increases of tensile strengths were observed with the decrease in particle size of filler in the composite up to 150 micron. Further decrement of filler particle size (140 micron) lead to decrease of tensile properties. Smaller particle size of fillers gave a considerable effect in rising the tensile properties of the composite. This behaviour was identified from the raise of tensile properties from 23 MPa to 33 MPa. Tensile strength is a parameter that shows the maximum number of stress could be received by a material before it undergoes cracking. The increase of the tensile strength is because of the smaller particle size can increase the area of composite interface, so the mechanical bonding between matrix and filler will be stronger. However, decreasing particle size further was promoting the agglomeration and lower tensile strength. This behaviour suggested that there was only small stress transfer from the matrix to fillers regardless the amount of fillers present.

Same observation was generated on the elongation at break of composite, where the composite shows relatively more flexible as the particle size smaller. Elongation at break value indicated a material ability to resist shape deformation before cracking occurrence. A material is classified as more elastic when it has higher elongation at break value. In contrary, a stiff material would have lower elongation at break value. The decrease of particle size of fillers would decrease the stiffness of a material as it would eventually higher the elongation at break value. Decreasing the particle size of filler until 140 micron would weaken the poor stress transfer as the contact between filler was intensified.

B. *Flexural Strength*

Figure 2 shows the effect of fillers particle size on flexural strength of Styrofoam filled with sawdust composites.

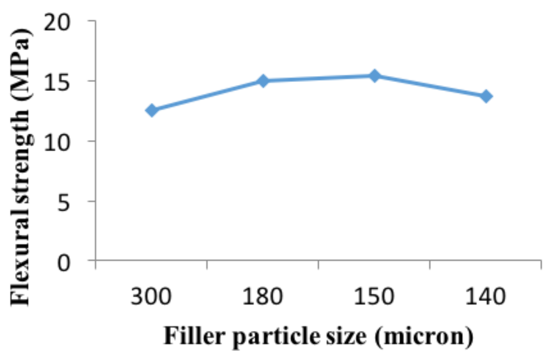


Figure 2. The effect of particle size of filler on flexural strength of wasted Styrofoam filled with sawdust

Generally, the increase of flexural strength was obtained with the decreased of particle size up to 150 micron. Further decrement of particle size (140 micron) resulted to weaker flexural properties. Flexural strength is a measurement that showed material's ability restrain transversal loads given to it. The increased flexural properties of the composites when smaller fillers were added, signified that the composite had good interfacial adhesion in which it could sustain transversal stress applied to it. Further decrease of fillers size lead to increase flexural strength as filler to filler contact was increased. Flexural strength is strongly related to elongation at break in tensile properties of a material. Flexural strength and tensile strength could have similar result if the material is homogeneous [16]. A homogeneous material is defined as a material in which its properties are same in every point without depending on certain locations [12].

A slightly drop of flexural properties at smaller particle size (140 micron) was caused by the poor interfacial adhesion between the fillers and matrix due to the limited stress transfer from the sawdust to matrix. Here, smaller particle size would create poorer stress transfer as the contact between fillers were enlarged (agglomeration). Agglomeration affected the ability of the material to resist transversal load as it decreased the flexural strength.

In this case, flexural and tensile strength be able to produce a similar trend, even though both tests stressing in different things. In flexural strength test, a material was subjected to a stress that was concentrated at certain local point and hence, the strength of the material was depended on the type of fillers intercalated at that point. Meanwhile in tensile strength, a material is given a pulling stress concentrated to the whole material at all points [13].

C. *Impact Strength*

Figure 3 shows the effect of particle size on the impact strength of wasted Styrofoam filled with sawdust. It is shown that using finer fillers from 300 to 150 micron have increased impact strength of the composite, although in the use of finer filler (140 micron) the impact strength dropped sharply. The increase of the impact strength is due to the smaller particle size that can increase the area of composite interface. Here, the mechanical bonding between matrix and filler will be stronger. Incorporating sawdust as filler as well as MAH as compatibilizer in waste Styrofoam increases its impact strength. Sawdust particle itself was known as a hard material, besides that, it is possible that the MAH is capable of creating a good mechanical bonding between matrix and filler. Hence, during impact process, the sawdust particle as well as MAH can withstand the crack propagation and can serve as the load transfer medium in the composite.

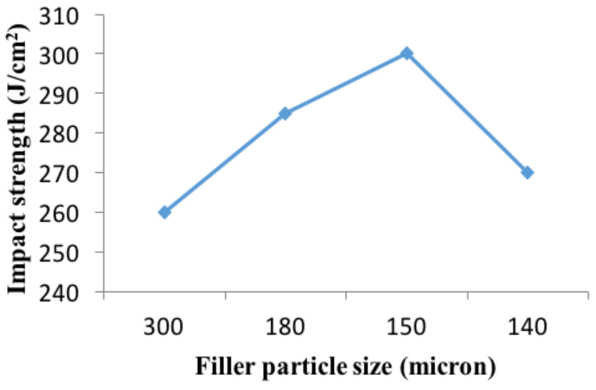
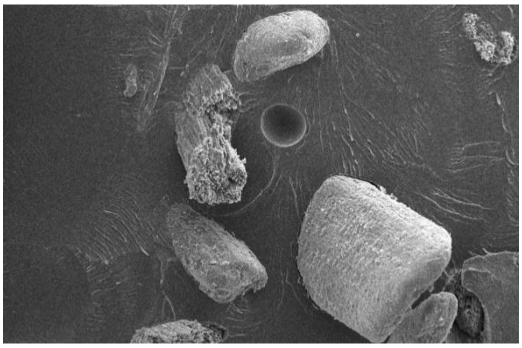


Figure 3. The effect of particle size on the impact strength of wasted Styrofoam filled with sawdust.

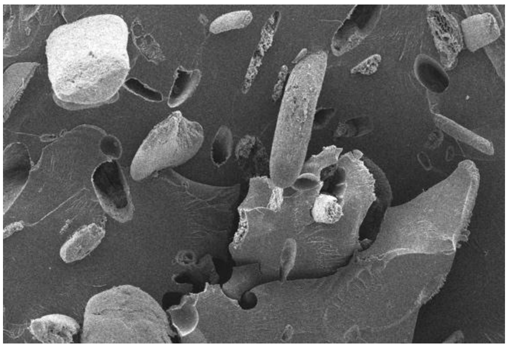
However, in the 140 micron of sawdust particle size, the decreases of impact strength have occurred. The decrease of impact strength is due to particle agglomeration of sawdust particle. The agglomeration will lower interfacial area thus load transfer will become limited resulting lower impact strength.

D. *Scanning Electron Microscopy*

Figure 4 shows images of morphology Styrofoam filled with sawdust composite with different particle size of sawdust.



(a)



(b)

Figure 4. SEM micrographs of surface Styrofoam-sawdust composite: (a) 150 micron; (b) 140 micron

It could be seen that the presence of sawdust in Styrofoam matrix (150 micron) resulted in good distribution and reduce the amount of the voids present in the samples. Moreover, the smaller particle size of sawdust seem to agglomerate adhere strongly to the Styrofoam matrix.

IV. CONCLUSION

The presence of 150 micron of sawdust as filler in Styrofoam matrix resulted in an optimum mechanical properties of composite. The values of tensile strength, flexural strength and impact strength have reached 33 MPa, 15.4 MPa, and 300 J/cm2. Image from SEM showed good distribution and reduce the amount of the voids present in this composite.

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