# The Effect of Adding MCC on the Mechanical Strength of the HDPE-Water Hyacinth Bio-Composite

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**Abstract.** This research aims to determine the effect of adding Microcrystalline Cellulose (MCC) to Bio-composites. MCC was put into a mixture of HDPE matrix and water hyacinth with a volume ratio of 0% and 1% MCC. Composites are made through extrusion and hot-pressing processes. The mechanical and physical properties of the composite were tested to determine the effect of adding MCC. The results of this study showed that the addition of 1% MCC increased the tensile strength by 4.6% with a strength of 30.81 MPa and a modulus of elasticity of 2190.63 MPa. The same thing happened during physical testing through density testing, where the addition of 1% MCC could increase the density to 1.016 gr/cm3. SEM testing was also carried out in this study, the results showed that the composite surface with the addition of MCC, voids and gaps that were previously seen to be closed by MCC so that the transfer of stress between the matrix and the fiber is better.

## 1 Introduction

Bio composites are composites composed of purely natural materials, either from reinforcement or the matrix [1]. One type of reinforcement for bio composites that can be used is a natural fiber. A natural fiber that can be used because it contains cellulose. Cellulose is an advanced material developed by lignocellulosic fibers from natural fibers which can be decomposed naturally, cheap and can be repaired [2]. In addition, cellulose has several other advantages such as biocompatibility, lightweight, biodegradability and abundant availability [3].

In recent years, researchers have intensively studied natural fiber composites with chemical treatment of the fibers. Chemical treatment aims to repair imperfect interfacial bonds due to the different properties of the matrix and fibers [4]. Alkali treatment and coupling agents are examples of chemical treatments on fibers that can significantly increase the mechanical strength of composites due to their ability to bond at the interface [5], [6].

However, chemical treatment of natural fibers is considered to still have drawbacks, one of which is voids. Void arises due to defects during the manufacturing process [7]. One way to solve this problem is to add MCC. Microcrystalline Cellulose (MCC) is a microcrystalline cellulose that can potentially cover the voids [8]. MCC can also be used as a reinforcement because it can also act as a nucleation center so as to form a network which results in increased stiffness, resistance and impact resistance of the composite [9]. Compared with natural fibers, MCC has surface area wider so that the mechanical properties are stronger [10].

When compared with natural fibers, MCC has surface area wider so that the mechanical properties are stronger [10]. MCC is produced by reacting cellulose with a strong mineral acid solution at boiling temperature. This removes the amorphous phase and reduces the cellulose chains polymerization rate, resulting in increased crystallinity of MCC. [11]. MCC is also characteristic of non-toxicity, biodegradable, recyclable, low density and easy to make filler/reinforcement for various types of composites [12], [13].

## 2 Materials and method

### 2.1 Material

Microcrystalline cellulose $(C_6H_{10}O_5)n$ is a product of EMD Millipore Corporation with the brand name KGaA with a density specification of 1.5 g/cm3 and a melting point of 232 ºC. The matrix used is Polyethylene with the type of HighDensity Poly Ethylene purchased from PT. Lotte Chemical Titan Nusantara. The melting point of HDPE occurs at a temperature of 126ºC - 134ºC and a density of 930 - 960 kg/m3. As for fiber, it uses water hyacinth fiber obtained from the Rawa Pening, Salatiga, Indonesia.

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### 2.2 Composite preparation

The composite consisted of water hyacinth fiber, HDPE and MCC. The process began with chemical treatment which is treated on water hyacinth using 2% alkaline solution (NaOH) for 12 hours. Water hyacinth was air-dried for 48 hours and baked in an oven at 70 ºC for 10 hours. Furthermore, the dry water hyacinth fiber and HDPE were carried out by crushing process with a crusher machine as well as a sieving process with a size of 40 mesh. Meanwhile, MCC was baked in an oven at 70 ºC for 2 hours. In the manufacture of composites, water hyacinth fiber and neat HDPE were mixed with a volume fraction of 30%:70%. Then MCC was added to the volume fraction of the mixture with a volume fraction of 0% and 1%, then the mixing process was carried out at 75 rpm for 1 minute. After that, the mixed material was extruded through the machine twin screw extruder at a temperature of 160ºC and a speed of 15 rpm. Then the extrusion results were processed again using a pelletizer machine to make pellets with a pellet length of 3-4 mm. The final process was pressing to make panels with parameters of temperature of 150 ºC, pressure 0.34 MPa, and holding time of 25 minutes.

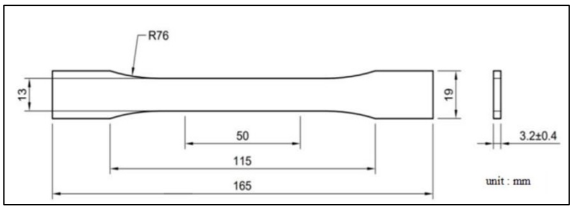


**Fig. 1.** Tensile test specimen

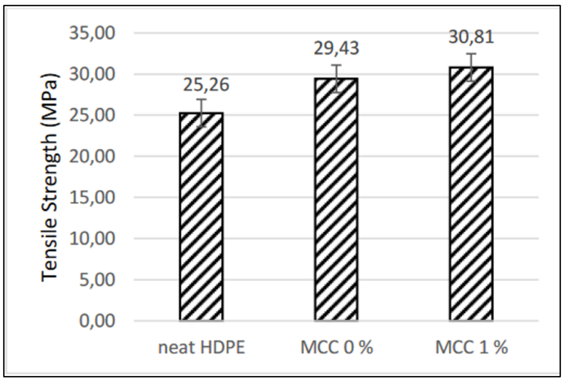


**Fig. 2.** Tensile test

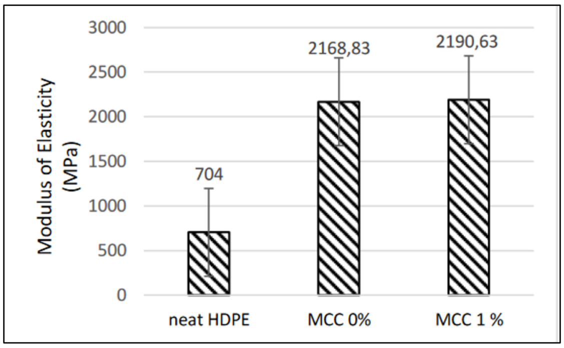


**Fig. 3.** Modulus of elasticity

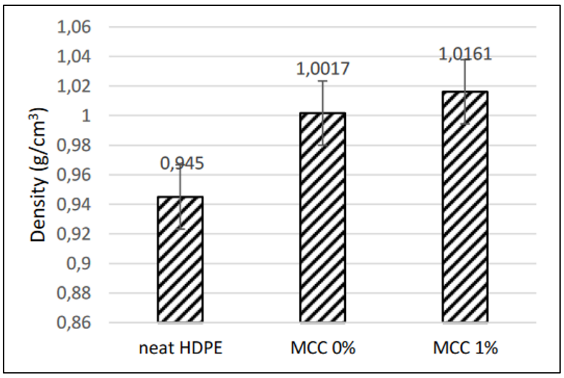


**Fig. 4.** Density

### 2.3 Characterization

Composite testing can be carried out through a Tensile Test using the JTM-UTS510 Universal Testing Machine (UTM). The tool has a maximum capacity of 5000 kg, a speed of 0-1000 mm/minute and a load cell of 50-2000 kg. Fig. 1 shows the sizes of the tensile test specimens carried out in accordance with ASTM D638 which has been used for tensile tests of various plastic materials.

Density tests can be conducted with an ACIS B-5000 digital balance that can hold up to 500 grams with a sensitivity of 0.01 gram. Density testing is based on the Archimedes principle and follows the ASTM D792 standard. SEM testing used the Thermo Scientific Particle X brand SEM photo test equipment. The sample is mounted on an aluminium stub and plated with gold. The acceleratin voltage used is 5 to 10 kV with a magnitude between 250 and 800 times.

## 3 Result and discussion

Comparison of the tensile strength between neat HDPE [14], the HDPE composite reinforced by water hyacinth fiber with and without MCC can be shown in Fig. 2. The tensile strength of neat HDPE shows a value of 25.26 MPa. Meanwhile, the HDPE-water hyacinth composite without MCC has a strength of 29.43 MPa. Then when the composite was added 1% MCC, the tensile strength increased to 30.81 MPa, or an increase of 4.6% compared to the composite without MCC.

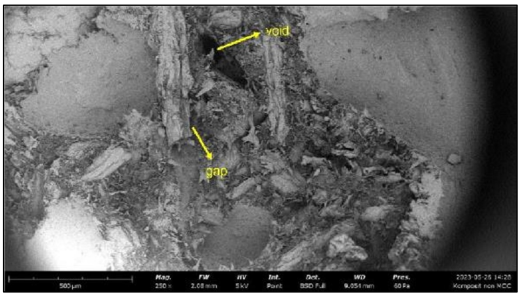


**Fig. 5.** Without MCC

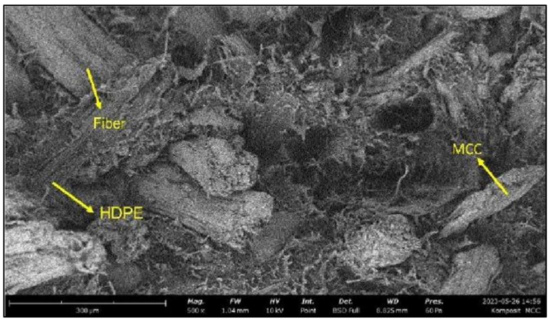


**Fig. 6.** MCC 1%

During the mixing process in the twin screw extruder, MCC will bond with HDPE while filling in the gaps between the water hyacinth fibers. A good bond between water hyacinth fiber, HDPE, and MCC is formed by mixing them together. [9]. When an external load is placed on the composite material, the MCC acts as a barrier to prevent crack propagation and aids in stress transfer between the fiber and matrix. As a result, this enhances the mechanical strength of the composite. [10], [15].

Fig. 3 shows the effect of the elastic modulus in the addition of MCC to the HDPE-water hyacinth composite. The elastic modulus of HDPE is 704 MPa. Meanwhile, the HDPE-water hyacinth composite without the addition of MCC had a modulus of 2168.83 MPa. The increase in the elastic modulus occurs when the MCC is added 1%, which is equal to 2190.63 MPa. Thus, the addition of 1% MCC is the optimal point achieved in the modulus of elasticity in the HDPE-water hyacinth composite. This shows that MCC can increase the stiffness of the HDPE-water hyacinth composite [16].

The density level of the HDPE-water hyacinth composite with the addition of MCC can be shown in Fig. 4. The results of the density test showed that the lowest value occurred in neat HDPE with a density of 0.945 and HDPE-water hyacinth composite without MCC of 0.9825 gr/cm3. Whereas for the HDPE-water hyacinth composite with a variation of the addition of 1% MCC has the highest density value of 1.0161 gr/cm3. This proves that MCC with a concentration of 1% managed to bind the HDPE matrix well and fill the gaps in the fibers.

Fig. 5 shows the HDPE-water hyacinth composite without the addition of MCC. In Fig. 5, it can be seen that the voids and gaps that occur between HDPE and water hyacinth fibers are still visible. Furthermore, in Fig. 6, the addition of MCC is carried out, the voids that occur appear to be reduced because they are filled with MCC so that the stress on the HDPE-EG composite can be transferred evenly from the fiber to the matrix.

## 4 Conclusion

The addition of microcrystalline cellulose (MCC) to natural fiber composites can increase tensile strength, elastic modulus and density compared to natural fiber composites without MCC.

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