Mechanical Properties of Composite Board Prepared by Using High Density Polyethylene (HDPE) and Saw Dust with Addition of Maleic Anyhride (MA) as Coupling Agent

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***Abstract*— Increasing amount of agriculture waste in Malaysia recent years has brought many environmental issues and economic concerns in the country. This study presents the excessive wood sawdust was recycled and used as organic filler and high density polyethylene (HDPE) as polymer matrix in produces the sample of composite board with the addition of maleic anyhride (MA) as coupling agent. Fillers and matrix were weight according to the percent formulation of 20:70, 30:60, 40:50 and 50:40 respectively. Though, the amount of coupling agent added was fixed to 10% of total weight of every sample. The composites were prepared by using hot press which needs to produce different molding for every mechanical properties and small amount of each sample were taken and their mechanical properties for flexural and tensile strength were studied. In conclusion, both flexural strength and tensile strength were found to improve with addition of coupling agent in composites which was related to improved interfacial bonding between the natural fibers as filler and the HDPE as a polymer matrix.**

***Keywords*—Polyethylene; Wood Sawdust; MA; Coupling Agent; Mechanical properties**

I. INTRODUCTION

Around the 1970´s, the concept of Wood Plastic Composite (WPC) has been designed. Conventionally, because the material which mainly devised of wood particles and thermoplastic polymer. Nowadays, the concept of WPC getting wider as the term WPC refers to any composites that consist of natural fibres and thermosetting or thermoplastic polymers [1]. As the primary elements are very contrast in chemical and physical properties, this kind of composite typically contains other enhancer to increase the harmony between the polymer matrix and the natural fibres. Regarding selection requirement of what types of polymer suits the composites, thermoplastics are commonly favored compared to others because they provide the benefit of the possibility in repeated melting processes, contrast with thermosetting polymers that most likely become stagnant in solid state after an initial increased temperature of one processing cycle which will cause the polymerization. In the manner of blending the natural fibres and acquiring the composites in a twin screw extruder, thermoplastics are most suitable choice. Therefore, after the composites acquired, the procedure followed by the extrusion or injection molding to accomplish the intended final products. The massive development of the WPCs has turned out simultaneous with the evolution of new processing techniques and technologies, in conjunction of the invention of new designs for most conventional products.

Though, flexural strength and modulus of the high density polyethylene (HDPE)/natural fibres (wood flour) composites has gradually improved by the use of reinforced HDPE as matrix. Regardless of the use of coupling agent, when reinforced HDPE has been used as matrix in the production of the composites, the better flexural strength and modulus were achieved. However, the addition of the coupling agent as a compatibilizer has particularly improved both the flexural strength and modulus, regardless of the type of matrix used. Hence, corresponds to the improvement of the interfacial adhesion between the matrix and filler of the composites, the increase in flexural properties was anticipated. The outcomes indicate the composites which composed between HDPE and wood flour could be improved remarkably by modifying the addition of the coupling agent to make the stronger bond between those two elements.

Polymer composites consist of either a thermoset or thermoplastic polymers are used to manufacture composites for a certain component application. Therefore, in order to suit the purpose for each of component is deliberated; the independent ingredients that produce the composite are customized. However, as molecules resist each other and phase separation occurs, the mechanical properties acquired are commonly menial owing to the segregation of phases and contradictory issues for effective recycling of composites and mixed-plastic wastes [2].

II. METHODOLOGY

A. Material

Recycled wood sawdust samples were taken from Fabrication Laboratory at Faculty of Civil Engineering, UiTM Shah Alam. High density polyethylene (HDPE) was used as the powder polymer matrix was obtained from Polymer Laboratory at Faculty of Chemical Engineering, UiTM Shah Alam. Maleic Anhydride (MA) was ordered by Faculty of Chemical Engineering UiTM Shah Alam from supplier in China.

B. Preparation of Filler

The sawdust initially soaked in water for an hour and dried in the oven at 120 °C for 24 hours. Then, it was grinded in cutting mill and sieved with 125 microns size sieve using sieve shaker. Then, the prepared filler is stored in the desiccator to avoid moisture absorption.

C. Compounding without Coupling Agent

Polymer and sawdust are initially weighed and packed according to the different ratio indicated in Table 1.

Table 1 SD-HDPE Composite Formulations

Formulation	SAW DUST (g)	HDPE (g)
30 % SD, 70% HDPE	12	28
40% SD, 60% HDPE	16	24
50% SD, 50% HDPE	20	20
60% SD, 40 % HDPE	24	16

Therefore, next step was mixing the desired amount of materials for each test; at 40 rpm with the temperature 180 °C SD/HDPE composites are prepared in a twin-screw extruder. Melting temperature range of HDPE is between 160 and 200 °C. To eliminate excess humidity from the fibre, the composites were dried for 24 h and stored in desiccator to avoid unexpected moisture contamination before hot-press forming. After that, the samples that came out from extruder were cut by palletizer. Three panels are produced for each parameter in the laboratory. Hence, each compound is separately spread as randomly as possible inside a metal in order to form a sample to prepare the composites.

The sample was pressed between the hot plates of a compression press at 180 °C for 10 min at 110 kg/cm^2 pressure, the final composites are made. The composite was cooled at 110 kg/cm^2 pressure by placing the composite between the two cold plates of another press for 10 min to avoid air from penetrating, which would promote the formation of bubbles.

D. Compounding with Coupling Agent

The samples were prepared using the same method as explained in compounding without coupling agent, however the addition of coupling agent to strengthen the bonding between sawdust and HDPE make changes in the ratio of the samples. Table 2 shows the formulation with the addition of the MAPE as the coupling agent.

Table 2 Composite Formulations with Addition of MAPE as Coupling Agent

Formulation	Saw Dust (%)	HDPE (%)	MAPE (%)
20% SD, 70% HDPE, 10% MAPE	20	70	10
30% SD, 60% HDPE, 10% MAPE	30	60	10
40% SD, 50% HDPE, 10% MAPE	40	50	10
50% SD, 40% HDPE, 10% MAPE	50	40	10

E. Mechanical Tests

The three-point bending flexural test method was conducted following ASTM D790 using Universal Testing Machine at 10 kN of crosshead. The prepared sample was measured according to the molding used which the dimension was 13.5 mm x 3.1 mm. For tensile strength the Testing Machine the dimension for prepared sample was 9.5 mm x 4 mm accordingly. These tests had been conducted three times using the same parameter to collect the average data. The results were discussed on the following section. test method was conducted following ASTM D882 using Universal

III. RESULTS AND DISCUSSION

A. Flexural Test without addition of Coupling Agent

Flexural test also known as bending test was conducted to observe the flexural strength of the prepared composites before and after the addition of maleic anyhride coupling agent to see the effect of the coupling agent towards the flexural strength. First of all, it is worth noting that unsatisfactory results were obtained with the coarse class samples at high sawdust content.

Table 3 Flexural Properties Data

Formulation	Modulus (MPa)	Ultimate (MPa)	Force (N)
30 % SD, 70% HDPE	1570	36.2	62.7
40% SD, 60% HDPE	1340	31.4	54.3
50% SD, 50% HDPE	1180	24.7	42.7
60% SD, 40 % HDPE	1090	22.7	39.3

Figure 1 and figure 2 show that the highest value of flexural modulus and ultimate stress with illustrated during the highest percent of HDPE which is 70%. As the matrix polymers have the flexible behavior towards the temperature, the mechanism of hardening the saw dust filler is increases as the number of matrix polymer increase during the hot press forming. It can be because the mechanism and properties between matrix polymer and saw dust filler are definitely different. There are no similar mechanisms between matrix polymers and natural fillers under compression loading had been found [3]. With the mixing of two different components it produce one final product which is wood plastic composite that can be improvise for the better purposes.

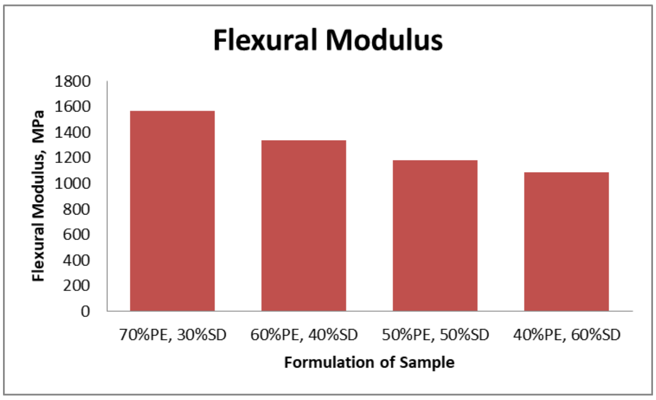


Figure 1 Flexural Modulus readings

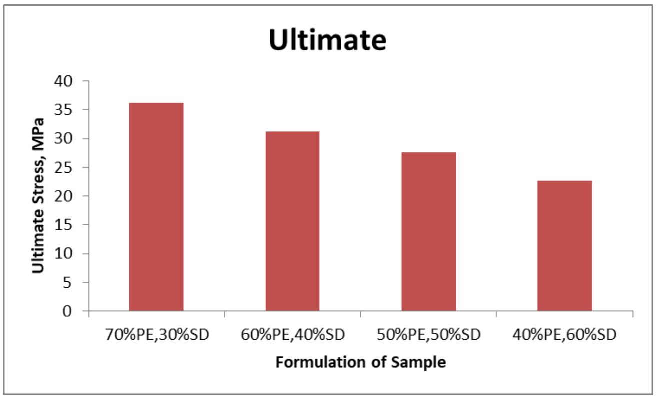


Figure 2 Ultimate Stress readings

According to data shown in Table 3, with the absent of maleic anyhride as a coupling agent, during the highest formulation of HDPE which is 70%, result shows the highest flexural modulus, ultimate stress and force with 1570 MPa, 36.2 MPa and 62.7 N respectively. In the other hand with the lowest formulation of

HDPE and highest filler, the result shows the lowest performance of the composite with 1090 MPa flexural modulus, 22.7 MPa ultimate stress and 39.3 N force. Figure 3 and figure 4 shows the graph that obtained from testing machine ASTM D790 with the highest value of stress and force.

Figure 3 and figure 4 shows the fracture of prepared composites at 36.2 MPa and 62.7 N which is the ductility is quite high because of the bonding between HDPE matrix polymer and saw dust natural fiber is brittle. The result can be summarized that the higher percent of HDPE as a matrix polymer shows the higher flexible rate of prepared composites. Therefore, the necessity of adding maleic anyhride as a coupling agent can be study further.

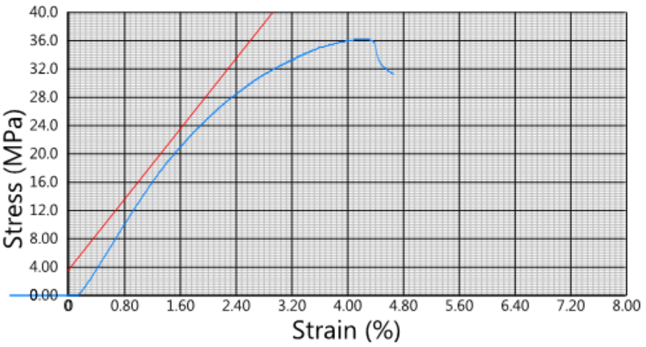


Figure 3 Graph of Stress-strain at the best performance without maleic anyhride (MA) a coupling agent

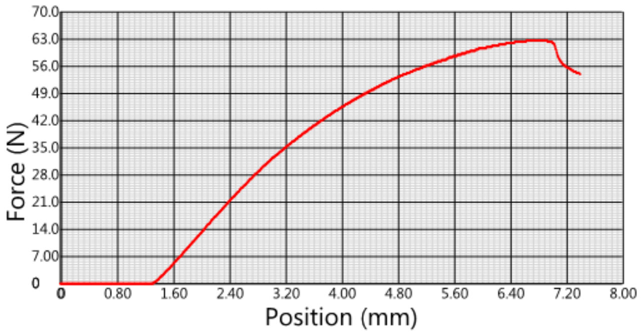


Figure 4 Graph of force at the best performance without maleic anyhride (MA) a coupling agent

B. Flexural Test with addition of Coupling Agent

Coupling agent is known as a chemical that enhances the adhesion between two different components which most likely not bound strongly together. The anyhride groups of the copolymers may react with the surface hydroxyl groups of natural fibers forming ester bonds whilst the other end of copolymer entangles with the polymer matrix due to their similar polarities [4].

This is why the coupling agent can strengthen the bonding between matrix polymer and natural fiber fillers. Therefore, with 10% addition of maleic anyhride as a coupling agent, it shows a better adhesion between wood and polymer, leading to better mechanical properties as follows.

Table 4 shows the result of the prepared composites with the addition of coupling agent. The results show that the flexural modulus at the 70 % of HDPE is increase from 1570 MPa (without maleic anyhride) to 2400 MPa (with addition of maleic anyhride). This is shown that the interfacial adhesion between HDPE and saw dust been improved with the mechanism of maleic anyhride. Therefore the bonding between HDPE and saw dust becomes stronger with the presence of coupling agent. However, the ultimate strength and force become weaker compared to the results before the addition of maleic anyhride as a coupling agent. This can be discussed further.

Table 4 Formulation with addition of Coupling Agent

Formulation	Modulus (MPa)	Ultimate (MPa)	Force (N)
20 % SD, 70% HDPE, 10% MA	2400	24.3	42
30% SD, 60% HDPE, 10% MA	2220	26.0	45
40% SD, 50% HDPE, 10% MA	1580	26.6	46
50% SD, 40 % HDPE, 10% MA	1130	22.4	38.7

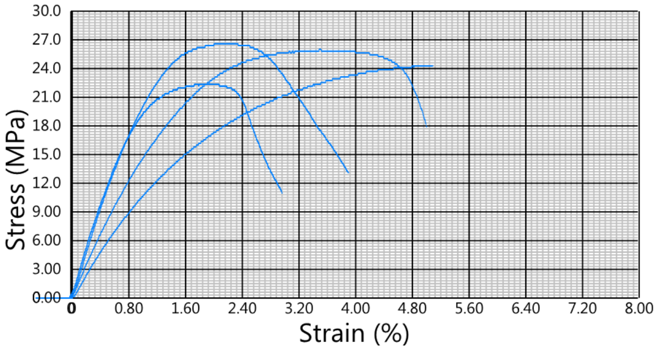


Figure 5 Graph of stress-strain with the addition of maleic anyhride (MA) a coupling agent

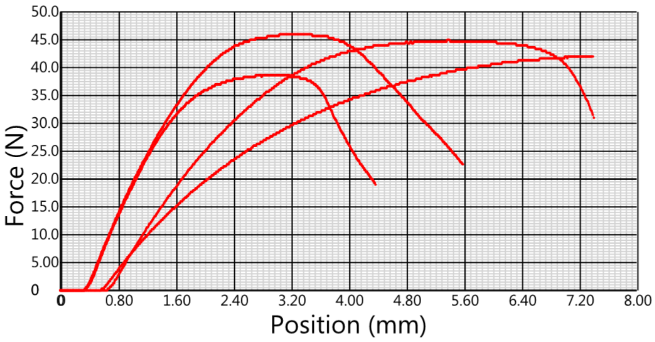


Figure 6 Graph of force with the addition of maleic anyhride (MA) a coupling agent

Figure 5 and figure 6 shows the graph of the stress-strain and force after the addition of maleic anyhride as a coupling agent. As illustrated above, the graph shows the fastest fracture was happening during 38.7 N which is the lowest percent of HDPE after the addition of maleic anyhride as a coupling agent and the slowest fracture during the highest modulus and force which is 2400 MPa and 42 N respectively.

This is shows that the percent of high matrix polymer with the addition of coupling agent gives the positive results towards the mechanical properties.

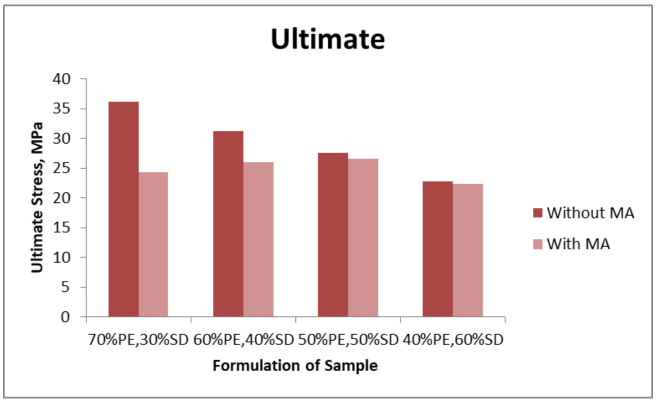


Figure 7 Comparison of Ultimate stress before and after addition of MA

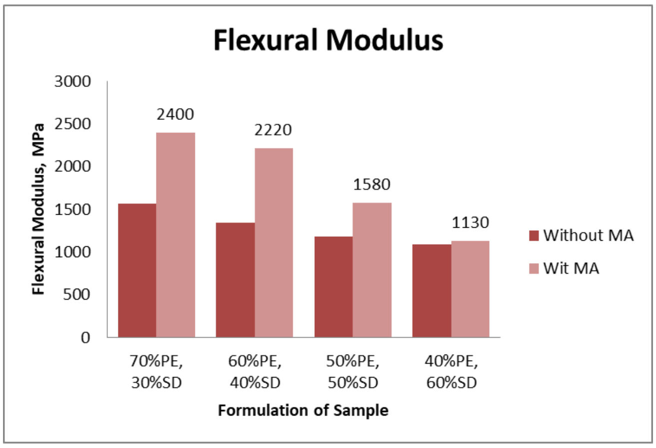
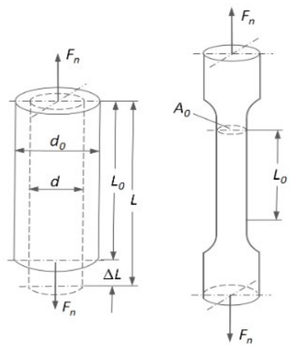


Figure 8 Comparison of Flexural Modulus before and after addition of MA

Figure 7 and figure 8 show the comparison before and after the addition of maleic anyhride as a coupling agent. The flexural modulus of the composites becomes greater relatively according to the percentage of matrix polymer and natural fibers. The highest flexural modulus is 2400 MPa and the lowest is 1130 MPa. At the highest content of saw dust as natural filler, it shows that the critical fiber content is required higher matrix polymer reinforcement to acquire the best result.

C. *Tensile Test without addition of Coupling Agent*

The tensile properties of polymers are important for the design of plastic parts and the prediction of their performance under stress, particularly when used in structural applications. The simplest case is homogeneous isotropic materials. In a static stress-strain experiment, a sample is pulled at a constant elongation rate and the stress, σ, is measured as function of strain, ε. A typical tensile test sample is shown below.



In most cases, the stress-strain response of a tensile sample is reported in terms of nominal or engineering stress and strain. Alternatively, the stress-strain response of a tensile sample may be reported in terms of true stress and true strain. For small elongations (< 0.1%), true stress and engineering stress are essentially the same. At low strain, the deformation of most polymeric materials is elastic and the measured stress is directly proportional to the strain (Hooke's law). According to mechanical properties measurement using ASTM D882, the sample foe tensile test were made both before and after addition of maleic anyhride as a coupling agent and each sample were shaped as shown in figure 9.

Figure 9 Shape of sample (Dumbell)

Table 5 Tensile properties

Formulation	Ultimate (MPa)	Break Stress (MPa)
30 % SD, 70% HDPE	0.824	0.927
40% SD, 60% HDPE	1.21	1.51
50% SD, 50% HDPE	1.81	1.62
60% SD, 40 % HDPE	1.51	1.35

According to Table 5, the highest ultimate value for tensile strength is 1.81 MPa at the composition of 50:50 between matrix polymer and natural fiber with the highest break stress 1.62 MPa. The value shows that the compound between HDPE and saw dust is weak without the addition of coupling agent. As we know, saw dust have the high brittle characteristic as it easily absorb moisture. However, as the saw dust has its own lignin and fiber, it can make a good bonding with the right material. From the result above, we can tell that the composition between HDPE and saw dust can be improved the tensile strength for a better use.

D. *Tensile Test with addition of Coupling Agent*

The problem of compatibility between the natural filler and matrix polymer can be overcome by modifying the filler-matrix interface as stated in previous section. The polar nature of wood-based fillers also simplifies the chemical modification of the filler surface. The use of coupling agents is stated to enhance the efficiency of natural fillers in the thermoplastic matrix [5].

Table 6 Tensile Strength with the addition of MA

Formulation	Ultimate (MPa)	Break Stress (MPa)
20 % SD, 70% HDPE, 10% MA	9.2	8.7
30% SD, 60% HDPE, 10% MA	7.36	7.1
40% SD, 50% HDPE, 10% MA	5.25	4.71
50% SD, 40 % HDPE, 10% MA	1.29	1.16

Table 6 shows that tensile ultimate stress and break stress totally improved with the addition of maleic anyhride as a coupling agent. The highest ultimate value for tensile test is 9.2 MPa which is definitely better than the tensile test before the addition of coupling agent which is only 1.81. Break stress shows the great improvement with the highest value is 8.7 MPa and the lowest is 1.16 MPa. The comparison had been illustrated in figure 9 and figure 10.

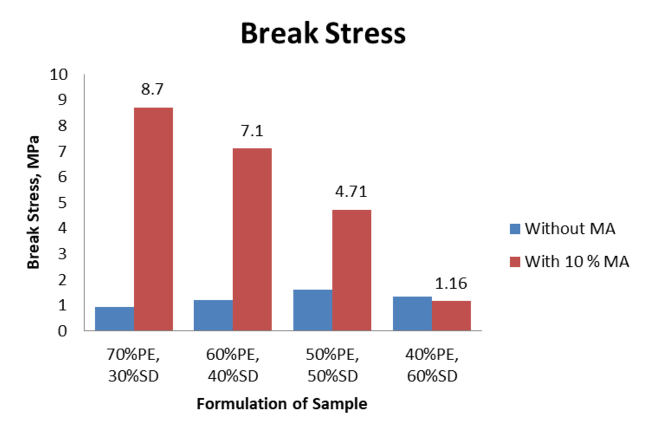


Figure 9 Break Stress readings

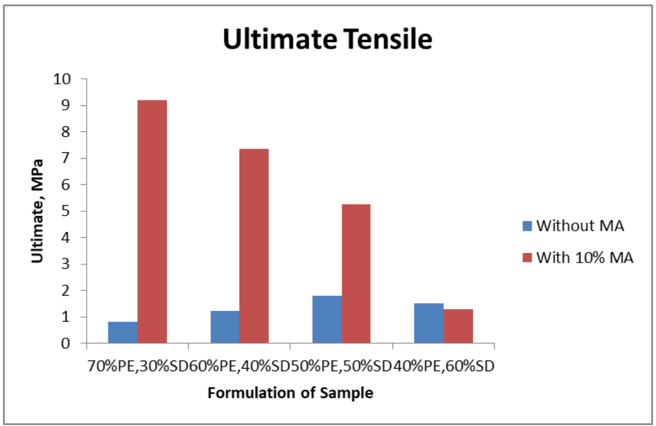


Figure 10 Ultimate Tensile readings

Figure 9 and figure 10 illustrated the trend of the tensile test readings for ultimate stress and break stress. It shows that break stress and ultimate stress gradually decrease with the decreasing number of HDPE percentage as a matrix polymer after the addition of maleic anyhride as a coupling agent . However, both readings shows the opposite trends during the absent of coupling agent, which is shows that the decreasing value of HDPE as a matrix polymer in the prepared composites resulting the increasing value of break stress and ultimate stress for tensile test. Therefore, it can be justify that the HDPE are relatively affected by the presence of coupling agent. And this can be tell that natural fiber relatively bonded with matrix polymer poorly as the higher number of HDPE, the weaker break stress and ultimate tensile showed.

IV. Conclusion

In this study, composites based on HDPE reinforced by saw dust natural fiber have been successfully prepared. In particular, the effect of coupling agent (maleic anyhride, MA) with the constant amount of ratio percent which is 10 % on mechanical properties of the composites was investigated for 70:20, 60:30, 50:40 and 40:60 percent composition of HDPE and saw dust respectively. Furthermore, it is shown that maleic anyhride (MA) can be a good coupling agent even if the polymer matrix is based on polyethylene. From the results obtained, both flexural strength and tensile strength were found to improve with addition of coupling agent in composites which was related to improved interfacial bonding between the natural fibers as filler and the HDPE as a polymer matrix.

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