USE OF CARBON FIBERS TO ENHANCE THE PHYSICAL AND MECHANICAL PROPERTIES OF WOOD COMPOSITES

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LIST OF SYMBOLS

$Wwet$	Initial weight
$Wdry$	Final weight
P	Peak Load
L	Length
b	Width
a	Thickness
w	Width
l	Length
Tf	Final thickness
Ti	Initial thickness
$M1$	Molarity
$V1$	Volume
$VHNO3$	Volume of acid nitric
ρ	Volume of water
m	Mass
$MORavg$	Average of Modulus of rupture
$IBavg$	Average of Internal Bonding
ω	weight
$TS\%avg$	Average of Thickness Swelling
VUF	Volume of Urea Formaldehyde

LIST OF ABBREVIATIONS

CF	Carbon Fiber
CNTs	Carbon Nanotubes
MWCNTs	Multiwall Carbon Nanotubes
SWCNTs	Single wall Carbon Nanotubes
MDF	Medium Density Fiberboard
UF	Urea Formaldehyde
MOR	Modulus of Rupture
IB	Internal Bonding
TS	Thickness swelling
UTM	Universal Testing Machine
MC	Moisture Content

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ABSTRACT

Medium Density Fiberboard is one type of board used widely in wood industry. Malaysia is one of the top exporters of MDF in the world. These boards becoming less popular in market due to low physical and mechanical strength. This research is on increasing the mechanical and physical property of MDF board by using carbon fiber as filler. The carbon fiber has the ability to increase mechanical properties of MDF. The main purpose of this research is to enhance the mechanical properties of the wood composite boards and the surface smoothness of the boards. The carbon fiber is first treated with nitric acid to modify the surface. The treated carbon fiber then used in the manufacturing of MDF boards. The different percentage of carbon fiber was used for comparing the results. The result shows that, adding carbon fiber as filler had improved the MOR, IB and thickness swelling values, as compared to standard board. So, it proved that the carbon fiber can improve the thermal and mechanical properties of wood composites. As a conclusion, the improvement of mechanical properties of wood composites will increase the demand of Malaysian MDF in global market.

PENGGUNAAN GENTIAN KARBON UNTUK MEMPERTINGKATKAN FIZIKAL DAN HARTANAH MEKANIKAL DARI RENCAM KAYU

ABSTRAK

Papan Sederhana Tumpat adalah salah satu elemen penting dalam industri perabot. Malaysia telah menjadi salah satu negara yang mengeluarkan Papan Sederhana Tumpat terbanyak di dunia. Namun papan negara Malaysia kurang mendapat sambutan disebabkan oleh daya tahan papan yang agak memberangsangkan. Projek ini bertujuan untuk meningkatkan daya tahan Papan Sederhana Tumpat dengan menambah serbuk karbon sebagai pengisi(filler). Serbuk karbon boleh menguatkan struktur Papan Sederhana Tumpat. Tujuan utama projek ini adalah untuk meningkatkan kekuatan komposit kayu dan juga kelicinan papan kayu ini. Serbuk karbon akan menjalani rawatan menggunakan larutan asidik. Serbuk karbon yang di rawat boleh digunakan dalam proses pembuatan Papan Sederhana Tumpat. Jumlah serbuk karbon yang berbeza akan digunakan di dalam setiap sampel Papan Sederhana Tumpat untuk membandingkan setiap bacaan yang terhasil. Hasil daripada ujian kekuatan menunjukkan peningkatan pada MOR, IB dan pengembangan ketebalan dengan meningkat bilangan serbuk karbon. Papan yang mengandungi serbuk karbon menunjukkan kadar peningkatan yang tinggi bagi ujian MOR, IB dan pengembangan ketebalan. Kesimpulannya, peningkatan sifat kekuatan komposit kayu akan memberi kesan kepada penghasilannya di Malaysia.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Wood composite is also known as engineered wood made from the hardwoods and softwoods used to manufacture lumber. Sawmill scraps and other wood waste can be used for engineered wood composed of wood particles or fibers. Wood composite is a panel prepared by pressing the fiber mixed with thermosetting resin. Usually, fiber board is derived from wood by certain processes. It will undergo hot pressing to get a panel with a desired product. The panel has some specific thickness between 3 mm to 40 mm as well. Wood composite industry is well established in Malaysia and had been used widely in furniture industry. Wood composite industry is one of the fast growing industries in Malaysia. Malaysia is one the largest exporter of wood composite in the world. Malaysia is the 3rd largest exporter after Germany and France.

In current wood composite industry, natural fiber is being used as the filler to enhance the mechanical properties and others properties to support the bio

composites. Bio composite is a material formed by a matrix or known as resin and a reinforcement of natural fibers which usually derived from plants or cellulose. The Ministry of Plantation Industries and Commodities Malaysia (MPIC) and Malaysia Timber Industries Board (MTIB) supporting the bio wood industries in Malaysia. Their objectives are to facilitate pre-commercialization of fiber and bio composite material, to stimulate interest in and to enhance the utilization of fiber and bio-composite materials in the country and to coordinate the overall development of the fiber and bio-composite industry in Malaysia. MTIB has been major source of earnings to contribute the nation's economic growth.

In current market, challenges for wood based industries come from the advance production development, production cost and also productivity competitiveness. The present fillers which is natural fiber used in wood composite industry is very costly. Based on the market concern, carbon fiber can be replaced as filler in wood production. Carbon fiber is one of the most famous things that had been attracting more scientists to do research on it. Carbon fiber is allotropes of carbon with a cylindrical structure. These cylindrical carbon molecules have very extraordinary properties which are valuable for optics, electronics and other fields of materials science and technology. Generally, because they have extraordinary thermal conductivity and mechanical and electrical properties, carbon fiber find applications as additives to various structural materials. Carbon fiber is a member of the fullerene structural family, which also includes the spherical buckyballs, and the ends of capped with a hemisphere of the buckyball structure. Their name is derived from their long hollow structure with the walls formed by one atom thick sheets of

carbon, called graphene. These sheets are rolled at specific and discrete angles and the combination of the rolling angle and radius decides the carbon properties.

The sample chosen to test carbon particle's effectiveness is Medium density fiber (MDF). Generally, Medium Density Fiber is a wood product formed by breaking down hardwood or softwood residuals into wood fiber combining it with wax and a resin binder and forming panels by applying high temperature and pressure. Medium Density fiber is denser than plywood. It is usually used in furniture industry. It is widely used in the manufacturing of furniture, kitchen cabinets, door parts, moldings, millwork and laminate flooring. The accessories include the construction of desks, high quality marker boards, work surfaces, pillars, and other products. The American National Standard for Medium Density Fiberboard classifies Medium Density Fiber by physical and mechanical properties and identifies product grades. Specifications identified in the Standard include physical and mechanical properties, dimensional tolerances and formaldehyde emission limits.

The reason to choose MDF as the sample testing mainly because of some advantages. The advantage includes MDF which give the smoothness on the surface and that makes it easy to apply paint, vanish and laminates directly to the surface. MDF is very versatile in use and can be coated with any color of user's choice. The molecular level structure of MDF is such that color applied to MDF has a very good binding. It can take up a variety of paints like varnishes, water based paints or even oil based. In addition, it is strong, provides longevity and resistant to warping that occurs over time effect by moisture. Moreover, compared to plywood and chipboard, MDF had been chosen based on the physical properties, which is dense, flat, stiff,

has no knot and easily to machine. Other than that, MDF board also can be drilled, machined and filed without damaging the surface if there is no grain formed. MDF can also be molded into different qualities as the fibers of MDF are very thin.

But, there are some little disadvantages of MDF. MDF can blunt sharp edges of construction equipment due to an extensive use of glue in its making. Besides that, MDF contains Urea Formaldehyde (UF) which can be released during sanding and cutting process. If you come in contact with it, it may lead to irritation in eyes and lungs. Proper ventilation is required when using it and facemasks are needed when sanding or cutting MDF with machinery. The dust produced when machining MDF is very dangerous. Hence, it is important to wear masks and goggles while cutting. As a whole, proper safety steps should be taken to conduct the MDF or otherwise it could be harmless and dangerous.

It is wise to develop MDF base properties in order to compete with other MDF producing industries. Adding additives as filler to enhance properties of MDF is newly discovered technology and it helps to increase production growth in market. Composites can be defined as a material made by two or more constituent with significantly different in chemical and physical properties which remain separated. In term of wood composites, there are two term usually been used which are matrix phase and fiber. Based on those two terms, the wood fibers as matrix phase and fiber used is carbon fiber. Matrix usually used to bind the fibers together so that the applied stress is distributed to all fibers. Other than that, it is used to protect the surface of the fibers from damage and to separate the fibers and restrain from crack propagation. The crack propagation will minimize the properties of the composites.

Other than that, the fiber must be strong, have high mechanical properties to support the stress applied to the composite.

1.2 Problem statement

The present wood composites in market are having poor physical and mechanical properties. Due to low thermal conductivity of wood fibers, the resin inside the wood composite is not completely cured and resulting in low mechanical properties. Urea Formaldehyde is thermosetting resin which can be brittle after curing. In the hot pressing, the thermosetting resin will be cured and make the fiberboard become dense and brittle. The curing time of urea formaldehyde will affect on the fibers to bind together and minimize the wood fibers pull out that will minimize the mechanical properties. Secondly, the cost of production is so high that the fiber boards are less competitive in the international market. Lastly, low mechanical properties such as bending strength and internal bonding and also thickness swelling. This properties will affect the qualities of wood composites (MDF) produced.

1.3 Research objective

The objectives of this research as below:

RO 1: Enhance the mechanical properties of wood composites.

RO 2: To improve the physical properties of the wood composites

1.4 Scope of the study

The method will be discussed in this part. The process begins with preparation of carbon fiber and analysis of percentage of carbon in wood fibers. Carbon fiber is prepared by burning wood composites. After that, the collected carbon fiber will be treated in the acid solution specifically Nitric Acid based on literature. The treatment is mainly to modify the carbon fiber so that it will disperse in the Urea Formaldehyde. SEM analysis will be done to verify the presence of carbon percentage. Other than that, FTIR analysis also will be done to study the carbon group presence in the carbon sample in various percentages of specimens. After that, the adhesive will be sprayed to the wood composites before it goes into hot pressing. The equipment to produce MDF is hot pressing machine which is used to produce the lab scale of MDF board. Hot Pressing will be used to compress the wood composite to desired thickness and density. At the end, all the MDF samples will be tested for Modulus of Rupture (MOR), Internal Bonding (IB) and Thickness swelling (TS). MOR and IB testing will be done by using Universal Testing Machine (UTM) by using standard method for testing wood while thickness swelling will be done manually by using caliper. Then, the result will be compared with the standard board in order to satisfy the objectives of this research.

1.5 Rationale and significance

It should give advantages to the wood composites (MDF) after mixing carbon fiber in the wood composites in the process based on the properties of carbon fiber. Firstly, higher conductive carbon fiber will increase the heating and cooling

rate of the composite. Other than that, higher chance to spread uniformly among woods fiber, caused by it sizes. Moreover, carbon fiber and graphite will enhance the surface smoothness along with other mechanical properties. It is also will not damage the circular saw, while cutting and other furniture making process. If the matrix and fibers disperse well, it will inherit the mechanical strength of the carbon fiber. This effect could produce high productivity of the MDF board and increase the demand of MDF for making the furniture as the strength of MDF increased.

CHAPTER 2

LITERATURE REVIEW

2.1 Urea formaldehyde

The Urea Formaldehyde is applied as glue in producing MDF board. “Urea-formaldehyde resins are formed by the reaction of urea and formaldehyde”. (Conner, 1996). According to Conner, the overall reaction of urea with formaldehyde is quite complex and till now it is difficult to understand the reaction of urea with formaldehyde although early studies regarding this research has been made. In current time, more than 75% of overall usage of Urea Formaldehyde is been used in wood industry for various purposes. Regarding the bonding problem, the hot press which available in all wood industry; will help the bond between saw dust and UF resin to be cured well. “The resin is used in the production of an adhesive for bonding particleboard (61%) of the urea-formaldehyde used by the industry, hardwood plywood (5%), medium density fiberboard (27%) and a laminating adhesive for bonding (7%)” (Conner, 1996). For instance overlays to panels, furniture case goods and interior flush doors. Besides that, the Urea Formaldehyde is

also known as the thermosetting resin which consists of cross-linkage bond. After curing is become brittle, it is so difficult to re-melt again as it is irreversible plastic which makes it as thermosetting. There are outnumber of advantages, which are including low curing temperature, water solubility, low cost, ease of use under a wide variety of curing conditions, excellent thermal properties, resistance to microorganisms and to abrasion, hardness and lack of color, especially of the cured resin (Conner, 1996). "Urea formaldehyde glues have several qualities that make them superior to all other glues. The 1st good quality is that, its long open working time which is 30-45 minutes in cooler weather. These are rigid glues that will not creep over time. Gap filling ability, which means that they will work when uniform clamping pressure is difficult. Other than that, resistance to moisture, solvents and also finishes. It also has an ability to glue oily woods such as a number of exotic woods".(D.J.Marks, 2007)

2.2 Composite

Combination of two or more than two is known as composite. Composites have been created to improve combinations of mechanical characteristics such as stiffness, toughness and ambient and high temperature strength (Callister, W. D. & Rethwisch, D. G., 2008). "Most of the composite materials are composed of just two phases. One is termed the matrix, which is continuous and surrounded the other phase, often called the dispersed phase" (Callister, W. D. & Rethwisch, D. G., 2008). In this research, the wood fiber can be characterized it as the matrix because it is used to surround the carbon fiber. The matrix used to protect the surface of the fiber from any defect cased by external forces. It would cause of minimizing the strength

of the fiber that would lead to crack propagation. In current world, there is a new composite regarding wood is introduced which known as Wood Polymer Composite (WPC). "It may be one of the most dynamic sectors of today's plastic industry. Wood–polymer composites generally exhibit low moisture absorption and high resistance to decay, insect, and UV ray damage. Wood has been treated with a variety of chemicals to change its physical characteristics over the years. From 1930 to 1960 a number of new wood treatments were introduced which is ethylene oxide addition to the hydroxyl groups, acetylation of the hydroxyl groups, and the phenol formaldehyde treatments" (Seong, S.K., Ha, N.Y. & In, U.H., 2008). "The WPC which is known as a structural material have been utilized in marine applications, including fender systems which are used to protect docking structures and vessels during vessel berthing. In the past, preservative-treated timber has been a commonly used material for structural elements in fender systems. An alternative material is sought to replace the wood members due to degradation from marine borers and the placement of environmental restrictions on the use of preservative-treated wood". (Seong, S.K., Ha, N.Y. & In, U.H., 2008).

2.3 Modulus of rupture

MDF board is a brittle specimen and tensile test is not suitable for it. To perform tensile test, it is required the dumbbell shape of specimen which is difficult for MDF board. Second, without fracturing MDF board, it is difficult to grip brittle material. (Callister, W. D. & Rethwisch, D. G., 2008). After all the consideration, it is suitable to do the bending test. This testing also known as three points bend test, which the load applied in the middle of the surface of specimens. Bend testing

determines the ductility or the strength of a material by bending the material over a given radius which is applied force is perpendicular with the position of the specimen. The specimen can be in rectangular or rod form. MOR is test the bending strength, which is tested to ensure that the addition of fillers did not change or damage the bending qualities of the board (Torrey, 2001). The static bending test is a three point bend test which measures ductility, the ability of a material to change form under pressure and keep that structure permanently. It also can determine tensile strength (Jessica, R., 2012) The three point bending test is works where the load will be applied in center of the specimen with constant rate of speed with supports at two edge of specimen til the specimen breaks at the center. (Torrey, 2001). The maximum force will be shown on the result after the specimen start to break. That value also known as peak load and use in the calculation of MOR. The calculation of MOR was performed using the following equation:

$$MOR = {}^{3PL}/_{2ba}{}^{2} \qquad \text{(Eq 2.1)}$$

(Torrey, 2001)

Where

MOR = Modulus of Rupture (N/mm^2)

P = Peak Load (N)

L =Length (mm)

a = Thickness (mm)

b =Width (mm)

2.4 Internal bonding

Internal Bonding test is used to test the strength of the bonding formed between matrix and the resin. “A steel or aluminum block is glued to the sample and used to hold the sample in the test machine. The test machine then pulls the sample apart at a uniform rate of motion dependent upon the thickness of the sample. The test continues until the sample fails. The important data point in this test is the maximum load on the sample before it fails (breaks)”. (Torrey, 2001). The better IB value will be obtained for the better bonding formed between matrix and resin as per theory. “The better the bond between the glue and strands, the better the strength properties of the boards”(Torrey, 2001). “The standard size for the specimen is around 50mm in length and 50mm in width. Then, the specimen was glued on the aluminum block and after the specimen settle run the testing it will reheat to substitute with others”. (Torrey, 2001). As per literature review, it used to calculate the Internal Bonding (IB) by using the given equation:

$$IB = P/_{w \times l} \qquad \text{(Eq. 2.2)}$$

(Torrey, 2001)

Where

IB = Internal Bonding (N/mm^2)

P = Peak Load or Maximum Load (N)

w = width (mm)

l = length (mm)

2.5 Thickness swelling

Thickness swelling test is to measure the water absorption of MDF board after put inside deep water for 24 hours. The thickness of the specimen will be calculated before and after soaked inside water (Torrey, 2001). The thickness will increase because it will absorb water as wood fiber is characterized as hydrophilic which means the tendency of absorbing water is high. Water absorption is slightly lower in samples having good bonding as it distract the water molecules (Torrey, 2001). Thickness measurements will be taken 12.7 mm from the edge at the center of side, using a digital indicator (Torrey, 2001). The figure 2.1 shows how to calculate thickness swelling. The equation as shown below to calculate the thickness swelling will be used after the final thickness was measured using:

$$TS=\left(\frac{Tf-Ti}{Ti}\right) x\ 100\% \qquad \text{(Eq 2.3)}$$

(Torrey, 2001)

Where

TS = Thickness Swelling (%)

Ti = Initial Thickness (mm)

Tf = Final Thickness (mm)

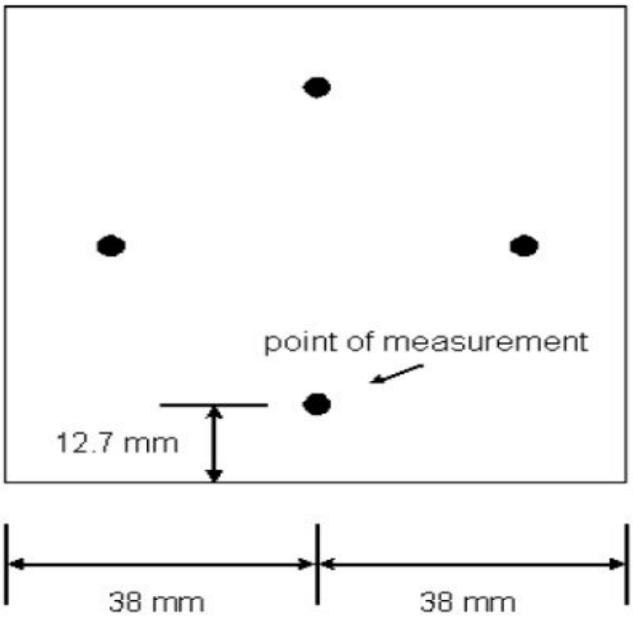

Figure 2.1 Thickness measurement of sample

2.6 Resin and wood treatment

Resin is a natural or synthetic complex and it hardens with the heat treatment. There are number of resin that has been used depending on the composition and potential usage. In plywood industry most commonly used resins are Melamine Urea-Formaldehyde (MUF) and Urea- Formaldehyde type resins. Resin plays the vital role in giving glue strength between the bonds in plywood. It also will give a desired shape inside the hot pressing. In the wood industry, curing is very much depending on the heat treatment given in hot press (Martinus L. Van Druten, 1997). In this research, only Urea-Formaldehyde is subjected into study because of its typical composition that would not require the formulation of more compounds and in hand reducing the costing of production of such resin. Since production Melamine Urea Formaldehyde requires more funding and cost. As stated above, UF resins is chosen because of its various unique properties such perfect adhesion to be used as