USE OF CARBON FIBER TO ENCHANCE THE PHYSICAL AND MECHANICAL PROPERTIES OF PARTICLE BOARD

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ABSTRACT

Particle board which well known as an engineered wood product manufactured or produced from wood chips, sawmill shavings, or even saw dust, and a synthetic resin or other suitable binder, which is pressed and extruded. 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 particle board by using carbon nano fiber as filler. The carbon nano fiber has the ability to increase mechanical properties of particle boards. The main objective of this research is to enhance the mechanical properties of the wood composite boards. The carbon nano fiber were used in the production of particle boards. The different percentage of carbon nano fiber was used for comparing the results for the mechanical strenght. The result shows that, adding carbon nano fiber as filler had improved the MOR, IB and reduce thickness swelling values, as compared to standard board. So, it proved that the carbon nano fiber can improve the thermal and mechanical properties of wood composites. The present of carbon nano fiber reduce the formaldehyde emission and increase the curing rate and also thermal stability is proven by the DSC and TGA analysis. As a conclusion, the improvement of mechanical properties of wood composites will increase the demand of Malaysian Particle Board in global market and also reduce the cost of production.

Keywords: Particle board, Modulus of Rapture (MOR), Internal Bonding (IB), DSC, TGA and Carbon Nano Fiber

ABSTRAK

Papan partikel dikenali sebagai produk kayu yang dibuat daripada serpihan kayu, , atau habuk kayu, bersama resin sintetik atau pengikat lain yang sesuai , yang ditekan dan ditumpatkan. Papan ini menjadi kurang popular di pasaran disebabkan oleh kekuatan fizikal dan mekanikal yang rendah. Kajian ini adalah untuk meningkatkan kekuatan mekanikal dan fizikal papan partikel dengan menggunakan karbon nano fiber. Karbon nano fiber mempunyai keupayaan untuk meningkatkan sifat-sifat mekanikal papan partikel. Objektif utama kajian ini adalah untuk meningkatkan ciri-ciri mekanikal papan komposit kayu. Karbon nano fiber yang digunakan dalam pemprosesan papan partikel. Peratusan yang berbeza karbon nano fiber telah digunakan untuk membandingkan keputusan untuk kekuatan mekanikal. Hasilnya menunjukkan bahawa menambah serat nano karbon sebagai pengisi telah meningkatkan Bond Dalam Negeri (IB), Modulus pecah (MOR)dan mengurangkan Ketebalan Bengkak (TS), berbanding kepada lembaga standard. Jadi, ia membuktikan bahawa karbon nano fiber boleh meningkatkan sifat haba dan mekanikal komposit kayu. Karbon nano fiber mengurangkan pelepasan formaldehid dan meningkatkan kadar pengawetan dan juga kestabilan terma terbukti dengan DSC dan analisis TGA. Kesimpulannya, peningkatan sifat mekanik komposit kayu akan meningkatkan permintaan Lembaga Kayu Malaysia di pasaran global dan juga mengurangkan kos pengeluaran

Katakunci: papan Partikel, Modulus pecah (MOR), Bond Dalam Negeri (IB), DSC, TGA dan Karbon Nano Fiber

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LIST OF SYMBOLS

P	Peak Load
L	Length
b	Width
a	Thickness
w	Width
l	Length
Tf	Final thickness
Ti	Initial thickness
$M1$	Molarity
$V1$	Volume
m	Mass

LIST OF ABBREVIATIONS

CNF	Carbon Nano Fiber
UF	Urea Formaldehyde
MOR	Modulus of Rupture
IB	Internal Bonding
TS	Thickness swelling
UTM	Universal Testing Machine
DSC	Differential Scanning Calorimetry
TGA	Thermogravimetric Analysis

1 INTRODUCTION

1.1 Background

Particle board which well known as an engineered wood product manufactured or produced from wood chips, sawmill shavings, or even saw dust, and a synthetic resin or other suitable binder, which is pressed and extruded. Particle board 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

The Malaysian timber industry is one of the major contributors to the Malaysian economy. Malaysia is one of the world’s largest exporter of tropical timber and timber products and the 10^{th} largest exporter of furniture (second in Asia) with over 160 export destinations. Malaysia has also established itself as a major producer and exporter of sawn timber, panel products (plywood, medium density fiberboard (MDF) and particleboard), flooring, doors and other joinery products.

In current particle board 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.

Particleboard is an ideal for applications such as wardrobes, wall units, TV cabinets, shelving, toys, cupboards and wall linings. Particleboard is the most commonly used substrate for applying laminates in bench top applications, and provides the most economical option for general indoor building requirements.

Figure 1.1: Particle Board

The challenges for wood based industries come from production cost, productivity competitiveness and also the advance production development. The present fillers which is natural fiber used in wood composite industry is very costly. Based from the market concern, carbon fiber can be replaced as filler in wood production. Carbon fiber is allotropes of carbon with a cylindrical structure. It has 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.

The reason to choose particle board as the main sample testing because of some advantages. Particle board are very cost effective because it can be made cheaply and more affordable. Particle board can be covered with thin layer of veneer or a plastic laminate give the board a solid timber look.

The disadvantage of particle board contain Urea Formaldehyde (UF) which can be released during sanding and cutting process. This can may cause lung and eye irritation. Particle board is less denser compare to the other board like plywood and this make it weak and easily damage. It also unable to support heavy weight material and this shows it has weak physical and mechanical strength.

1.2 Motivation

Low Strength Particle Boards:

Particle board furniture is weak board compared to other kinds of engineered woods such as plywood and MDF. Due to its properties it is less dense and can easily get damaged while handling.

Low life, low durability:

Apart from being low on strength, particle boards are also easily damaged because of moisture and humidity. This means that furniture made from these boards will not last very long. This is without doubt the major drawback of particle board furniture.

Particle board furniture clearly to last for around 2 to 3 years. Now compare this with plywood which lasts easily for 15-20 years, or with good quality solid wood furniture that lasts for several decades and is handed over from one generation to the next.

Cannot support heavy loads:

Particle boards are almost never used in applications where the boards will be subjected to heavy weights. Being low on strength, particle boards are only suitable for holding low weights, or as forming the walls of cabinets and the like.

1.3 Research objective

The objectives of this research is:

- RO 1: To enhance the mechanical and physical properties of particle board.
- RO 2: To study the morphology of particle boards using Field Emission Scanning Electron Microcopy (FESEM) Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA)

1.4 Research Scope

This research is focus to investigate the effect of carbon nano fiber on the mechanical and physical strength of particle boards. The particle boards are made using various concentration of carbon nano fiber. This boards will be tested on Thickness swelling, Modulus of Rupture and Internal bond in order study the mechanical and physical strength. The morphological structure of particle board is study using Field Emission Scanning Electron Microcopy (FESEM). The boards sample used to measure formaldehyde emission. The boards sample also will be test Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) Analysis in order to study the thermal stability and the curing rate.

1.5 Organisation of this thesis

The structure of the reminder of the thesis is outlined as follow:

Chapter 2 provides a description of the applications and general design features of the particle board. This chapter also provides a brief discussion of the advanced experimental techniques available for the preparation of the mixture of urea formaldehyde and carbon nano fiber and production particle board, mentioning their applications and the purpose of their production.

Chapter 3 gives a review on how to produce particle board using hot press. The carbon nano fiber will be mixed manually with the wood particle. The equipment to produce particle board is hot pressing machine which is used to produce the lab scale of particle board. Hot Pressing will be used to compress the wood composite to desired thickness and density.

Chapter 4 is discuss on all the results obtain throughout this research. The particle board will be tested on Modulus of Rupture (MOR), Internal Bonding (IB), Thickness swelling (TS), Field Emission Scanning Electron Microscopy, Formaldehyde Emission Testing, Differential Scanning Calorimetry (DSC) Analysis and Thermogravimetric Analysis (TGA).

Chapter 5 is discuss on the conclusion and the recommendation of this experiment.

2 LITERATURE REVIEW

2.1 Composite

When two or more different materials combined together to form a single superior material is define as composite. Natural composites exist in both animals and plants. Wood is a composite, it is made from long cellulose fibres (a polymer) held together by a much weaker substance called lignin. Cellulose is also found in cotton, but without the lignin to bind it together it is much weaker. The two weak substances lignin and cellulose together form a much stronger one. Most of composite have three constituent: matrix phase, reinforcement phase and interphase which refer to zone across which matrix and reinforcing phases interact. The reinforcement phase is usually stronger and stiffer than the matrix, and it gives the composite its good properties. On other hand, matrix phase holds the reinforcements phase in an orderly pattern. Because the reinforcements are usually discontinuous, the matrix also helps to transfer load among the reinforcements. Most of composite just made of two phase only. One phase is called the matrix, which continuous and surround the other phase called the dispersed phase (Callister, W. D. & Rethwisch, D. G., 2008).

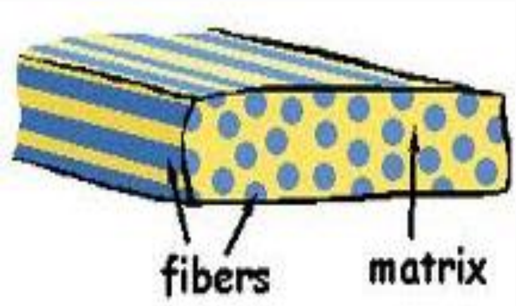

Figure 2.1: Composite structure

Most of the composite was created to improve the combination of mechanical properties such toughness, temperature resistance and stiffness (Callister, W. D. & Rethwisch, D. G., 2008). Composites are fairly inert as they do not rust, they do not directly suffer galvanic (electrical) corrosion caused by stray currents and they can easily be formulated to resist ultra violet radiation. The range of composite today is such that if there is not one for a specific project, then it can probably be designed using an appropriate resin and reinforcing material. Due to incorporation of several different types of fibres into a single matrix led to the development of new hybrid bio-composites. The behavior of hybrid composites is a weighed sum of the individual components in which there is a more favorable balance between the inherent advantages and disadvantages. Also, using a hybrid composite that contains two or more types of fiber, the advantages of one type of fiber could complement with what are lacking in the other. As a consequence, a balance in cost and performance can be achieved through proper material design (Idicula *et al.*, 2006). The properties of a hybrid composite mainly depend upon the fiber content, length of individual fibres, orientation, extent of intermingling of fibres, fiber to matrix bonding and arrangement of both the fibres. The strength of the hybrid composite is also dependent on the failure strain of individual fibres. Maximum hybrid results are obtained when the fibres are highly strain compatible (Cristiane *et al.*,2009) . These investigations have shown that in some cases the application of composite materials can be of structural interest, as they give greater strength and ductility to wooden elements, compared to the performance that wood is able to provide on its own. Some tests on the reinforcement of wooden beams with composite materials have been carried out, limited to the case of Carbon Fiber fabrics (CFRP) (N. Plevris, T.C. Triantafillou, 1992). A preliminary research in the quasi-static loading of glulam beams with carbon fiber reinforcement were performed by (U.Meier, 1995). Triantafillou subsequently studied the shear behavior of glulam beams reinforced at the ends with carbon fiber strips (T.C. Triantafillou, 1997). Other studies on the shear reinforcement of wooden elements with composite materials have been conducted in recent years (J. Fiorelli, A. Alves Dias, 2003)In recent years, wood–fibers have gained significant interest as reinforcing material for commercial thermoplastics. They are now fast evolving as a potential alternative to inorganic fillers for various applications. Wood–fiber offers several advantages like low density, high specific properties, non-abrasive to processing equipment, low cost and most importantly biodegradability. However the primary drawback of using wood–fibers for reinforcement is the poor interfacial adhesion between polar-hydrophilic wood–fibers and nonpolar-hydrophobic plastics. This results in poor mechanical properties of the final product (A. Karmarkara, *et al*., 2007). In this research the wood fiber will function as the matrix as it is surrounding the carbon fiber. The matrix is used to protect the surface of the fiber from the external force. By this it can increase the strength of wood fiber and minimizing the chances of crack propagation on the wood fiber. In this current world, Wood Polymer Composite (WPC) was introduced. This wood polymers has high resistance towards insect, UV ray damage and decay and also exhibit low moisture absorption. Lots of improvement have been done using variety chemical on wood composite to improve its physical characteristic. Addition of Ethylene oxide o the hydroxyl groups, phenol formaldehyde treatments, and acetylation of hydroxyl groups. 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 (Seong, S.K. *et al*., 2008).

2.2 Urea Formaldehyde

Urea-formaldehyde resins are formed by the reaction of urea and formaldehyde. Urea Formaldehyde are widely used in wood industry. More than 70% of Urea Formaldehyde resin is used by the forest products industry for a variety of purposes. The resin were used in the production as 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). Urea Formaldehyde which function as a glue in board production. Although it has weak bonding between wood fiber and urea formaldehyde but it can be overcame with the present of hot press. The pressed wood industry makes extensive use of urea formaldehyde resin as a binder for its medium and high density fiberboard (MDF/HDF) products. Its outstanding flexural modulus and tensile strength lends fiberboard products excellent structural characteristics. These products are found in many domestic and commercial buildings in the form of wall cladding, laminate flooring, furnishing, and finishes. Composites and finishes based on this resin are also highly resistant to chemical and bacterial attacks which make them ideal for kitchen and bathroom use. One of the few disadvantages of using this resin is the potential health risks involved with exposure to the formaldehyde vapors released during its curing and decomposition. Urea-formaldehyde resins are formed by the reaction of urea and formaldehyde (Conner, 1996). The Urea Formaldehyde also known as the thermosetting resin which is consists of cross-linkage bond. It is irreversible plastic which is can’t re-melted and after curing it as it become brittle. The advantage of Urea Formaldehyde are , it is low cost, ease of use under a wide variety of curing conditions, low cure temperatures, water solubility, resistance to microorganisms and to abrasion, hardness, excellent thermal properties, and lack of color, especially of the cured resin (Conner, 1996). Besides that, it have ability to feel the gap, which make Urea Formaldehyde work when the uniform clamping pressure is difficult. This glue also won’t creep over the time as it has long open working time which is 30-45 minutes in cooler weather. Other than that, resistance to moisture and also solvent. It also has an ability to glue oily woods such as a number of exotic woods” (D.J.Marks, 2007).

2.3 Modulus of Rupture

Tensile test is not suitable for brittle sample as it is difficult to prepare if it require geometry. It also difficult to hold and place brittle sample without fracturing it. In order to avoid this problems, Bending test is the suitable test as it applied force perpendicular with the position of the sample. Modulus of Rupture, frequently abbreviated as MOR, (sometimes referred to as bending strength), is a measure of a specimen’s strength before rupture. It can be used to determine a wood species’ overall strength; unlike the modulus of elasticity, which measures the wood’s deflection. This test method also known as three points bend test, where the load are applied in the middle of the surface of sample. By this test 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 can be determined. The bending test at three point can determine the ability of a material to change form under pressure and keep that structure permanently and also cant measure ductility. Beside that tensile strength of a sample also can be determine (Jessica, R., 2012). MOR is used to test bending strength, which to ensure that the addition of fillers did not change or damage the bending qualities of the board. The load will applied at the center of sample with the constant speed with supports at two edge of specimen til the specimen breaks at the center (Torrey, 2001). The maximum force were determined at the point where the sample starts to break. The calculation of MOR was performed using the following equation:

$$MOR = {}^{3PL}/_{2ba}{}^{2} \quad \text{(Torrey, 2001) (Eq 2.1)}$$

Where

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

P = Peak Load (N)

L =Length (mm)

a = Thickness (mm)

b =Width (mm)

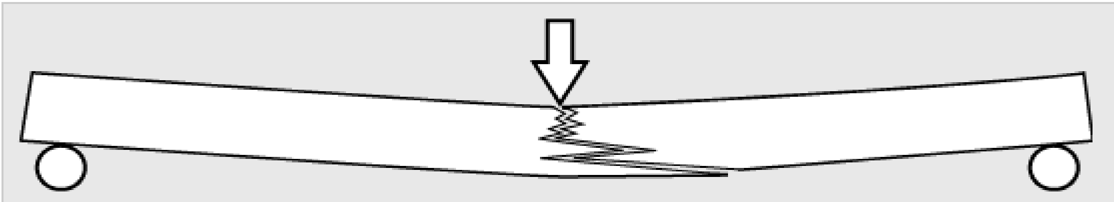

Figure 2.2: Modulus of Rupture Testing

2.4 Internal bonding

Internal Bonding test is done to determine the strength of bonding which formed between matrix and resin. This testing involves bonding specimen blocks to the top and bottom surfaces of the test specimen with a suitable adhesive. The loading fixtures, which grip the specimen blocks, are attached to the test machine and tension is applied perpendicular to specimen surface until the specimen fails. Tensile strength is then calculated by dividing the maximum load at failure by the cross-sectional area of the test specimen. The test machine will pull the sample apart in uniform and constant rate of motion. The motion rate depends on the thickness of sample. The test will done until the sample break. The maximum load can be determine before the sample break (Torrey, 2001). According to Torrey, the better the bond between the glue and strands, the better the strength properties of the boards. The sample will be prepared according to standard size around 50mm in length and 50mm in width. The sample will be glued on the aluminium block and after the specimen settle run the testing it will reheat to substitute with others (Torrey, 2001). The calculation of Internal Bonding was performed using the following equation:

$$IB = P/_{w \times l} \qquad \text{(Torrey, 2001)} \quad \text{(Eq 2.2)}$$

Where

IB = Internal Bonding (N/mm^2)

P = Peak Load or Maximum Load (N)

w = width (mm)

l = length (mm)

2.5 Thickness Swelling

It's a method used to determine and measure the thickness difference after deep it in the water. The thickness of sample will increase due to the presents of water. Wood fiber characterized as hydrophilic, so tendency to absorb water is higher. —Thickness swelling is slightly lower in samples that have better bonding.‖ (Torrey, 2001). This thickness swelling was tested by submerged it in the tap water in room temperature for 24 hours (Torrey, 2001). —Thickness measurements were taken 12.7 mm from the edge at the center of side, using a digital indicator‖ (Torrey, 2001).

$$TS=\left(\frac{Tf-Ti}{Ti}\right) x\ 100\% \qquad \text{(Torrey, 2001) (Eq 2.3)}$$

Where

TS = Thickness Swelling (%)

Ti = Initial Thickness (mm)

Tf = Final Thickness (mm)

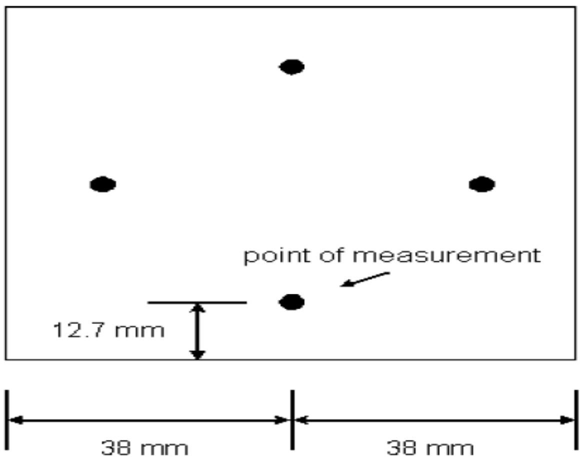

Figure 2.3: Thickness measurement of sample

2.6 Carbon Fiber

Carbon fiber has been described as a fiber containing at least 90% carbon obtained by the controlled pyrolysis of appropriate fibers. The characterization of carbon fiber microstructure has been mainly been performed by x-ray scattering and electron microscopy techniques. In contrast to graphite, the structure of carbon fiber lacks any three dimensional order. In PAN-based fibers, the linear chain structure is transformed to a planar structure during oxidative stabilization and subsequent carbonization. Basal planes oriented along the fiber axis are formed during the carbonization stage. Carbon fiber is synthesis by thermal treatment for Pan-based. This process was outlined by the Deifendrorf and co-worker. In this process, spinning of PAN in to fiber form, then oxidizing the fiber at 200-300C and carbonizing the fiber at 1000-2500C in inert atmosphere. On this process the strength of fiber is controlled by stretching the carbon fiber as well as changing the heating rates, the extent of oxidation and final carbonization temperature. The first step is cyclization within the backbone to form ladder structure. The structure is stabilizes by heating into high temperature. It stretch during the cyclization in order to maintain alignment of polymer (S.M. Lee, 1993).

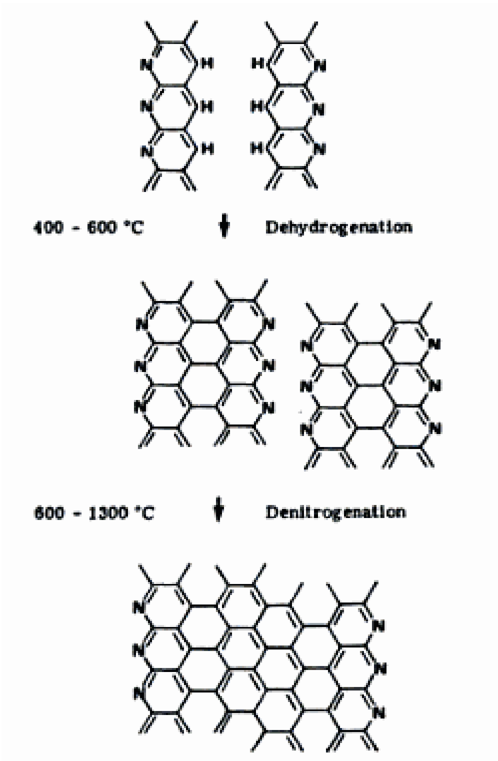

Figure2.4: Proposed mechanism for carbonization of cyclicized PAN fiber inti aromatic carbon sheet

(Source: Handbook Of Composite Reinforcement by S.M. Lee)

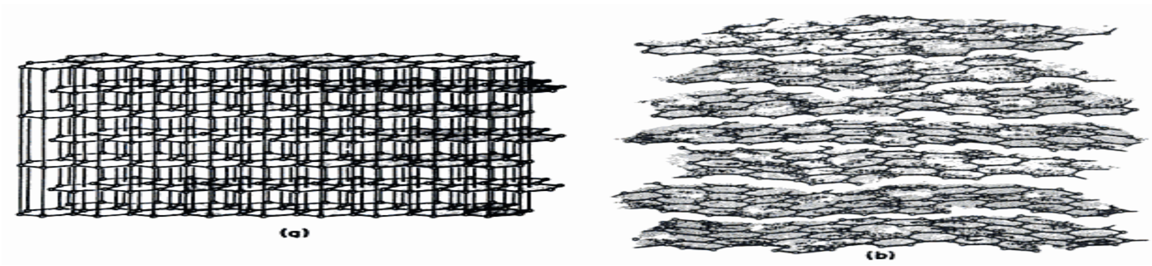

Figure2.5: Structural Model Of Graphite and Carbon Structure: (a) perfect graphite crystal and (b) turbostratic model
(Source: Handbook Of Composite Reinforcement by S.M. Lee)

Due to the carbon sheet is imperfect, the formation of ideal graphite structure cant be formed like in Figure 2.5 (a). Instead a disordered crystal structure, the turbostratic is formed Figure 2.5 (b). Wide-angle x-ray data suggests an increase in stack height and orientation of basal planes with an increase in heat treatment temperature. A difference in structure between the sheath and the core was noticed in a fully stabilized fiber. The skin has a high axial preferred orientation and thick crystallite stacking. However, the core shows a lower preferred orientation and a lower crystallite height. Carbon fibers have widely applied in recreational, commercial and civilian aircraft, recreational, industrial, and transportation markets. Carbon fiber are used in composites with a lightweight matrix (Raghavendra R. Hegde *et al*., 2004). Carbon fiber are classified into several types according to carbon fiber properties, Based on modulus, strength, and final heat treatment temperature, carbon fiber can be classified into the following categories:

1. Based on carbon fiber properties,
2. Based on precursor fiber materials,
3. Based on final heat treatment temperature,

1. Based on carbon fiber properties, carbon fibers can be grouped into:

- Ultra-high-modulus, type UHM (modulus >450Gpa)
- High-modulus, type HM (modulus between 350-450Gpa)
- Intermediate-modulus, type IM (modulus between 200-350Gpa)
- Low modulus and high-tensile, type HT (modulus < 100Gpa, tensile strength > 3.0Gpa)
- Super high-tensile, type SHT (tensile strength > 4.5Gpa)

2. Based on precursor fiber materials, carbon fibers are classified into:

- PAN-based carbon fibers
- Pitch-based carbon fibers
- Mesophase pitch-based carbon fibers
- Isotropic pitch-based carbon fibers
- Rayon-based carbon fibers
- Gas-phase-grown carbon fibers

3. Based on final heat treatment temperature, carbon fibers are classified into:

- High-heat-treatment carbon fibers (HTT), where final heat treatment temperature should be above 2000°C and can be associated with high-modulus type fiber.
- Intermediate-heat-treatment carbon fibers (IHT), where final heat treatment temperature should be around or above 1500°C and can be associated with high-strength type fiber.
- Low-heat-treatment carbon fibers, where final heat treatment temperatures not greater than 1000°C. These are low modulus and low strength materials.

YEAR	**POUNDS**
1992	13,000,812
1993	14,598,544
1994	17,425,452
1995	19,714,671
1996	20,672,741
1997	25,900,000

Table 2.1: Worldwide shipment of carbon fibers for composites

(Source : Raghavendra R. Hegde, *et al*., 2004)

The advantages of Carbon Fiber are physical strength, specific toughness, light weight, high dimensional stability, low coefficient of thermal expansion, low abrasion, good vibration damping, strength, toughness, fatigue resistance, self-lubrication, high damping, chemical inertness, and high corrosion resistance (Raghavendra R. Hegde, *et al*., 2004). Carbon fiber was also tested in the medium density board (MDF) which shows 0.1 % percentage shows best result in Internal bonding and Modulus Of Rapture compare to other percentage of carbon fiber. This is due to carbon fiber agglomerate (T.Khan, *et al*., 2013). The well interfacial adhesion between carbon fibers and matrix can be also obtained only by the formation of physical interaction e.g., Lu's group put to work air plasma to modify carbon fibers, and concluded that mechanical interaction has a most important effect on the interfacial adhesion of composites (C. Lu *et al*., 2007). In contrast, Yuan's group establishes that the chemical interaction but not the physical interaction is the key and requisite step to improve the interfacial adhesion (L.Y. Yuan *et al*., 1991).

Figure 2.6: Carbon Fiber

3 MATERIALS AND METHODS

3.1 Materials

3.1.1 Urea Formaldehyde

Urea Formaldehyde or known as urea methanol. It is made from urea and formaldehyde heated in the presence of a mild base such as ammonia or pyridine. This thermosetting resin which is brittle when curing at some temperature. It used as a glue to bind all the wood particle to produce particle board. This resin is in white color and in liquid form. Aqueous Formaldehyde will be added to mixed granular urea to get liquid form of urea formaldehyde in industry. This resin can be purchased through University Malaysia Pahang Chemical Engineering Laboratory.

3.1.2 Wood particle

Rubber wood fiber is the main material to manufacture the particle board. The rubber wood fiber are already supplied from chemical engineering laboratory.

3.1.3 Carbon Nano Fiber

Carbon nono fiber is the material to use to mix with urea formaldehyde as a additional filler. The carbon nano fiber was supplied by my supervisor Dr. Arun Gupta.

3.2 Apparatus

3.2.1 Hot Press

Hot Press used to compress the agglomerates wood fiber to become particle board after forming it using mold. Stopper was placed with 6mm size in thickness on the both sides of particle. The temperature for the hot press process is 180°C and 15 MPa in pressure. Particle board is leave about four minutes. After time is out, particle board is taken out from the hot press and leave it cool. The brand of hot press is Lotus Scientific with model number of 22009-25. The series number is 90105.