MAKING OF WOOD COMPOSITE BY USING NATURAL RUBBER LATEX AS AN ADHESIVE

NORLIRABIATULADAWIYAH BINTI CHE ANI

Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Chemical Engineering

Faculty of Chemical & Natural Resources Engineering
UNIVERSITI MALAYSIA PAHANG

JANUARY 2014

MAKING OF WOOD COMPOSITE BY USING NATURAL RUBBER LATEX AS ADHESIVE

ABSTRACT

A preliminary investigation into Natural Rubber Latex (NR) and starch adhesives for use in the manufacture of Medium Density Fiber (MDF) panels from rubber wood fibers is reported. This research is on increasing the mechanical strength and physical properties of MDF using Natural Rubber Latex (NR) as an adhesive. NR latex has ability to increase mechanical properties of MDF by doing a chemical formulation itself. In others word, NR latex not give a good result in mechanical testing without any others chemical improvement just like we added starch to give the better strength of MDF. Three samples which are 5g of starch with 15g of NR latex, 10g starch with 10g of NR latex and 15g of starch with 5g of NR latex were prepared. Adhesive preparation trials, physico-chemical testing of adhesives and mechanical testing of adhesives bonded to MDF have been completed. The morphology of the specimens was characterized using Thermo gravimetric Analysis (TGA) and Fourier Transform Infrared Spectroscopy (FTIR). The mechanical results of these limited tests show that when 10g starch with 10g NR latex shows more strength compared to other two variables. From the TGA graph, it was observed that the thermal stability of composite based on starch was higher than composite with less composition on starch.

MEMBUAT KAYU KOMPOSIT DENGAN MENGGUNAKAN GETAH ASLI SEBAGAI PELEKAT

ABSTRAK

Satu penyiasatan awal ke dalam semula jadi susu getah dan kanji pelekat untuk kegunaan dalam pembuatan serat ketumpatan sederhana (MDF) panel daripada gentian kayu getah dilaporkan. Kajian ini adalah untuk Getah Susu meningkatkan kekuatan mekanikal dan sifat-sifat fizikal MDF menggunakan Susu Getah Asli (NR) sebagai pelekat. Susu Getah Asli mempunyai keupayaan untuk meningkatkan sifat mekanik MDF dengan melakukan formulasi kimia sendiri. Dalam perkataan lain, susu getah asli tidak memberi keputusan yang baik dalam ujian mekanikal yang lain tanpa sebarang peningkatan kimia seperti kami menambah kanji untuk memberi kekuatan yang lebih baik daripada MDF. Tiga sampel yang terdiri daripada 5g kanji dengan 15g susu getah asli, 10g kanji dengan 10g susu getah asli dan 15g kanji dengan 5g susu getah asli telah disediakan. Perbicaraan penyediaan pelekat, ujian fiziko- kimia pelekat dan ujian mekanikal pelekat terikat kepada MDF telah selesai. Morfologi spesimen dicirikan menggunakan Thermo gravimetrik Analisis (TGA) dan Spektroskopi inframerah transformasi Fourier (FTIR). Keputusan mekanikal ini ujian terhad menunjukkan bahawa apabila 10g kanji dengan 10g susu getah getah asli menunjukkan kekuatan lebih berbanding dengan dua pemboleh ubah. Daripada graf TGA ini, ia telah diperhatikan bahawa kestabilan terma komposit berdasarkan kanji adalah lebih tinggi berbanding komposit dengan komposisi kurang pada kanji.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

MOR	Modulus of Rupture (eq 2.1, 3.4 and 4.5)
P	Peak Load (eq 2.1, 3.4, 4.3 and 4.5)
L, l	Length (eq 2.1, 2.2, 3.3, 3.4, 4.2, 4.3, 4.4, 4.5 and 4.7)
a, t	Thickness (eq 2.1, 3.4, 4.2, 4.4, 4.5 and 4.7)
b, w	Width (eq 2.1, 2.2, 3.3, 3.4, 4.2, 4.3, 4.4, 4.5 and 4.7)
IB	Internal Bonding (eq 2.2, 3.3 and 4.3)
TS	Thickness Swelling (eq 2.3, 3.2 and 4.1)
Ti	Initial Thickness Swelling (eq 2.3, 3.2 and 4.1)
Tf	Final Thickness Swelling (eq 2.3, 3.2 and 4.1)
ρ	Density (eq 3.1)
m	Mass (eq 3.1)
V	Volume (eq 3.1)
p	Dry density (eq 4.2, 4.4 and 4.7)
W	Weight (eq 4.2, 4.4 and 4.7)

LIST OF ABBREVIATIONS

MDF	Medium density fiberboard
LVL	Laminated veneer lumber
NR	Natural rubber latex
UF	Urea formaldehyde
PVOH	Polyvinyl alcohol
OSB	Oriented Strand board
DSC	Differential scanning calorimetry
TGA	Thermo gravimetric analysis
XRD	X-ray diffraction
FTIR	Fourier transforms infrared spectroscopy
UTM	Universal Testing Machine
MOR	Modulus of rupture
FESEM	Field emission scanning electron microscopy
M	Moisture content
IB	Internal bonding
SB	Static bending
TS	Thickness swelling

1 INTRODUCTION

1.1 Background of study

Medium-density fibreboard (MDF) is an engineered wood product formed by breaking down hardwood or softwood residuals into wood fibres, combining it with wax and a resin binder, and forming panels by applying high temperature and pressure. It is made up of separated fibres, but can be used as a building material similar in application to plywood. It is stronger and much denser than normal particle board.

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 3mm to 40mm as well.

Within three decades, the medium density fibreboard (MDF) industry has grown and contributed significantly to the external trade of the wood sector of Malaysia. The development of the MDF industry in Malaysia started in 1987 but has since rapidly developed to nine plants, eight of which is in the peninsula. The production, consumption, export and import status of MDF in Malaysia is provided in Table 1 (Mohd Shahwahid Hj. Othman, 2009).

Table 1-1: Production, consumption, export and import status of MDF in Malaysia ('000m^3)

Year/Item	1995	2000	2005	2010
Production	350	1000	1500	2000
Consumption	100	180	290	417
Export	250	820	1210	1583
Import	0	0	0	0

The Industry consists of panel products such as Plywood, Particleboard, Laminated Veneer Lumber (LVL) and Medium Density Fibreboard (MDF). In Malaysia there are 11 MDF plant, 11 Particleboard plants and few hundred plywood mills. In 2006 Malaysian Timber industry contributed RM 23.44 billion through export. Bio composite

industry is the fourth biggest industrial sector of Malaysian Economy. Production of MDF is shown in Table 2.

Table 1-2: MDF manufactures in Malaysia

Mill	Location	Capacity (m^3/day)
Takeuchi	Johor Bahru	300
Merbok	Sg.Petani	700
Hume	Nilai	470
Dongwa MDF	Nilai	370
Evergreen	Batu Pahat	700
Robin	Mentakab	370
Guthrie	Kulim	370
Segamat Panel	Segamat	300
Daiken	Bintulu	315
Samling	Miri	285
Agro Bio Fibre	Gemas	55
Total Capacity		4235

Bio composite is a material formed by a matrix or known as resin and a reinforcement of natural fibers which usually derived from plants and 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 Malaysia.

In this study, the sample chosen to test Natural Rubber Latex as an adhesive is Medium Density Fiberboard (MDF). The use of MDF is one of the wood-based composites which is low cost in manufacture and has the highest profit margin. MDF usually used in furniture applications. For an instance it used for interior door skins, moldings, flooring substrate, and interior trim components. Besides, Malaysia is the world's third largest exporter of MDF after Germany and France.

Furthermore, MDF has his own special characteristic. Despite of inexpensive, MDF also eco-friendly oppose to plywood. This is because MDF produce from quick growing pine woodlands which are regularly replenished. The reproduction takes between 15 and 40 years to mature. MDF which is wood-based composite is compacted together with

adhesive. These factors tend to longevity and smooth surface area to facilitate the application of laminate, varnish and oil painting.

But, there are some 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 release during sanding and cutting process. It may lead to irritation in eyes and lungs when have contact. 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 googles while cutting. As a whole, proper safety steps should be taken to conduct the MDF or otherwise it could be harmless and dangerous.

Malaysia is the one of biggest production of Natural Rubber Latex (NR) in the world. There are abundance numbers of rubber plantation. The total of production latex in Malaysia on 2012 is 75,985 tonnes. About 46% of the total world's rubber is produced in Malaysia. The rubber plantation was started in Malaysia in 1877. This plantation is successfully in Malaysia because of hot-wet climate is most suitable for its growth. The greatest production is in Jahore State of Southern Malaysia. Rubber cultivation occupies about 4-2 million acres or about 65% of the total cultivated area in the country.

Natural rubber latex (NR) is one of the natural adhesive extracted from latex of only one kind of tree which is name as *Hevea braziliensis*. Hevea rubber is obtained in many tropical regions of Southeast Asia. NR latex consists of solvent solution, latexes and vulcanizing type. Moreover, latex can found in nature as milky sap that coagulates when expose to air. Nowadays, rubber cultivation is favourable light because of the rising of environmental consciousness.

The physical properties of NR latex are more superior compare to non-latex synthetic products. Field latex, the feedstock material for NR latex that traditionally was sourced primarily in Malaysia and Thailand and now is available in several new regions around the world including India and China. Furthermore, NR latex is less expensive than most petroleum based synthetic products whose cost continues rise and fluctuates with the rising cost of crude oil. Today, there are over 40,000 commercially available products made from NR latex (Travis Honeycutt)

There are some reasons mills was use NR latex as an adhesives at most high compared to others adhesive. NR latex can be classified as excellent resilience, moisture and water resistance. Others than that, NR latex have special features which are excellent tack, good strength and the surface can be tack freely to touch and yet bonds to similarly louted surface.

Around year 2004 until 2008 Malaysia NR latex industry has undergone very rapid and fundamental changes with appearances of many new competitor in particular the growth of some traditional supplier and the emergence of new ones. The changes and consequent challenges have impacted on Malaysia's comparative and competitive advantages in NR latex cultivation in terms of internally and externally.

Malaysia also the fifth biggest consumer of NR latex because of largest production of latex gloves, catheters and latex thread.

In Malaysia, our industry was making wood composites by using of urea formaldehyde as an adhesive. This is not successfully in market due to environmental issues and poor mechanical properties regarding the usage of urea formaldehyde itself. Urea formaldehyde is carcinogenic and can danger to human, animal and environment. Others than that, urea formaldehyde can effect a bronchial irritant and asthma trigger and connected to multiple chemical sensitivity. Therefore, the usage of urea formaldehyde must be reduced or virtually eliminate for safety purpose.

1.2 Objectives

The following are the objectives of this research:

- Making of wood composite by using Natural Rubber Latex as an adhesive.
- To compare mechanical properties of wood composite by different composition of Natural Rubber Latex as an adhesives.
- To prepare environment friendly plywood (MDF) using NR latex adhesive modified by Starch.

1.3 Scope of this research

The scope of this study is to use NR latex as an adhesive and study the physical mechanical properties of wood-rubber composite. The purpose is to compare the mechanical properties of wood composite using different composition of NR latex as an

adhesive. Beside from that, in order to get better wood composite, study on the best formulation of adhesive to be added to the wood must be carried out. With this study, it aims to create a new channel to produce a new type of composite by using NR latex as an adhesive. The process begins with preparation of NR latex and starch and analysis of percentage of adhesive in wood fibers. Other than that, FTIR analysis also will be done to study the NR latex group presence in the board sample in various percentages of specimens. The adhesive will be sprayed to the wood composites before it goes into hot pressing. The equipment to produce the 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 composites to desired thickness and density. After all, physical test will be carried out on Modulus of Rupture (MOR), Internal Bonding (IB), Water absorption and Thickness Swelling. 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 calliper. Then the result will be compared with the standard board in order to satisfy the objectives of this research.

1.4 Problem of Statement

The present wood composite 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 fibreboard become dense and brittle. The curing time of urea formaldehyde will effect 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 fiberboards are less competitive in the international market. Lastly, low mechanical properties such as bending strength and internal bonding and also thickness swelling. These properties will affect the qualities of wood composites (MDF) products.

2 LITERATURE REVIEW

2.1 Introduction

In this paper, basically it describes on the wood composites and the comparison between NR latex adhesive with urea formaldehyde adhesives. Other than that, it will also describe on the effect of NR latex adhesive on the physical and mechanical properties of a wood composite. Besides, all the materials such as starch and urea formaldehyde (UF) also discussed in this part.

2.2 Wood 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, 2008).

The wood-based industry has long been an important part of the dynamic of manufacturing sector in Malaysia. Despite being classified as low-tech industry, the industry is one of the main divers of Malaysia's economic growth particularly in terms of country's export revenue. Also, the low technological entry barrier to the industry is deemed to be beneficial to the local enterprises, as participation in the industry is not limited to a particular or exclusive group of players. In fact, the whole value chain of Malaysia's wood-based industry is made up of local enterprises. It is among the very few industries in the country that is able to transform the raw materials into the final product, and subsequently to penetrate the global market.

Wood composite is a wonderful material, available, economic, aesthetically pleasing, with goo mechanical properties (Mader, 2011). The term 'composite' is used to describe any wood material bonded together with adhesives. Wood based composite materials are classified into the following categories which are panel products (plywood, oriented strand board (OSB), particle board, fiber board, medium density fibreboard (MDF), hard board), structural timber products (glued-laminated timber (glulam), laminated veneer lumber (LVL), laminated strand lumber and wood-non wood composites (wood fiber-thermoplastic, inorganic-bonded composites) (cai, 2012).

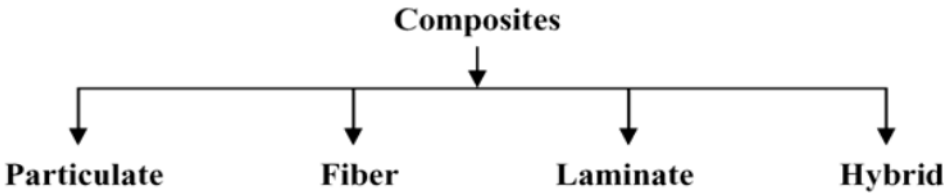

Figure 2-1: The classification of wood composite

Composites are one of the most advanced and adaptable engineering materials known to men. Progresses in the field of materials science and technology have given birth to these fascinating and wonderful materials. Composites are heterogeneous in nature, created by the assembly of two or more components with fillers or reinforcing fibers and a compactable matrix (N.Abilash,2013).

Wood composites, such as fiber board and particleboard, are processed from woody materials in the shape of fibers, flakes, shavings, and many other types of wood elements bonded with synthetic resin-adhesives consolidated under high pressure. The internal stress induced in the composites during hot pressing will result in greater thickness swelling of the wood composites compared to normal wood after exposure to moisture. Wood composites swell at a rate defined by temperature and moisture (Sheldon Q. Shi, 2006).

Composites are hybrid materials made of a polymer resin reinforced by fibers, combining the high mechanical and physical characters of the fibers (M.Sivapragash, 2013). Composites combine a high stiffness and strength with a low weight and their admirable feature of corrosion resistance in polymeric composites. These composites have economic benefits by using inexpensive raw materials and zero maintenance during service. Composites are now a part of everyday life, and have entered nearly all major industrial, commercial and domestic sectors, including aerospace, packaging, sports industry and hose hold appliances (M.Sivapragash, 2013).

In recent years, wood composite 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 composite offers several advantages

like low density, high specific properties, non-abrasive to processing equipment, low cost and most importantly biodegradability (Ajay Karmarkar, 2007).

2.3 Natural Rubber Latex (NR)

In the last decade, the world NR industry has undergone very rapid and fundamental changes with the appearance of many new players, in particular the growth of some traditional suppliers and the emergence of new ones. Much of the changes and consequent challenges, both internally and externally, have impacted on Malaysia's comparative and competitive advantage in NR cultivation.

The rubber cultivation industry or the upstream sector became a major raw material supplier to two value-added resource-based industries. With this development, the competitiveness of the rubber industry as a whole has been greatly enhanced.

Chemically NR latex is cis 1,4-polyisoprene. A linear, long chain polymer with repeating isoprenic units (C5H8), it has a density of 0.93 at 20° C (Maya JACOB JOHN, 2012).

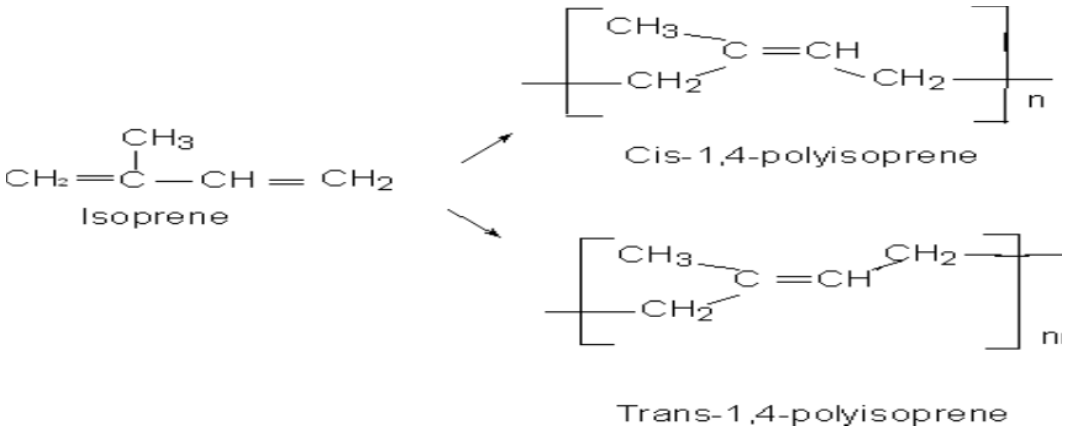

Figure 2-2: Structure of NR latex

Table 2-1: The most component in NR latex

Components	%
Rubber hydrocarbon	93.3
Acetone extract	2.9
Protein	2.8
Moisture	0.6
Ash	0.4

Generically, NR latex refers to a stable dispersion (emulsion) of polymer micro particles in an aqueous medium. NR latex maybe formed naturally or synthetic. NR latex as found in nature is the milky sap of many plants that coagulates on exposure to air. It is a complex emulsion in which proteins, alkaloids, starches, sugars, oils, tannins, resins and gums are found. In most plants, NR latex is white, but some have yellow, orange, or scarlet latex is the early process to collect the fresh natural rubber (Y., 2011).

NR products are derived from Hevea brasiliensis latex, a milky fluid obtained by tapping the bark of Hevea trees (Figure 4). Like all plant materials, latex contains growth-related substances such as proteins, carbohydrates, and other organic and inorganic constituents. The rubber hydrocarbon particles (the elastic component sought in all NR products) comprise 25% to 45% of the latex system. The non-rubber substances constitute only a small percentage of the latex system (Esah Yip, 2002).

Adhesives made from natural rubber, which is essentially poly-isoprene, are very tacky and are used in pressure sensitive applications or where long bond times and tack are required such as tapes, ceramic tile adhesives, flooring adhesives (Ajay Karmarkar, 2007). The unique characteristics of NR latex are high strength, flexibility and elasticity. Most NR latex products are derived via a sulphur vulcanisation system, which achieves the desired physical properties for the product application (R. Roslim, 2012).
Other than that, natural rubber is limited by its high molecular weight, low miscibility will low molecular weight resins, low polarity and low UV and thermo-oxidative stability resulting in discoloration during the lifetime of a pressure sensitive adhesive (PSA) product (K. Don Kim, 2001).

Application of NR in rubber products gives the product very useful technical characteristics of very good tensile strength, high resilience, excellent flexibility and

resistance to impact and tear, low heat-build-up, plus good "green" strength and building tack (Maya JACOB JOHN, 2012).

2.4 Starch

Starch is a relatively inexpensive and renewable product from abundant plants and use as binders, sizing materials, glues and paste but the strength of the bonding capacity is not good for glue wood (Zhenjiong Wang, 2011). It is a white, granular, odourless, and tasteless powder that is insoluble in cold water, alcohol, or other solvents (Mark C. Swanson, 2002). Starch is widely use in commodity applications in food, paper making, fine chemicals and packing materials because of low environmental impact. These promising technologies may provide an environmentally friendly alternative to the present of UF adhesive in wood composites industries (Magdy M. Senna, 2012). It can be obtained from various plant materials such as corn, potato, rice, wheat, sago and many more and widely available throughout the world commonly used in food industries.

There are some advantages of uses starch as an adhesive which are simple process, easy to operate, good adhesion and film forming, non-formaldehyde emission and sustainable development today (Haiyan Tan, 2011).

2.5 Urea formaldehyde (UF)

Urea–formaldehyde resins have been extensively used by the wood-based panel industry for more than 100 years, due to their good performance in the production of wood composite (E. Roumelia, 2012). Urea–formaldehyde (UF) resin adhesive is a polymeric condensation product of the chemical reaction of formaldehyde with urea (Byung-Dae Park n, 2011).

By using different conditions of reaction and preparation a more or less innumerable variety of condensed structures is possible. UF resins are the most important type of the so called amino plastic resins. Currently, approximately 6 billion tons are produced per annum world-wide, based on a usual solids content of 66% by mass (Dunky, 1998).

About 90% or more of the world's wood composite production is made with urea formaldehyde (UF) resins. UF resins, the most well-known amino resins, have many advantages such as low cost, ease of use under a wide variety of curing conditions, the fastest reaction time in hot press, water solubility, low cure temperatures, resistance to microorganisms and to abrasion, excellent thermal properties, and their colorless qualities, especially the cured resin compared to other resins (S. Borann, 2011).

In spite of some advantages such as lower cost, fast curing, good performance in the panel, water solubility and colorless, UF resin adhesives also possess a critical disadvantage which is formaldehyde emission from the panels (Byung-Dae Park, 2013). The formaldehyde emission results primarily from UF resins in wood-based composite panels. In addition, lower resistance of UF resins to water also limits the use of wood-based panels bonded with UF resin adhesives to interior applications. Furthermore, the formaldehyde emission from the panels used for interior applications is known as one of the main factors causing sick building syndrome in an indoor environment. Therefore, the formaldehyde emission issue has been one of the most important aspects of UF resin research.

UF resin adhesives also possess a critical disadvantage, formaldehyde emission from the panels. Its lower resistance to water also limits the use of wood-based panels bonded with UF resin adhesives to interior applications. Furthermore, the formaldehyde emission from the panels used for interior applications is known as one of the main factors, causing sick building syndrome in an indoor environment. Therefore, the formaldehyde emission issue has been one of the most important aspects of UF resin research (Byung-Dae Park n, 2011).

Many products were produced with formaldehyde based resins, which emitted formaldehyde vapor and lead to consumer dissatisfaction and health related complaints. These emissions have caused various symptoms, the most common of which are irritation in the eyes and the upper respiratory tract (S. Borann, 2011). When the human body is exposed to formaldehyde in high doses there is a risk of serious poisoning, and prolonged exposure can lead to chronic toxicity and even cancer. For these reasons, regulatory pressure has recently reduced or eliminated formaldehyde emissions from wood products on a world-wide scale.

2.6 Modulus of Rupture (MOR)

MDF board is a brittle specimen and tensile test is not suitable for it. To perform tensile strength, 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, 2008). After all the consideration, it is suitable to do the bending test. Bend testing determines the ductility or the strength of materials by bending the materials 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 from under pressure and keep that structure permanently. It also can determine tensile strength. 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 till the specimen breaks the center. The maximum force will be shown on the result after 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:

$$MOR = \frac{3PL}{2ba^2} \qquad eq\ (2.1)$$

Where:

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

$P =$ Peak Load (N)

$L =$ Length (mm)

$a =$ Thickness (mm)

$b =$ Width (mm)

2.7 Internal Bonding (IB)

Internal bonding test is used to test the strength of the bonding formed between matrix and the resin. 'A steel or aluminium 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 before it 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 bonding between the glue and strands will give the higher strength properties of the boards. The standard size for the specimen is around 50mm in length and 50mm in width. Then, the specimen was glued on the aluminium block and after the specimen settle run the testing it will reheat to substitute with others. Calculation for internal bonding by using the given equation:

$$IB = {}^{P}/_{w}\ x\ l \qquad eq\ (2.2)$$

Where:

$IB =$ Internal Bonding (N/mm^2)

$P =$ Peak Load or Maximum Load (N)

$w =$ Width (mm)

$l =$ Length (mm)

2.8 Thickness swelling (TS)

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. 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. Thickness measurement will be taken 12.7mm from the edge at the center of side, using a digital indicator. The equation below show how to calculate the thickness swelling after the final thickness was measured:

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

Where:

$TS =$ Thickness swelling (%)

$Ti =$ Initial Thickness (mm)

Tf = Final Thickness (mm)

3 MATERIALS AND METHOD

3.1 Introduction

In this part, we will be discussing about the method on manufacturing MDF board, starting from preparation and dilution of adhesives up to the testing of wood panel. These methods are important in order to maintain the high standard of MDF board. It will also help the readers to understand more on this particular part. These methods had been employed to produce three different boards with three composition of NR latex and starch as a formulation on adhesives. The density of MDF board prepared is density is 800 kg/m3 with the dimension of 25 cm x 25 cm and thickness of 6 mm. The important parameters tested were Modulus of Rapture, Internal Bonding, Water Absorption and Thickness Swelling. On the other word, the resin was tested by using TGA and FTIR in term of curing kinetics and thermal properties. Then, it also covered on the material used to produce specimen, equipment used, and how it is been tested. The process involved to produce MDF board for lab scale is almost the same as the industrial scale. The industrial scale including chipping, refining of wood chips, drying, gluing, forming, prepress, hot press and finishing board. This chapter will covered all process for lab scale.

3.2 Raw Materials

Wood fibers

Rubber wood fiber is the main material to manufacture the MDF board. It will stop from absorbing moisture after it had been kiln dried. The color of rubber wood fiber is yellow light. The rubber wood fibers are already supplied from chemical engineering laboratory.

Natural Rubber Latex (NR)

NR is produced from *Hevea Brasiliensis* latex. The feature of latex is a milky liquid obtained by tapping the bark of Hevea trees itself. The use of NR is to bind the rubber wood fiber. The purpose by using latex as an adhesive because of latex contains proteins, carbohydrates and other organic and inorganic constituents.

Starch

Starch is an organic chemical produced and stored by all green plants. It is a white, granular, odourless, and tasteless powder that is insoluble in cold water, alcohol, or other solvents. The type of starch use is rice starch. The moisture content in the starch is between 7.5-13.0%. The pH value is below than 0.6. The chemical was purchased it by supervisor at Permula Chemicals Sdn Bhd, Gebeng, Kuantan.

Acetone

Acetone is used to dilute high viscosity of NR. Acetone ((CH3)2CO) is a colourless liquid used for cleaning purposes in the laboratory and as a dilution solvent. In the laboratory it is used for rinsing laboratory glassware because of its low cost and volatility. It is ideal for thinning rubber adhesive. Acetone is purchase from Technical Unit Lab on 15th March 2013.

Acetone is extreme flammability liquid so it needs to conduct with highly protection. Below are the physical properties of Acetone:

Table 3-1: Properties of acetone

Molar mass	58.08 g mol^{-1}
Appearance	A clear colorless liquid with a sweetish odor
Density	0.791 g cm^{-3} at 25°C(lit)
Melting point	93.9 °C
Boiling point	56.1 ^{o}C
Solubility in water	Soluble in all proportions in water.

3.3 Apparatus

Blender

The uses of blender machine are to mix, blend and separate the wood fiber with adhesives. The rotary blade inside the blender machine is work to distribute the