FORMULATION OF MELAMINE UREA FORMALDEHYDE (MUF) RESIN BY USING VARIOUS TYPES OF FILLER

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Thesis submitted in fulfillment of the requirement
for the award of the degree of Bachelor in Chemical Engineering

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JANUARY 2012

ABSTRACT

The performance of adhesive in term of working properties and quality is improved by the types of material use as filler. Industrial Flour (IF), Pre treatment and post treatment Palm Kernel Meal (PKM) and Palm Kernel Cake (PKC) are chosen for this research as filler for the comparison in wood adhesive production. Melamine Urea Formaldehyde (MUF) resin is selected as the resin for wood adhesive production because of less costly and high water resistant compared to Melamine Formaldehyde (MF) and Urea Formaldehyde (UF) resins (Dunky, 2003). This is because the cost of MUF resins depends on the ratio of melamine and urea. The objective is to compare the types of filler use for wood adhesive production in term of working properties and its quality. The shear strength and wood failure for wood adhesive was studied to determine the working properties of plywood. The experiments were conducted with temperature in specific range and the pressing time from 50s to 350s. The sieve shaker experiment will be done by using different type of sieve to get the different sizes of filer's particle size, to use the uniform size of fillers. The research study can be conclude that the better performance of wood adhesive in term of mechanical properties likes strength, durability and quality are based on materials which is types of filler use whether using Industrial Flour (IF), pre treatment and post treatment Palm Kernel Meal (PKM) or Palm Kernel Cake (PKC). The optimum value of temperature and pressing time were determined using Response Surface Methodology (RSM).

ABSTRAK

Prestasi pelekat dari segi sifat kerja dan kualiti dapat dipertingkat oleh jenis penggunaan bahan sebagai pengisi. Tepung gandum, Palm kernel yang belum dirawat dan yang telah dirawat iaitu palm kernel meal dan palm kernel cake telah dipilih sebagai pengisi dalam penghasilan pelekat kayu untuk kajian ini. Resin Melamin Urea Formaldehid (MUF) dipilih sebagai resin untuk penghasilan pelekat kayu kerana kos yang rendah dan kalis air berbanding dengan resin Melamin Formaldehid (MF) dan Urea Formaldehid (UF) (Dunky 2003). Hal ini kerana kos resin MUF bergantung kepada nisbah melamin dan urea. Objektif kajian ini adalah untuk membandingkan jenis penggunaan pengisi untuk penghasilan pelekat kayu berdasarkan sifat kerja dan juga kualiti. Kekuatan ricih dan kekuhan kayu untuk pelekat kayu dikaji untuk menentukan sifat-sifat kekuatan papan lapis. Eksperimen ini telah dijalankan dengan suhu dalam julat tertentu dan masa menekan dari 50 saat sehingga 350 saat. Pengisi diayak dengan menggunakan saiz ayak yang berbeza untuk mendapatkan saiz zarah yang berlainan untuk dijadikan sebagai saiz pengisi yang seragam. Oleh itu, kajian penyelidikan ini boleh dikonklusikan bahawa prestasi pelekat kayu yang baik adalah berdasarkan sifat-sifat mekanikal seperti kekuatan, ketahanan dan kualiti yang mana bergantung kepada jenis penggunaan pegisi sama ada menggunakan tepung gandum, Palm kernel yang belum dirawat dan yang telah dirawat iaitu palm kernel meal dan palm kernel kek. Nilai optimum untuk suhu dan masa menekan ditentukan dengan menggunakan kaedah tindakbalas permukaan.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Malaysia is one of the wood suppliers of wood-based products in world region, especially to Japan, Taiwan, Singapore and Middle East. According by Malaysia Timber Industry Board, Malaysia is the leader for the production and export of veneer, tropical log wood and plywood. Total plywood exports from Malaysia amounted to RM 5000 million in 2009 and RM 4900 million in 2010 (Malaysian Timber Industries Board, 2010).

Adhesive is the material that applied to the surfaces of particles to join them permanently by and adhesive bonding (Wu.s, 1982). According to Hartland S (2004), adhesion is about two different bodies were held together by intimate interfacial contact such that mechanical force or work can be transfer across the interface.

There are several types of thermosetting adhesives such as Melamine Formaldehyde (MF), Urea Formaldehyde (UF) and Melamine Urea Formaldehyde (MUF). For this research, the thermosetting adhesive used is MUF. Melamine urea formaldehyde (MUF) resin is a thermosetting polymer type which is produced by the reaction between urea with melamine and formaldehyde (Pizzi.A, 1994). According to Rowell (2005), MUF used for this research because less costly depends on melamine and urea ratio and have better water resistant compared to UF and MF.

This research is to find out the performance of MUF resin based adhesives by using various types of filler in terms to compare the mechanical properties of the materials. The filler in the adhesive is used to fill up all small holes at the surface of wood to prevent or to reduce the formation of weaker boding. Besides that, fillers also used to reduce the penetration of resin into the small holes of the wood (Pizzi, 1994). The filler that are using for this study are post treatment and pre treatment palm kernel which are Palm Kernel Meal (PKM) and Palm Kernel Cake (PKC) and also Industrial Flour (IF). PKM is the by product palm kernel oil industry by using extraction method from the meat in the nut of the palm oil fruit (Bono.A, 2009). The extraction method is actually the treatment to remove the oil in order to increase the protein level. According to Ong *et.al* (2004), PKC is a tropical agro-industrial by-product which is obtained from the palm oil industry which is already been used in the production of a variety of microbial enzymes such as alpha amylase, metalloprotease, tannase and mannanase.

Thus, this study will also to find out the performance of MUF resins with various filler as a wood adhesive based on several factors by using the several method of testing.

1.2 RESEARCH BACKGROUND

Production of wood adhesive for wood industries are the approaches for establishes the safety wood products for the world in future. A MUF resins with Palm Kernel Meal (PKM) is contributes to reduces the non environmental issues. Current research developed by a research team of the Department of Chemical Engineering in University Malaysia Sabah, (UMS) was studied the MUF resin as based wood adhesive in Malaysia. It states that the MUF resin properties are affected by the all components; melamine, formalin, urea$_{1,}$ urea$_2$ and Ammonium Chloride (NH_3Cl) as a hardener. The filler using which is PKM, PKC and IF is an amides groups because of the protein present in this fillers.

1.3 PROBLEM STATEMENTS

Filler are the important thing for MUF resin based adhesive to enhance binder performance for produce the good plywood adhesive (Sellers *et.al*, 2005). Based on Economic term, the industrial flour is too expensive and also has lower wood performance. Therefore this study is to investigate the performance of formulation of melamine urea formaldehyde (MUF) resin as a based adhesive according to the material which is the filler's types, pressing time and temperature.

1.4 RESEARCH OBJECTIVES

Based on the aforementioned research background and problem statement, the objectives of this study are:

I. To compare the types of filler using such as Palm Kernel Meal (PKM), Palm Kernel Cake (PKC) and Industrial Flour (IF) in MUF resins as a based adhesive production.

II. To investigate the performance of MUF resins with various filler as a wood adhesive based on several factors by using the several method of testing.

1.5 RESEARCH SCOPES

In order to accomplish the objectives, the scope of this research is focusing on the several criteria. Basically, this research is to study the performance melamine urea formaldehyde (MUF) by using various types of filler. Therefore, the scope of this study is preparation of fillers such as palm kernel meal (PKM), palm Kernel Cake (PKC) and industrial flour (IF) filler with MUF resin in uniform particle size of filler. However, this research also carried out with shear strength test and wood failure for adhesive product in order to investigate it performance according to Japanese Agriculture Standard (JAS)

(Japanese Agriculture Standard, 2003). Software Design Expert which is Research Surface Methodology (RSM) will be applied for result analysis.

1.6 RATIONAL AND SIGNIFICANCE

MUF resins is wood adhesive for wood industries are the approaches for establishes the safety wood products for the world in future. "MUF resin is safer than Melamine Formaldehyde (MF) and Urea formaldehyde (UF) because the combination of melamine and urea will reduces the formalin that can cause carcinogenic in the resins".

The filler use in industries is high costly. The filler uses in industries have the high cost but low working performance. Therefore, this study was done because the low cost material but high working performance as fillers in wood based adhesive is still in research.

Since the Palm Kernel Meal (PKM) and Palm Kernel Cake (PKC) are green product and non toxic can be used as filler in formulation of MUF resins.

CHAPTER 2

LITERATURE REVIEW

2.1 PLYWOOD

Plywood is a wood product manufactured out of many sheets of veneer, or plies, pressed together and glued, with their grains going in opposite directions. It might be extremely strong, though not very attractive, and was treated in many different ways depend on its application (Smith *et.al*, 2003). The other definition of plywood is a laminate made of thin layers of wood.

According to Rowell *et.al* (2005), plywood is the thin veneer wood layers bonded together by an adhesive into sheet form. There are two types of plywood which is construction plywood and decoration plywood. The construction plywood was produced using softwoods while the decoration plywood was produced using softwoods and also with hardwoods layer in outer surface.

Plywood structures or also known as ordered fibrous composites are frequently encountered in natural systems, mostly in skeletal or protective extracellular tissues where mineral deposition often occurs (Guille MM *et.al*., 1998).

2.2 RESIN

Resin is any class of solid, semi solid or liquid organic material generally the product of natural or synthetic origin with a high molecular weight and with no melting point (Harper *et.al*, 1996). The primary functions of the resin are to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage (American Composites Manufactures Association, 2004).

In addition, resin is a natural or synthetic compound which begins in a highly viscous state and hardens with treatment. Typically, resin is soluble in alcohol, but not in water. There are a number of different classes of resin, depending on exact chemical composition and potential uses. There are numerous applications for resins, ranging from art to polymer production, and many consumers interact with products which contain resin on a daily basis. Natural resin comes from plants while synthetic resins made by adding polymer and resins which is cheaper and easier to refine. Basically, synthetic resin is much more stable, predictable, and uniform than natural resin as well, since it is made under controlled conditions without the possibility of the introduction of impurities. These resins are made by combining chemicals in a laboratory to stimulate a reaction which results in the formulation of a resinous compound (WiseGEEK, 2003).

The synthetic resins consist of two types which is thermosetting and thermoplastic that used in the production of plastics, paints, and many of the same substances that natural resin was used in.

2.3 THERMOSETTING RESINS

Thermosetting resins are usually liquids or low melting point solids in their initial form. When used to produce finished goods, these thermosetting resins are preserved by the use of a catalyst, heat or a combination of the two. Once cured, the solid thermosetting resins cannot be converted back to their original liquid form (American Composites Manufactures Association, 2004).

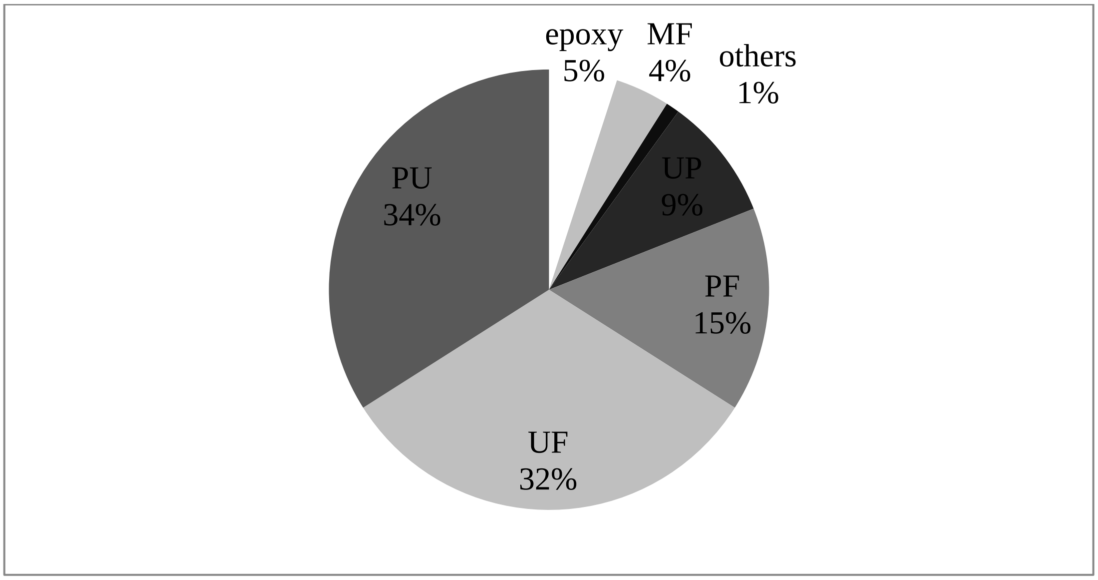

Figure 2.1: Estimation of World Thermosetting Resin Production

The figure above shows the market share estimation market share of world thermosetting resin production by material in 2002. The thermosetting resins consume totaling virtually 25% of the world's total plastics production. Based on the data, Polyurethanes (PU) at 34% comprise the major sector of that current consumption, with urea-formaldehyde (UF) at 32%, phenol-formaldehyde (PF) at 15%, unsaturated polyesters (UP) at 9%, epoxies at 5%, melamine-formaldehyde (MF) at 4% and 1% is for others taking up the remainder. These percentage breakdowns are not expected to change significantly by 2007, although some resins, for example the epoxies, are expected to see growth in excess of the forecast 2.5% over the next five years at the expense of other thermosetting resin. The current worldwide consumption of thermosetting resins across the whole industrial is totally in 27 million tones. Collectively, that industry continues to grow a rate forecast to marginally over 2.5% per annum. Taking that estimate, some five years from now the consumption will have risen to 31 million tones (Forsdyke *et.al*, 2002).

The most common thermosetting resins used in the composites industry are unsaturated polyesters, epoxies, vinyl esters and phenolics. The difference between these groups the proper material for a specific application.

2.4 MELAMINE UREA FORMALDEHYDE (MUF) RESIN

Melamine urea formaldehyde resin (MUF) is an adhesive thermosetting resin. According to Pizzi.A *et.al* (1994), Melamine urea formaldehyde (MUF) resin is a thermosetting polymer type which is produced by the reaction between urea with melamine and formaldehyde. Based on the research done by Bono *et.al* (2003), the MUF resin is affected by the dosage of mole ratio of Melamine and Formaldehyde and also the molar ratio of the Urea at each reaction stage in which the amino compounds are reacted. However, the containing of Melamine in this resin will increase the bonding strength and reduced the formaldehyde emission compared to the others adhesive thermosetting resins such as Melamine Formaldehyde (MF) and Urea Formaldehyde (UF) resins (Northeast Forestry University, 2009).

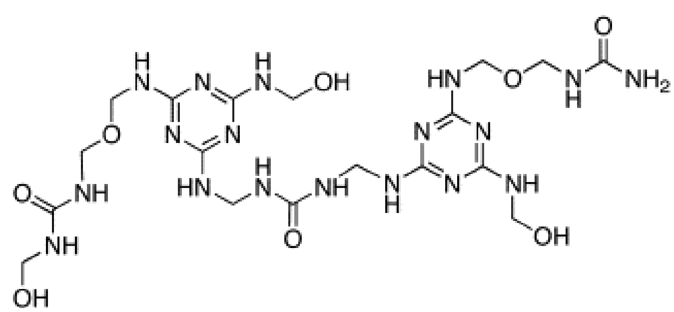

Figure 2.2: molecular structure for Melamine-Urea-Formaldehyde

Nowadays, the MUF resins are widely used as an adhesive in wood production, coating technologies, paper industries and also as a main material in kitchenware production. In different application, many types of MUF resins properties are needed.

Table 2.1: Design Layout of MUF resin (A.Bono *et.al*, 2003)

Types of MUF Formulation	**F1**	**F2**	**F3**	**F4**
Number of reaction stage	3	2	3	3
In 1st and 2nd Stage of Resin Processing				
F: U_1	8.00	3.38	8.50	9.00
F:M_1	3.00	3.03	2.97	2.91
F: (U_1+M_1) (Total mole ratio)	2.20	1.6	2.20	2.20
In 3rd Stage of Resin Processing				
F:U_3	3.38	-	3.47	3.55
F: (U+M) (total/final mole ratio)	1.60	1.60	1.60	1.60
Mel% (of total resin weight)	29.56	29.56	30.16	30.62
Urea% (of total resin weight)	12.67	12.65	12.27	11.97

Table above was regarding the design experiment in observation of reaction in formulation of Melamine Urea Formaldehyde resin. The resin was produced at different number of reaction stages and different mole ratio for each reaction stages in order to determine the resin curing period, solubility in water and resin storage stability.

2.5 FILLER

Nowadays filler is the most important thing as part of based wood adhesive to improve the working material in order to produce the good wood adhesive. Ebnessajad (2008) stated that the term filler refer to the neutral substances that was added to the adhesive to improve the workings properties of that material in term of strength, permanence and also quality. According by (Bosshard *et.al,* 1996) filler was refers to solid additives that are incorporated into the plastic matrix and can be classified based on their effect on the mechanical properties of results mixture.

Generally, filler was used to fill the gaps for the surface of material. There were several types of fillers that used in industries. For example wood filler, reinforcing filler, extender, inert filler, hardener and etc.

2.5.1 INDUSTRIAL FLOUR

Industrial flour also known as Wood Flour. Wood flour was a finely ground product manufactured from the waste stream of lumber using industries and the protein contains was about 12%. Wood flour had a variety of uses based upon physical or chemical characteristics. Applications can be as simple as being a soil extender in a nursery much to open the soil or as complex as becoming a filler in a plastic resin matrix imparting unique properties (American Wood Fibers, 2011).

2.5.2 PALM KERNEL CAKE

Currently Malaysia produced annually quantity of 1.4 million tons of palm kernel cake (PKC) as a by-product in the milling of palm kernel oil. PKC was considered a medium grade protein feed, which containing 14.6 to16.0% crude protein, useful for fattening cattle either as a single feed, with only minerals and vitamins supplementation, or mixed with other feedstuffs. It had also become the main ingredient in dairy cattle ration. Two types of PKC exist, the expeller pressed and the solvent extracted, because of different methods of kernel oil extraction and differences in their oil content; 5 to 12% in the expeller pressed PKC and 0.5 to 3% in the solvent extracted type. Although PKC supplied both protein and energy, it was looked upon more as a source of protein. PKC by itself was a medium grade protein feed and with its high fiber content it was often consider as suitable for feeding of animals. PKC was ranked a little higher than copra cake but lower than fish meal and groundnut cake especially in its protein value (Devendra *et.al*, 1977). A.Bono *et.al* (2010) stated that the palm was pre treatment of palm kernel because it was obtained from the Palm Oil Mill that contained of trace oil.

2.5.3 PALM KERNEL MEAL

The global production of PKM was increased due to the tremendous growth of the oil palm industry in many parts of Asia and Africa. Malaysia currently produced 2460 Metric Tone of Palm Kernel Meal, the current global leader in the oil palm industry (PORLA 2000). Palm Kernel Meal was by product from the manufacturing of palm kernel oil by using the mechanical extraction of palm kernels process. Dark brown protein meal contained high relative oil and high fiber levels. Palm kernel meal was a good source of protein and fat. However the protein level in the Palm Kernel Meal which 20 % will help to reduce the formaldehyde emission.

However, the Palm Kernel Meal was the post treatment of palm kernel which from palm kernel cake (PKC) by using soxhlet solid-liquid extraction technique in order to remove prior oil. The traced oil must to remove to avoid interference during the production of wood adhesive. Prior the palm kernel cake was grinded to form the fine particle to improve the extraction efficiency. The extraction was done at solvent boiling point which is Iso-Propanol and was left running for 10h and then dried in oven for removal of trace solvent (A.Bono *et.al*,2010).

2.5.4 SOY BEAN MEAL

According to Evangelista (2010), the improvement of reforming capability based on the modification of the formulations by increasing the quantities of soy flour. All the modified glues containing soy flour or concentrate had good reforming properties and adhesive strengths that were at least equal to that of the control glue. Simple cost analysis also indicated that when soy flour was used, the modified formulations were cheaper to produce than the current blood-based glue. Soybean meal, as received, contained very little oil (0.9%db) and 52.8% (db) crude protein. The amount of oil determined was close to the typical 0.6% (db) in commercial soybean meal and the protein content was, likewise, within the 49–54% (db) reported for the meal (Wolf WJ, 1983).

Table 2.2: Viscosities and Bonding Strength of Plywood With IF and Soybean Meal (Evangelista, 2010)

Parameters	**Protein Extenders**		
	IF (13.8%CP,db)	**Soybean Meal (52.8%CP,db)**	**Soybean Meal Modified**
Glue viscosity after mixing,CP	2345±205a	1010±85b	1145±265b
Glue viscosity after overnight standing,CP	2330±170a	1275±95b	1080±305c
Wet tensile strength,psi	211±42a	186±36b	209±44a

**Values are mean ±standard of duplicate preparation of glue mixes for viscosity and six boards(20 test specimens per board) in total from duplicate glue mixes for tensile strength. Values across columns followed by different letters are significantly different (p>0.05) CP crude protein,db dry basis*

Based on above, ground soybean protein products will wet and swell in water, but remain undispersed until treatment with strong alkali (Lambuth AL, 1994). However, Lambuth (1994) aslo reported that the akaline process releases useful adhesive properties of the meal by breaking the internal hydrogen bonds of the ussualy coiled protein molecule, unfolding the structure and making the exposed reactive group from amino acids available for wood adhesive. Babcock GE *et.al*, (1947) have been used the soybean meal in the Phenolic Resins formulation as wood adhesive for lab to find the strength specifications and also to shows the favorable resistant to mold action and exterior weathering conditions. Although the soybean was modified to incrased the performance but it still the lower one.

2.5.5 BARK STEM

The incorporation of bark along with wood in particleboards has also been studied. Generally, as bark usage increases, particleboard strength decreases (Muszynski et.al., 1984, Blanchet et.al, 2000). In order to increase the performance, desirable filler features include low cost, consistent quality, and sufficient supplies commonly used in wood adhesive production. Seller (1994) stated that, a few report described the used of bark in made wood adhesive mixed fillers.

According to Eberhardt *et.al,* (2006), the bark stem based filler was prepared from the bark meal. The bark filler fractions passing through 200, 35 and 80-mesh sieves by sieve shaker after blending processing. The preparation of adhesive was prepared as in table 2.3 using the three bark-based fillers and a furfural residue control (FuraTex, Bates & Co., Inc.).

Table 2.3: Adhesive mix for bonding plywood (Eberhardt *et.al,* 2006)

COMPONENT	ADHESIVE MIX (%)	MIX SOLID (%)
Filler	6.7	15.0
Extender	7.4	16.6
Sodium Hydroxide solid	1.6	3.6
Resins solid	28.9	64.8
Total mix solid	44.6	100.0
Total mix water	55.4	
Total mix	100.0	

Values for percent wood failure and shear strength are shown in Table 2.4 by using four different times to assess the performance of bark-based fillers.

Table 2.4: Wood Failure and Shear Strength Performance for Bark-based Fillers (Eberhardt *et.al*, 2006).

TEST	**FILLERS TYPE**	**ASSEMBLY TIME (MIN)**			
		10	**20**	**40**	**60**
Wood Failure (%)	Bark filler A	45	66	61	73
	Bark filler B	90	91	91	91
	Bark filler C	80	86	88	93
	Furfural Residue	57	77	92	77
Shear Strength (KPa)	Bark filler A	1510	1440	1470	1270
	Bark filler B	1610	1740	1450	1630
	Bark filler C	1790	1570	1490	1460
	Furfural Residue	1690	1500	1480	1520

*** Bark-based fillers were prepared from bark fractions rich in eitherobliterated phloem (filler A) or periderm (filler B) tissues; a fillerwas also prepared from whole bark (filler C) as received.*

Despite the problems encountered with bark filler A, the values for shear strength were not indicative of poor performance while the ash content of bark filler B was considerably lower than that obtained for bark filler. Thus, through the grinding and classification processes employed, plywood adhesive mix filler with improved performance and lower ash than that which could be obtained by directly grinding the bark as received was able to produced. Moreover, under the conditions employed, a filler based on bark can be produced that can perform as well as furfural residue. The working performance of bark filler increased according to the layer of the bark. The internal layer of bark stem had the good performance compared to external bark stem (Eberhardt *et.al*, 2006).

2.6 USING OF FILLER (C.A.Harper, 2002)

The using of fillers was depends on their types.

Reinforcing filler

- Reinforcing filler was used to improve certain mechanical properties such as modulus or tensile strength. Besides, it also used to increase the tensile, compressive and shear strength, increased the heat deflection temperature, reduced the shrinkage, and improved the modulus and creep behavior.

Extender

- Using of extender was to reduce the cost of compound.

Inert filler

- Inert filler was use in industries to increase the density of compound, reduce the temperature, improve the hardness and increase the heat deflection temperature.

Basically, the filler in the wood adhesive was used to fill up all small holes at the surface of wood to prevent or to reduce the formation of weaker boding. Besides that, fillers also used to reduce the penetration of resin into the small holes of the wood (A.Pizzi *et.al*, 1994). Harper (2002) stated that the filler was used in term to promote interaction with the polymer and allowed for good interfacial adhesion and also made the good interfacial bonding. According to Ebnesajjad *et.al* (2008), filler was used to reduce the material cost. It also used to modify adhesives to manage such properties. For example heat resistance, thermal conductivity and thermal expansion.

CHAPTER 3

METHODOLOGY

3.1 MATERIALS

The materials that used in this research were Melamine Urea Formaldehyde (MUF) resins as a raw material of wood adhesives. In order to produce the adhesive, the formulations of MUF resins were used were mixed with the filler and hardener. For fillers, the materials used were pre treatment palm kernel which was Palm Kernel Cake (PKC) and post treatment palm kernel was Palm Kernel Meal (PKM) and also industrial flour (IF). Below show the chemical that will be used during experiment progress.

1. 37% Formalin
2. Urea
3. Melamine
4. Ammonium Chloride

3.2 APPARATUS

In this research, below show the apparatus that will be used during experiment progress.

a. Viscometer
b. Heating Mantel
c. Universal Testing
d. Indicator Paper
e. Four-Necked Flask
g. Sieve Shaker Machine
h. Motor Mixer
i. Water Bath
j. Thermometer

3.3 EXPERIMENTAL WORKS

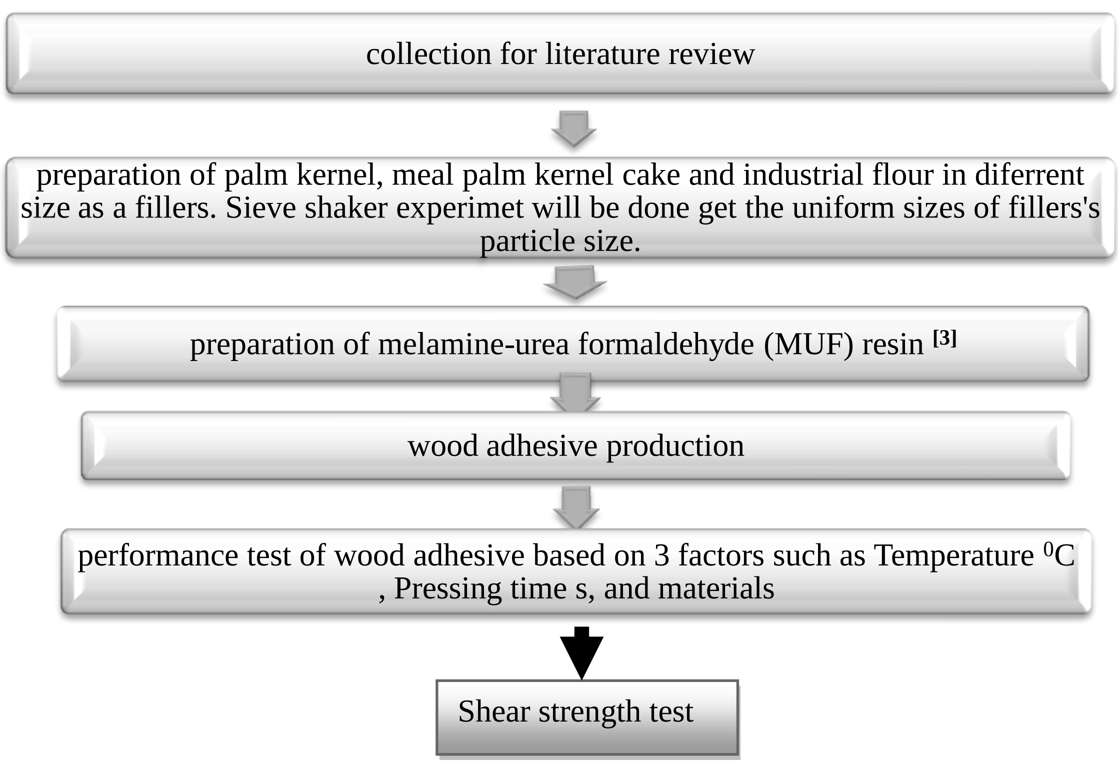

Figure 3.1: Flow chart of the research method

3.4 PREPARATION OF MUF RESIN (Awang Bono *et.al,* 2003)

Formalin (37%) was poured into the four-necked flask followed by melamine and first urea. The mixture was blended homogenously using a stirrer connected to a motor (VELP Scientifica stirrer), which was set to speed 50 rpm. The mixture has a white colored solution. Then, pH was adjusted to a range of 8.8 to 9.0 by adding few drops of NaOH/caustic soda solution (20%) or soda ash solution (25%). At the same time, solution pH and temperature were recorded. The temperature and pH was recorded for every 5 minutes till the end of the production process. After that, heating process was started and at the same time, stopwatch was started until the temperature reached 80˚C. This temperature was maintained until end point was reached. The temperature maintained was subjected to change according to desired temperature which could be 80˚C, 85˚C or 90˚C. The end point can be determined by dropping the mixture solution into a beaker of water at 30˚C temperature for every 5-10 minutes. If the droplet is diluted in the water, without any trace (no whitish streak), meaning the end point has not achieved yet. Next, the condition of the solution was observed during this period. The initial white solution would turn clear at the temperature between 70˚C-80˚C. When the end point was reached, the heating process was stopped while continued stirring. NaOH/caustic soda solution (20%) or soda ash solution (25%) was added slowly to increase the pH value to a range of 8.8 to 9.5 this is in order to stop the polymerization of resin. The solution was allowed to cool down to ambient temperature by immersing the four-necked flask into cool water. Second urea was added when the temperature dropped to 60˚C. The cooled resin was transferred to a plastic container for further testing and plywood production.

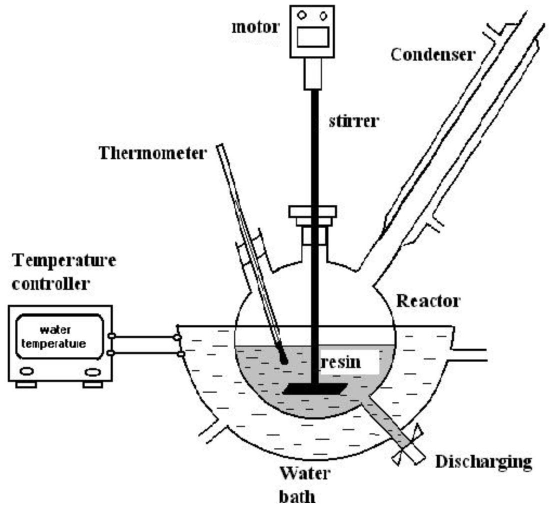

Figure 3.2: Schematic Equipment Set Up for Resin Production (Bono.A, 2003)

3.5 PREPARATION OF GLUE

300g of MUF Resin was weighted into beaker. Then, 12 g of Urea was added into the MUF resin mixed well with a mixer for 5 minutes. After that, this was followed by 50g of filler and mixed well for 5 minutes. Next, the 13 g of hardener which is ammonium chloride was added into the mixture and mixed for 5 minutes. The initial viscosity of the glue prepared should be 20 until 24 cps. If the glue viscosity below this range, it could be adjusted with filler. Glue pot life was checked and recorded for every 30 minutes until it exceed 150 cps by using viscometer, with first spindle. However these, glue only exceed for 9 samples. The ratios of each type of elements for the glue preparation are:

1) MUF resin = 80%
2) Urea = 3.2%
3) Filler = 13.33%
4) Hardener = 3.47%

3.6 SAMPLE PLYWOOD MAKING

Core was put on the analytical balance and the reading was set to zero. 21 g of wood adhesive or glue was poured on one of the core surface and the glue was spread on it by using glue spreader. The face veneer was put on the core surface and clamped together. The face veneer grain direction should opposite with the core grain direction. This step was repeated by applied it for another side of the core and back veneer. Then, this plywood was undergo cold press process for 20 minutes with pressure 9 kg/cm^2 and followed by hot press with pressure 9kg/ cm^2 and temperature 125±5˚C for 224 seconds. The preparation of the testing normal samples using hot press at pressure 1MPa is as given in table 3.1.

Table 3.1: samples preparation for hot press

TEMPERATURE (^0C)	PRESSING TIME (s)	SAMPLE
100	50	P1
	150	P2
	250	P3
125	50	S1
	150	S2
	250	S3
150	50	T1
	150	T2
	250	T3

3.7 PERFORMANCE TEST OF WOOD ADHESIVE (Awang Bono et.al,2003 and JAS,2003)

3.7.1 PLYWOOD TESTING METHOD

3.7.1.1 SHEAR STRENGTH TEST

1. Preparation of test pieces

- 9 to 12 test pieces with a dimension shown below shall be prepared from each sample of plywood.

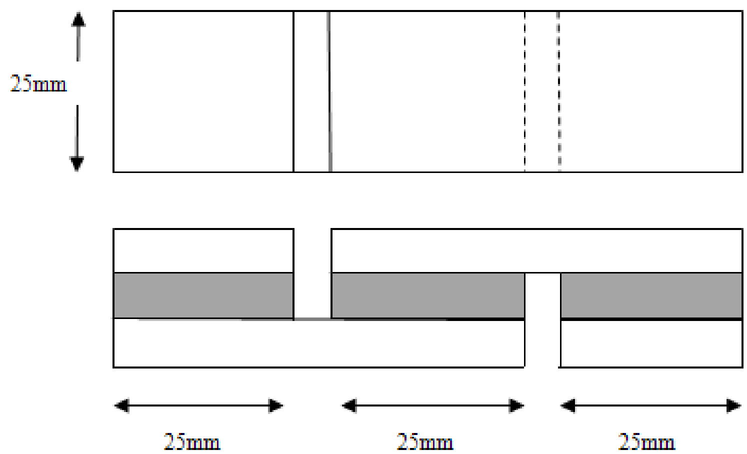

Figure 3.3: Plywood Test Pieces

2. Cyclic Boiling Test

- Test pieces, after being immersed in boiling water for 4 hours, are dried at a temperature of 60 ± 3^0C for 20 hours. Further the test pieces are immersed in boiling water for 4 hours, and immersed in water of room temperature to get cool. After that, bonding strength test shall be conducted in a wet condition, and measure the maximum load and wood failure ratio and then calculate the shear strength and average wood failure ratio. The shear strength was done by using the Universal Testing Machine (UTM).

3.8 EXPERIMENTAL DESIGN ANALYSIS

For the analysis, the three level factorial of Response Methodology Surface (RSM) Design Expert (version 6.0.8, Stat-Ease Inc., Minneapolis, USA) was chosen in doing the analysis for predicted the value of the shear strength of each samples. Constrains were constructed as in table 3.2.

Table 3.2: RSM Analysis Construct

PARAMETER	**UNIT**	**LOWER LIMT**	**UPPER LIMIT**
A: Temperature	Degree C (^{0}C)	100	150
B: Pressing Time	Second (s)	150	250