Optimization of Mechanical Properties in Natural Hybrid Polymer Composite using Polypropylene (PP), Banana Stem Fiber (BS) and Pineapple Leaf Fiber (PALF)

by

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CERTIFICATION OF APPROVAL

Of Research Project

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Approved by,

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Universiti Teknologi PETRONAS

TRONOH, PERAK

May 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and the original work herein has not been undertaken or done by unspecified sources or persons.

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ABSTRACT

A study was carried out to investigate the optimization of the natural hybrid polymer composite which was made using polypropylene (PP) as matrix and banana stem fiber (BSF) and pineapple leaf fiber (PLF) as a reinforcement. The coupling agent which was Maleic anhydride grafted polypropylene (MAPP) was added in the composite to improve the bonds between polymer and natural fiber. This study ~~is~~ was aimed to investigate how two reinforcement in a single matrix will enhance the mechanical properties of the composites. The banana stem fiber was hybridized with pineapple leaf fiber to improve the mechanical properties of the banana stem fiber. Hybrid composites were prepared using banana/pineapple fiber of 100:0, 70:30, 50:50, 30:70, 0:100 ratios while overall weight percentage of the fiber was fixed as 30 wt%. The composite will be tested according to the standard for tensile strength (ASTM D638), flexural strength (ASTM D790) and the morphology of the composite will be studied under the scanning electron microscopy (SEM) machine.

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CHAPTER 1: INTRODUCTION

1.1 Background of Study

Natural fiber is getting an attractive attention for the past few years to be used as a reinforcement in the polymer composite. Natural fiber is produced from animals and plants for example jute, hemp, sisal, bamboo, pineapple, banana, kenaf, wool and cotton. Natural fiber has been introduced to replace the synthetic fiber due to increasing costs of plastic, environmental concerns and movement towards greening technology. The use of green material is now very important and widely practiced due to the concern for global warming and oil depletion [1]. Unique intrinsic properties such as light weight can satisfy the requirement of global market especially for those industries who concern in weight reduction for example automotive and aerospace industries [2].

Other than light weight, it is proved by the researchers that natural fibers have many advantages like low density, low cost, recyclable, biodegradable, non-abrasive nature, have relatively high strength, high degree of flexibility during processing and high stiffness [2], [3], [4], [5]. However, some arguments have been raised that biodegradable polymer would not be sufficient enough as replacement material for fossil-based polymer. Therefore, the hybrid composites is being introduced. Hybrid composite is a composite that contains two or more types of reinforcement in a single matrix. It has been said that hybridization of two types of short fibers having different length and diameter offers some advantages over the use of one fiber in a single matrix [3]. Most study on hybridization of the polymer shows positive improvement on their properties [3], [5] , [6]. Many studies of hybridization had been performed using banana and kenaf, kenaf and sisal, sisal and banana, and also kenaf and corn husk [3], [5], [6].

This research was carried out to determine the optimization of mechanical properties of polypropylene (PP) composites, using banana stem fiber as the reinforcement to be used and had been highlighted as the objective for this research. In order to improve the mechanical properties, pineapple leaf fiber was added into the composition to form a hybrid composite. Composition of the fiber were varied and mechanical test such as tensile, flexural and impact test will be carried out to select the best composition of the fibers. The composites will be fabricated by using the compression molding machine.

1.2 Problem Statement

The use of natural fiber as a reinforcement in polymer composites is gaining a wide interest especially from aerospace and automotive industries as the demand for light weight material are increasing. Other concerns included cost and environmental aspects, green technology and oil depletion. There are also concerns said that single reinforced natural fiber would not be enough to replace synthetic fiber [6], [3].

1.3 Objectives

1) To investigate how two reinforcement in a single matrix polymer would affect the mechanical properties of the composites.
2) To compare the tensile strength, flexural strength and impact of the two reinforcement with different fiber loading in the composites.
3) To compare the result of rule of hybrid mixture (RoHM) and experimental value.
4) To investigate how coupling agent will help in improving tensile strength of the hybrid composites.

1.4 Scope of Study

The research focused on hybridization of the banana fiber and pineapple leaf fiber as reinforcement in a single matrix which is polypropylene. The main scopes of the activities are:

1) Mixing the coupling agent MAPP with PP using twin screw extruder.
2) Calculate the tensile strength and modulus of elasticity using rule of hybrid mixture (RoHM)
3) Establish the mechanical testing; tensile strength and flexural strength for natural fiber hybrid composites which have different composition of matrix-fiber.
4) Compare the experimental result with the theoretical result.
5) Study morphology using the Scanning Electron Microscope (SEM).

CHAPTER 2: LITERATURE REVIEW

2.1 Overview

Composites genuinely are the combination of two or more materials which have different physical and chemical properties in order to obtain specific characteristics and properties. Composites may consist of matrix and the reinforcement. The matrix can be either metallic, ceramic or polymer. Despite from its origin, the purpose of having the matrix is to give the composites the shape, appearance, environmental tolerance and durability [7]. While, the reinforcement is believed to improve the mechanical properties of the composite since it is stronger and stiffer than the matrix. The reinforcement can consist of fibrous, powdered, spherical, crystalline or whiskered and it also can be either organic, inorganic, metallic, ceramic or polymeric material [7].

The properties of composites actually depend on the behavior and characteristic of the interface between matrix and reinforcement. A better interfacial bonding will hence enhance the improvement of the mechanical properties for the composites. So, the research open a new sight for engineering field to develop composites that have superior mechanical properties. Some of the researches work on the hybridization. Hybridization is a promising strategy to improve and toughen the composites material [8].

The awareness of the environmental issues and oil depletion is gaining a huge engrossment to the nation nowadays. Hence many researchers stimulated the search for sustainable material which is using natural fiber (plant fiber) composite instead of the synthetic fiber composite [9]. Natural fiber reinforced composite gives a better mechanical properties and it is also ecofriendly. Besides, it is a lignocellulosic fiber which is able to impact certain benefits to the composites for example having low density, high stiffness, low cost, renewability, biodegradability, and high degree of flexibility compared to synthetic fiber [2], [4].

In addition, natural fiber offers more advantages to the composite where it has non-abrasive nature and high specific mechanical properties [9]. The use of natural fiber-polypropylene composites is growing in a global market especially for automobile and aerospace industries as they are demanding in the weight reduction material [2], [10].

2.2 Application of the composites

Natural fibers composite become an interesting alternative for the most widely applied fiber in the industry nowadays because it offers the opportunity for eco-friendly products, reduces the energy consumption, light weight, insulation and absorption properties, reduction in the dependence on petroleum based and forest product based material and reduces carbon emission [11]. The work reported by Drzal et al. in figure 1 shows the trend of application of bio based composites in United States of America in year 2000 and 2005 [12]. The trend of using bio based composites keeps increasing and it is soon predicted that this trend will change the whole global market of composite.

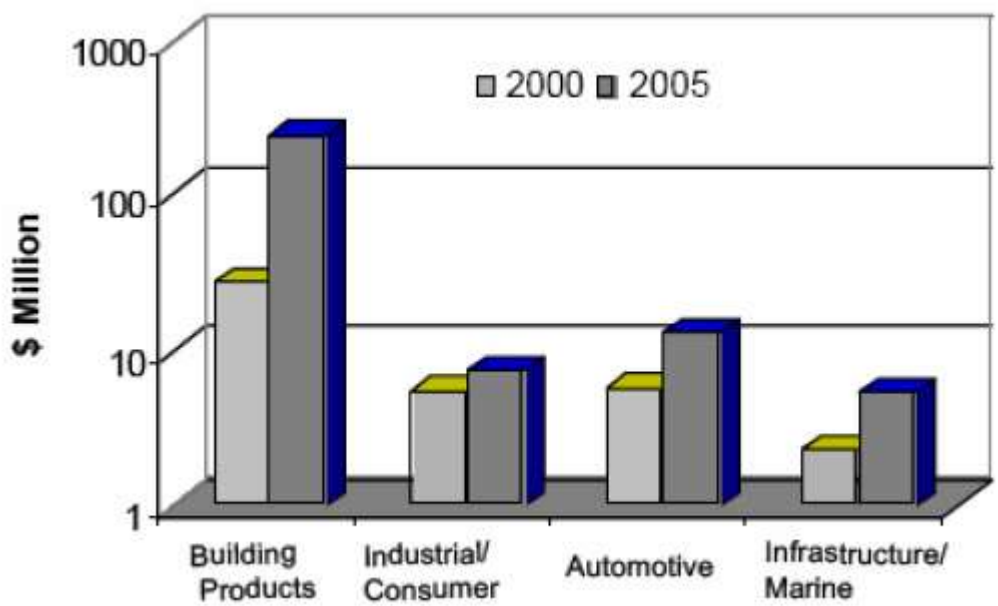


Figure 1: Current trend of bio based composite by application in United State of America 2000-2005

The use of bio composites provides large opportunities in the construction industries as it gives a sustainable approaches towards an ecological balance. Besides, the natural fiber can be used as reinforcement in cement matrix so that it can make low cost building material and occupy large carbon footprint in the ecosystem [13]. The example of building material that used natural fibers are panels, claddings, roofing sheets and tiles, slabs, and beams. However, researches on these bio composites are still ongoing because of the problems encountered with the natural fiber such as product performance due to poor fiber matrix interface and fiber variability [13].

The trends towards the use of natural fibers started in the years of 1990 in Europe and become the leading market of plastic composites in construction and also automotive industries [14]. In order to remain in this competitive market, the automotive industries started to optimize the price versus the quality. Natural fiber is believed to have the potential to substitute glass fiber as a reinforcement in the composites. Furthermore, the main driver for utilization of natural fiber composites are the demands for light weight parts where it leads to a lowering in fuel consumption and it is biodegradability, hence reducing the waste disposal problem [14].

Natural fibers can be processed into various automotive applications for example door cladding, seatbacks lining and packages shelves, dashboard, door panel, package tray and etc. [14]. Shuda et al. in their research said that all the major vehicle manufacturers around the world are using natural fiber in their automotive applications for example listed in the Table 1.

Table 1: The applications of natural fiber in various automotive applications *[14]*.

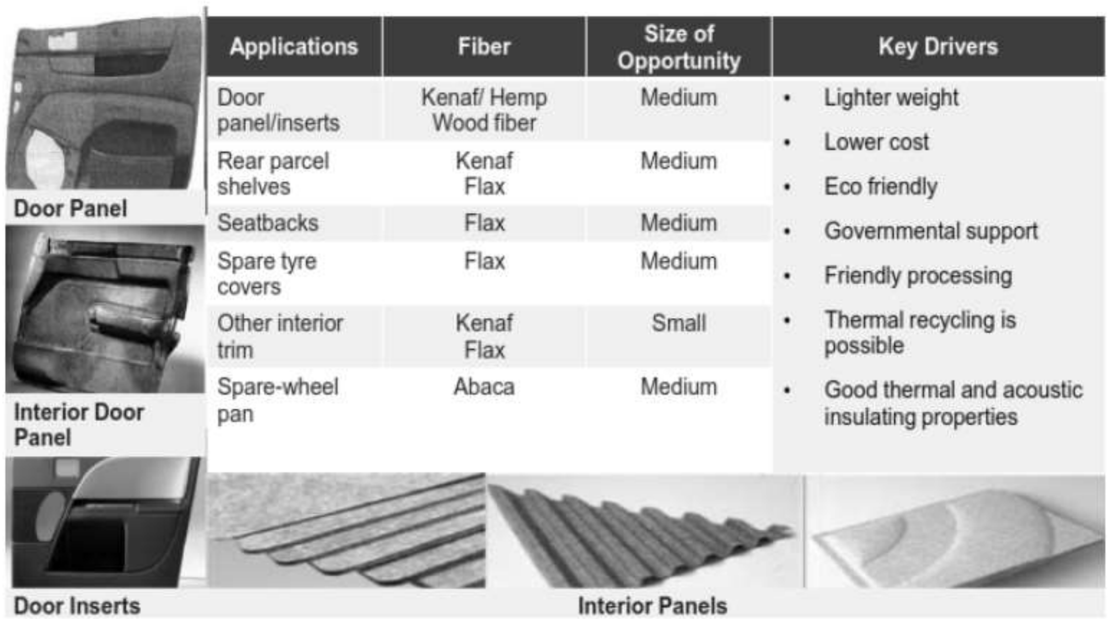
Model	Manufacturer	Applications
Rover 2000 and others	Rover	Rear Storage shelf/panel, insulation
Passat Variant, Golf A4, Bora	Volkswagen	Seatback, door panel, boot – lid finish panel, boot- liner

A2, A3, A4, A4 Avant, A6, A8	Audi	Hat rack, boot lining, spare tire-lining, side and back door panel, seat back
3, 5, 7 series	BMW	Seatback, headliner panel, boot-lining, door panel
Pilot	Honda	Cargo area
406	Peugeot	Front and rear door panel
Alfa Romeo 159	Fiat	Door Panel
C, S, E and A class	Mercedes Benz	Door panel, glove box, instrument panel support, insulation, seat backrest panel, trunk panel and seat surface
Raum	Toyota	Floor mats, spare tire cover

2.3 Natural Fiber

Natural fiber can be either plant based fiber or animal based fiber and as for the plant fiber, it can be categorized as wood fibers and non-wood fibers. Wood fibers consist of soft and hard woods. The example of wood fibers are cedar, pine, cherry and walnut. While non-wood natural fiber consists of kenaf, banana, pineapple, cotton, wheat, jute, flex, sisal, bamboo, grass and etc. However, this natural fiber can be classified in term of utilization whether it is primary or secondary fiber. The primary fiber is the fiber extract from the primary plant in which it is grown for their fiber content whereas the secondary fiber is the fiber from the waste. For example; banana stem fiber, pineapple leaf fiber, cereal stalks and coir fiber [15].

This natural fiber is used in various applications as mentioned earlier in this report. It can be either used in automotive, construction, packaging and others industrial appliances. It becomes interesting because it has a light weight feature, low cost and biodegradability. As for the automotive application, Shuda et al. in their research mentioned that coconut coir fiber is used to make seat bottom, back cushion and head restraint and abaca is being used in making underfloor body panel [14]. Figure 2 shows the list of fiber which is used in automotive applications.



Applications	Fiber	Size of Opportunity	Key Drivers
Door panel/inserts	Kenaf/ Hemp Wood fiber	Medium	• Lighter weight • Lower cost • Eco friendly • Governmental support • Friendly processing • Thermal recycling is possible • Good thermal and acoustic insulating properties
Rear parcel shelves	Kenaf Flax	Medium	
Seatbacks	Flax	Medium	
Spare tyre covers	Flax	Medium	
Other interior trim	Kenaf Flax	Small	
Spare-wheel pan	Abaca	Medium	

Figure 2: List of automotive applications and natural fiber

The reported work by Shuda et al. mentioned that flax, hemp, sisal, wool and other natural fiber were used to make 50 Mercedes-Benz E-class components [14]. The Mercedes-Benz company are working in a large range of natural fiber in order to replace glass fiber. BMW group also make use of the natural fiber for example flax and sisal in the interior door lining, cotton for sound proofing and kenaf for package trays and door panel.

2.4 Hybridization

In the recent years the development of the hybridization of the polymer with two or more reinforcement in a single matrix boost the mechanical properties of the composites. Hybrid composites are the material made up with two or more reinforcement in a single matrix [3]. Venkateshwaran et al. [3] said hybridization of two types of short fiber offer some advantages compared to those composites that have fiber alone in a single polymer matrix.

The hybridization gives many advantages over the single fiber such as having a better overall property combinations and also the failure of hybrid composites is not as catastrophic as with single fiber composites [6]. The matrix is soft and ductile and it serves as the purposes to bind the reinforcement together, protect the fiber, and transfer the load to the fiber and also to separate the fiber and inhibit crack propagation [15]. While, reinforcement is strong and stiffer which will improve the mechanical properties of the composites [16].

2.5 Matrix: Polypropylene (PP)

Polypropylene (PP) is widely used as a matrix in composites fabrication for the past few decades. Polypropylene is a polymer under thermoplastic group which will soften or melted when exposed to heat and consist of linear or branched chain molecules having strong intramolecular bonds but weak intermolecular bonds [7]. Thermoplastic has re-softening ability where the scrap thermoplastic is able to put back in the process, in other term it is easier to recycle [17]. It possess various advantages compared to polyethylene as it can withstand higher working temperature and also has a greater tensile strength [16].

Besides, Polypropylene has a good resistances to chemical attack and excellent fatigue resistance [18]. PP product is light in weight, has low moisture absorption rate, resistant to strain, though and resistant to heat [16]. Polypropylene also has some useful properties like dimensional stability heat distortion temperature, flame resistance and transparency [16]. The properties of polypropylene is as in table 2 [19].

Table 2: Mechanical Properties of Polypropylene *[19]*

Matrix	Processing Temperatures (ºC)		Specific Gravity		Water Absorption (% 24h)		Tensile Strength (MPa)		Elongation at break (%)		Tensile Modulus (GPa)		Flexural Strength (MPa)	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
PP	191	288	0.90	0.91	0.01	0.03	31.0	41.9	100	600	1.15	1.57	42	56

Due to its excellent properties in corrosion and chemical leaching resistant, polypropylene is used in the manufacturing piping system. It is able to withstand any forms of physical damage including impact and freezing. Polypropylene also can be used in manufacturing medical and laboratory items as it can withstand heat an autoclave. Due to the same reason, kettles and plastic tubs for dairy product are being made from this type of plastic. There are many applications out there that use polypropylene as a main polymer because of its excellent properties.

The most common type of manufacturing technique for polypropylene is injection molding which usually used by cutlery parts and automotive part such as batteries. The method of manufacturing is basically possess melt processing technique. It can be achieved via extrusion and molding [20]. Instead of that, there are many other techniques used for processing polypropylene for example thermoforming sheet for processing apparels and diapers and also cast film for adhesive tape.

2.6 Reinforcement

2.6.1 Banana Stem Fiber (BSF)

Banana stem fiber is a type of bast fibers which is in Musaceae family where the fiber is produced from the inner bark of banana tree or pseudo stem and provides structural strength and rigidity to the stem [21], [22]. Banana fiber is easy to get without any cost included since it is a waste product of banana cultivation and banana tree is one of the tree~~s~~ that are most planted in Malaysia [23]. The physical and mechanical properties of banana fiber is as follow:

Table 3: Physical and mechanical properties of banana stem fiber *[2]*

Fiber	Density (g/cm³)	Tensile Strength (MPa)	Tensile Modulus (GPa)	Elongation at break (%)
Banana Stem fiber (BS)	1.3	600-750	29-32	2-4

The extraction of banana stem fiber can be done using three methods which are chemical, mechanical and manual extraction. From these three methods, mechanical extraction is the best way to obtain the good quality and good condition fiber. Besides, mechanical extraction is an eco-friendly method of extraction [24]. Banana stem fibers can be used in many applications for example to make bond papers, replacement of glass fibers in composites material, manufactured of mattresses, pillows and cushions in the furniture industry, making bags, purse, mobile phone cover and also being used in manufacture of textiles [24].

According to a study on mechanical properties of natural fiber polymer composites [25], the polymer reinforced with banana fiber is the best composites among the various composites. The flexural test for banana reinforced composites showed higher stiffness compared to coir and sisal and the density test result showed that banana has low density which is 1101 Kg/m³. It is an attractive parameter in designing light weight material.

2.6.2 Pineapple Leaf Fiber (PLF)

Pineapple leaf is one of the natural wastes in Malaysia. It can be obtained at lower cost since its full potential does not being developed by the Malaysian. Pineapple is a tropical plant which names as Ananas comosus and it is herbaceous monocots [23]. The fiber from the leaves is long fiber bundle which is stiff and hard [22]. Table 4 shows the properties of pineapple leaf fiber.

Table 4: Physical and Mechanical properties of pineapple leaf fiber *[26]*

Fiber	Density (g/cm^3)	Tensile Strength (MPa)	Tensile Modulus (GPa)	Elongation at break (%)
Pineapple leaf Fiber (PALF)	1.44	413-16277	34.5-82.5	1.6

Long time ago before any machines have been discovered, pineapple leaf fibers is extracted using retting method. Retting is a process of removing fibers from plants using enzymes from microorganism. The plants will be placed in a pond for a few weeks and it will undergo natural decay process in removing unnecessary cellulose [22]. On the other hand, the fiber can be extracted by using scrapping machine in which the leaves are fed through the feed roller and being scratched by the other roller to remove the waxy layer on top of the pineapple leaf fiber [27].

From the reported work, a study on the suitability of Pineapple Leaf and Napier Grass as a finer substitution for paper making industries were establish [28]. The chemical composition and a study on morphology of the both fibers were analyzed. Table 5 shows the result of chemical composition of both fibers from the research. Pineapple fiber has a lower ash, lignin and hemicellulose content while exhibits higher cellulose, holocellulose and moisture content compared to Napier grass. SEM analysis depicted that arrangement of the fiber in pineapple leaf formed a strong fiber structure.

Table 5: Chemical Composition of Pineapple Leaf Fiber and Napier Grass fiber

Composition (%)	Pineapple Leaf Fiber	Napier Grass Fiber
Ash Content	4.5	14.6
Cellulose Content	66.2	12.3
Holocellulose Content	85.7	80.4
HemiCellulose Content	19.5	68.2

Lignin Content	4.2	10.7
Moisture Content	81.6	11.7

Munirah Mokhtar et al [11] comparatively studied on the characterization and treatments of pineapple leaf fiber (PALF) thermoplastic composite for the construction application. Before being reinforced with polypropylene (PP), PALF is chemically treated to hinder the water content. The results shown that the flexural strength and modulus of treated PALF reinforced with PP composites increased linearly with the increment of fiber loading. While, for the tensile strength, the result is decreasing as the fiber loading increased. This phenomenon may appeared due to the poor interfacial bonding between fiber and PP matrix.

2.7 Coupling Agent: MAPP

Works by Mohamad Jani [29] emphasized on the effect of Maleated Polypropylene (MAPP) on the tensile strength, impact and thickness swelling properties of the kenaf fiber reinforced with polypropylene composites. Coupling agent is known as an additive in improving the adhesion, dispersion and compatibility between the hydrophilic cellulose which is fiber itself and hydrophobic matrix. Epolene 43 has been loaded in the compounding process with the different concentrations (1%, 3% and 5% wt.). This study proved that composites with coupling agent depicted a better adhesion between filler and matrix. The finding of SEM in figure 3 proved the good bonding between interfacial regions and resulting an outstanding nature of mechanical and physical properties of the composites.

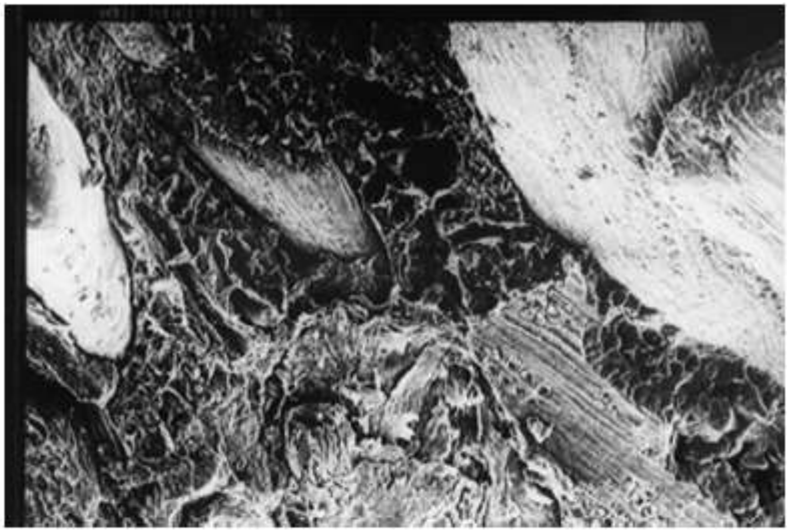


Figure 3: The SEM micrograph of Epolene 43 Kenaf treated sample *[29]*

A study on engineering the fibre-matrix interface in natural composites [30] highlighted that treatment with MAPP improves wetting of the fibers as it reduces the polarity and promote wetting by the viscous polymer matrix. However, the major disadvantage of this treatment is that it increased the cost of the composites.

2.8 Finding from Researchers

Natural fiber may possess low thermal stability, inhomogeneous quality and supply cycles, poor water resistance and susceptibility to rot [3], [5]. Jayamani et al. [5] described that natural fiber is dominated highly hydrophilic because of unsettled polarity from cellulose and lignin to the hydroxyl free groups. Gandini et al. [31] agreed that two major limitations of using natural fiber as a reinforcing element which are: 1) the composites are subject to loss of mechanical properties because of the fiber strong sensitivity to the water and moisture, and 2) the hydrophilic has a poor compatibility with hydrophobic matrix hence causes a weak interfacial adhesion. The poor interfacial bonding may produce undesirable mechanical and physical properties of the composites [5] as a weak interface do not transfer enough stress from the matrix to the fiber [32].

Thus, in this recent years, many researchers believe that by modifying the fiber surface or modifying the matrix or use of coupling agent will enhance a better interfacial adhesion and provide a better mechanical properties [4], [32]. Several of surface treatments have been promoted by the literature for instance treatment by alkali, silane, benzoylation, electric discharge, acetylation and peroxide. Paul et al. [2] had performed a study of the effect of fiber loading and chemical treatment on the thermophysical properties. The fiber surface was performed using different concentration and different method of treatment which are alkalization, benzoyl chloride treatment, KMnO4 treatment and silane treatment. The model result showed that all the chemical treatment enhance thermophysical properties but only the fiber that was treated with benzoylated and 10% NaOH showed a major increasing in the thermophysical properties.

Olodele et al. [33] carried out the experiment on the effect of the chemical treatment on the mechanical properties of sisal fiber reinforced polyester composites. They performed the treatment on the sisal fiber using the same concentration and different method of treatment which are NaOH, KOH,H_2O_2, and ethanol. The outcome of the experiment showed that KOH treatment enhance the tensile and hardness properties of the polyester composites than other treatment. From the past research, it is absolutely proved that chemical treatment increases the mechanical and physical properties of the fiber since it reduces the polarity of the cellulose fiber surface [2].

The use of coupling agent in the composites also helps in improving the mechanical properties of the composites. Khalid et al [34] studied the effect of MAPP as coupling agent on mechanical properties of natural fiber composites. The research was done by varying the percentage of weight concentration of MAPP which are 2%, 3%, 5% and 7% wt. It was found that 2% of MAPP gave the best result compared to other concentrations. MAPP did enhance the composites matrix adhesion that led to improvement of bio composite performance. However, the study highlighted with the increased in the concentration of MAPP in the PP matrix above 2%, there was a substantial decrease in mechanical strength [34].

Venkateshwaran et al. [21] investigated on the mechanical behavior of banana/sisal reinforced hybrid composites by varying the fiber length and weight percentage. They concluded that the tensile, flexural and impact strength depended on the weight percentage and fiber length. There were some increments in the mechanical properties of the composites but still the hybridization of the natural fiber with the natural fiber did not show a huge mechanical properties as compared to the hybridization of the synthetic fiber.

Elammaran et al. [5] stated that hybrid composite's properties may depend on the fiber orientation ore configuration, fiber content, length of the individual fiber, extend of intermingling of fiber and also bonding between matrix and fiber. They said that the mechanical properties may be increased significantly if there is a careful selection of reinforcing fiber used. Despite of having a good mechanical properties, hybrid composite seem to have a balancing between the cost and the performance comparable to the single fiber as a reinforcement.

Literature shown that tensile strength can be predicted using the equation instead of having the experiment in the lab. Venkateshwaran et al. [3] predicted the tensile properties of banana/sisal hybrid composites by using the RoHM (role of hybrid mixtures) equation and properties of the pure composites. The author compared the result of RoHM equation and experimental and the result is closer but a little bit higher than the experimental value. Anyhow, most of the researchers have an argument in the values that were produced from the calculation since it did not include the internal or external factor which is the chance of formation of void between fiber and matrix during the preparation of composites.

Till this day, there are only few numbers of the research papers on hybridization of two natural fiber as reinforcement and using biodegradable polymer. And there are a lot of predictions that lead to the advantages of mechanical properties when dealing with different volume or configuration. Therefore, this research was aimed for optimization of the mechanical properties of natural hybrid composites using different configuration, different weight ratio the effect of chemical treatment for the use of car dashboard. Borealis and Borouge [35] the providers for innovative chemical and plastic solution for the infrastructure emphasized the standard properties car dashboard as in table 6.

Table 6: Standard properties for car dashboard *[35]*.

Filler Content (%)	Density (kg/m^3)	Flexural Modulus (MPa)	Tensile Stress at yield (MPa)	Impact, Charpy notched 23˚C (kj/m^3)	Impact, Charpy notched -20˚C (kj/m^3)
9-20	950-1040	1700-2050	17-23	16-45	3.5-6

CHAPTER 3: METHODOLOGY

3.1 Tools and Equipment

The experiment used the tool and equipment as in table 7 below:

Table 7: List of Equipment and its function

Bil.	Equipment	Function
1	Color- Exact 1100 NP Twin Screw Extruder 	Mixed and extrude PP and MAPP to be a compounding material.
2	Carver Inc Compression Molding Machine 	Compressed the natural hybrid polymer composites into the desired shaped for tensile and flexural test according to ASTM standard.
3	Llyod Universal Testing Machine 	Carried out the tensile test and flexural test and obtained significant mechanical properties.
4	Compression Mold for tensile test	Medium to compress composites into the dog bone shape according to the

		standards.
5	Compression mold for flexural test 	Medium to compress composites into the flexural shape according to the standards.
5	Scanning Electron Microscopy	Analyzed the morphology of natural hybrid polymer composites.

3.2 Material

The material used for this research is as follow:

3.2.1 Polypropylene (PP)

Polypropylene in figure 4 acts as a matrix that binds the fiber together. The function of matrix is to transfer the load to fiber without fracturing, to support and protect the fiber and as a principal load-carrying agent [7]. It was obtained from Lotte Chemical TITAN Holding Sdn. Bhd. It has a density of 0.9 g/cm^3, melting flow index of 42 g/10 min and melting point with a maximum processing temperature of 300°C.

Figure 4: Polypropylene in granule

3.2.2 Banana Stem Fiber (BSF)

Banana stem fiber (BSF) in figure 5 is obtained from Conifer Handmade Mumbai, India. It is in the form of raw fiber and yarn fiber which is about 1 kg each. It has a density of 1.3 g/cm^3 and can withstand temperature up until 200˚C.

Figure 5: Raw and yarn Banana Stem Fiber

3.2.3 Pineapple Leaf Fiber (PLF)

Pineapple Leaf Fiber (PLF) in figure 6 is purchased from the Conifer Handmade Mumbai, India. It is in the form of raw fiber and yarn fiber for about 1 kg each. The properties of PLF are, it has a density of 1.44 g/cm³ and can bear with higher temperature.

Figure 6: Raw and yarn Pineapple Leaf Fiber

3.2.4 Maleic Anhydride Grafted Polypropylene (MAPP)

MAPP is known as a coupling agent which gives a flexible layer to the matrix and fiber interfacial which will improve their bonding and reduces the number of void traps [7]. MAPP in figure 7 is also known as Fusabond P 613, obtained from Dupont Packaging & Industrial Polymer Malaysia. The properties of the MAPP as in table 8:

Table 8: Properties of MAPP

	Density (g/cm³)	Melting point (ºC)	Maximum processing temperature	Melting flow index (g/min)
MAPP	0.903	162	300	4 g/10 min

Figure 7: MAPP Fusabond P 613 in granule

3.3 Sample preparation

The preparation of the material as follows:

3.3.1 Mixing PP with MAPP

The process of mixing PP with MAPP is done by using twin screw extruder machine according to the weight ratio shown on the table 9. While, table 10 depicted the temperature profile at the extruder zone. The compounded PP and MAPP is melted and processed in the machine and extruded with 3.00 mm thickness. Then it will be quenched in water bath and palletized using palletizer. The compounding process takes places at the temperature of 170˚C with the screw speed of 50 rpm. This speed is ideal for the melt process for twin extruder machine. The process of compounding and palletizing is depicted in figure 8.

Table 9: Material Composition for compounding PP and MAPP

Bil	Material	Weight (%)
1	Polypropylene (PP)	95
2	Maleic Anhydride Grafted Polypropylene (MAPP)	5
	Total	100

Table 10: Temperature profile in twin screw extruder

Barrel Temperature Settings (°C)						
Zone	1	2	3	4	5	6
Temperature(°C)	148	133	137	162	165	191

Figure 8: Summary of the process compounding PP and MAPP

3.3.2 Composite Fabrication

The experiment will be conducted using the same configuration but with a different volume fraction of fiber. The matrix of the composites will be fixed at 70 wt% since the previous research said that the composite will give an optimum result when it is at 70-30 wt%. The fiber used is a long fiber. The composition of the matrix fiber is shown in table 11.

Table 11: The composition of matrix fiber

Composite	Matrix (PP with MAPP) (wt. %)	Fiber (BSF) (wt. %)	Fiber (PLF) (wt. %)	Total (wt. %)
PP/BSF/PLF 1	70	30	-	100
PP/BSF/PLF 2	70	20	10	100
PP/BSF/PLF 3	70	15	15	100
PP/BSF/PLF 4	70	10	20	100
PP/BSF/PLF 5	70	-	30	100
PP/BSF/PLF 6	100	-	-	100

The weight of matrix and fiber will be calculated according to its weight percentage in the composite composition. The weight is determined using the volume of mold used and the density of the each material. Table 12 below stated the calculated volume of tensile and flexural mold based on the standard and table 13 shows the density of the each material.

Table 12: Volume for tensile and flexural mold

Mold	Volume (m^3)
Tensile	1.32×10^{-5}
Flexural	6.35×10^{-6}

Table 13: Density of the material

Material	Density (kg/m^3)
Polypropylene	900
Banana Stem Fiber (BSF)	1300
Pineapple Leaf Fiber (PLF)	1440

A sample calculation of compounding PP and fiber weight for tensile and flexural mold is shown below. The calculated weight for tensile mold and flexural mold are depicted in table 14 and 15.

1) Tensile mold

Compounded Polypropylene (70%) = $0.7 \times 1.32 \times 10^{-5} = 9.24 \times 10^{-6}\, m^3$

$$\rho = \frac{m}{v}$$

$$m = \rho \times v$$

$$m = 900 \frac{kg}{m^3} \times 9.24 \times 10^{-6} m^3$$

$$m = 8.316 \times 10^{-3} kg$$

Banana Stem Fiber (15%) = $0.15 \times 1.32 \times 10^{-5} m^{-3} = 1.98 \times 10^{-6}\, m^3$

$$m = 1300 \frac{kg}{m^3} \times 1.98 \times 10^{-6} m^3$$

$$m = 2.57 \times 10^{-3} kg$$

Pineapple Leaf Fiber (15%) = $0.15 \times 1.32 \times 10^{-5} m^{-3} = 1.98 \times 10^{-6}\, m^3$

$$m = 1440 \frac{kg}{m^3} \times 1.98 \times 10^{-6} m^3$$

$$m = 2.85 \times 10^{-3} kg$$

2) Flexural Mold

Compounded Polypropylene (70%) =$0.7 \times 6.35 \times 10^{-6} = 4.45 \times 10^{-6}\, m^3$

$$\rho = \frac{m}{v}$$

$$m = \rho \times v$$

$$m = 900\frac{kg}{m^3} \times 4.45 \times 10^{-6}m^3$$

$$m = 4.005 \times 10^{-3}kg$$

Banana Stem Fiber (15%) = $0.15 \times 6.35 \times 10^{-6}m^3 = 9.53 \times 10^{-7} m^3$

$$m = 1300\frac{kg}{m^3} \times 9.53 \times 10^{-7}m^3$$

$$m = 1.24 \times 10^{-3}kg$$

Pineapple Leaf Fiber (15%) = $0.15 \times 6.35 \times 10^{-6}m^3 = 9.53 \times 10^{-7} m^3$

$$m = 1440\frac{kg}{m^3} \times 9.53 \times 10^{-7}m^3$$

$$m = 1.37 \times 10^{-3}kg$$

Table 14: Calculated weight for each material in tensile mold

Composite	Matrix (PP with MAPP) (wt. %)	Weight (g)	Fiber (BSF) (wt. %)	Weight (g)	Fiber (PLF) (wt. %)	Weight (g)
PP/BSF/PLF 1	70	8.316	30	5.148	-	-
PP/BSF/PLF 2	70	8.316	20	3.432	10	1.901
PP/BSF/PLF 3	70	8.316	15	2.570	15	2.850
PP/BSF/PLF 4	70	8.316	10	1.716	20	3.802
PP/BSF/PLF 5	70	8.316	-	-	30	5.702
PP/BSF/PLF 6	100	11.88	-	-	-	-

Table 15: Calculated weight for each material in flexural mold

Composite	Matrix (PP with MAPP) (wt. %)	Weight (g)	Fiber (BSF) (wt. %)	Weight (g)	Fiber (PLF) (wt. %)	Weight (g)
PP/BSF/PLF 1	70	4.005	30	2.477	-	-
PP/BSF/PLF 2	70	4.005	20	1.651	10	0.914
PP/BSF/PLF 3	70	4.005	15	1.240	15	1.370
PP/BSF/PLF 4	70	4.005	10	0.826	20	1.829
PP/BSF/PLF 5	70	4.005	-	-	30	2.743
PP/BSF/PLF 6	100	5.715	-	-	-	-

After the sample is weighed according to the composition, it will be put inside the mold cavity. However, before that, a thin layer of wax is applied on the surface of mold to ensure the composite will be easily removed. While waiting for the sample to be prepared, the machine is preheated at 170˚C for 15 minutes. The hybrid composite is prepared using sandwich method where the matrix and fibers are being put layer by layer. For the first layer, PP layer is put in the mold followed by the banana stem fiber, a layer of PP is again being put on top of banana stem fiber, and followed by pineapple leaf fiber and last but not least, a layer of PP is put on the top side to cover the fiber.

Then, composites will be prepared by compression molding machine at 170 $\pm$ 3ºC and at a pressure of 10 ton force pressure for about 40 minutes [8]. The mold is subjected to compressive load until the mold cover fully closed. After that, it is allowed to cold down at 80 ˚C in 40 minutes. The composite is then removed from the mold.

3.3.3 Mechanical Testing Preparation

3.3.3.1 Tensile test

For the tensile strength testing, specimen is made according to the ASTM D638 Type 1 for reinforced composite shown in figure 9 and the test will follow the detail procedures in ASTM D638 [24]. The specimen dimension is presented in the table 16 below.

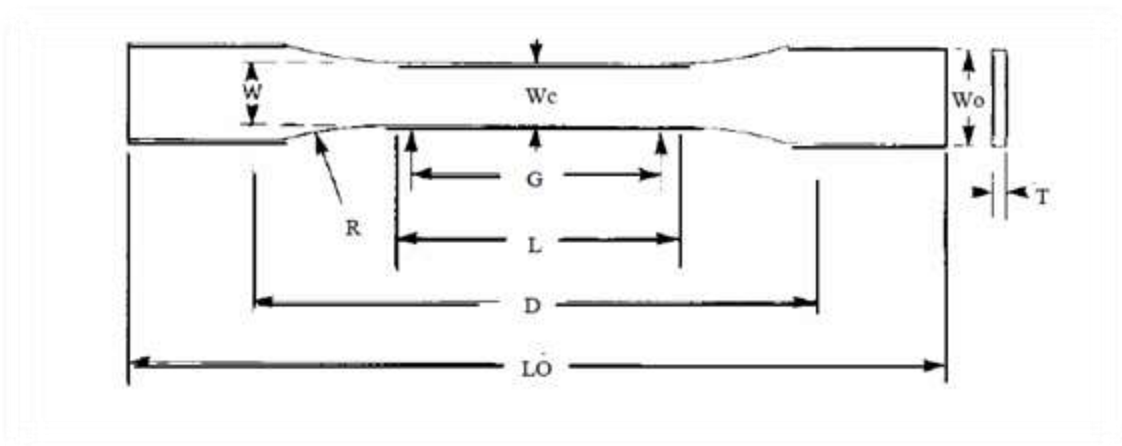


Figure 9: Type I shaped

Table 16: Specimen dimension for tensile specimen *[24]*.

Dimension	Length (mm)
W- width of narrow section	13 ± 0.5
L- Length of narrow section	57 ± 0.5
WO- Width overall	19 ± 6.4
LO- Length overall	165
G- Gage length	50 ± 0.25
D- Distance between grips	115 ± 5
R- radius of fillet	76 ± 1
T- thickness	7 or under

The procedure of the testing are as follows:

1. The width and thickness of the specimen are measured to the nearest 0.025 mm using the applicable method.
2. The specimen is then placed in the grips of the testing machine. The alignment of the long axis of the specimen and the grip with and imaginary line joining the points of the attachment of the grip to the machine need to be taken care.
3. Attached the extension indicator. It is required a class B-2 or better extensometer when the modulus is being determined.
4. The speed of testing is being set at 5 ± 25% mm/min. And the machined is started.
5. The load-extension curve of the specimen is recorded.
6. Last but not least, the load and extension at the yield point and at the moment of rupture is recorded.

Figure 10: A specimen undergo tensile test

3.3.3.2 Flexural test

Three point bends testing will be conducted based on ASTM D790 M test method 1, procedure A to measure flexural strength [4]. Procedure A is basically designed for materials break at comparatively small deflection and it shall be used for measurement of flexural properties and modulus. It employs a strain rate of 0.01 mm/mm/min. The recommended test specimen for molding materials is 127 by 12.7 by 3.2 mm tested flatwise on a support span. The procedures of the testing are as follows:

1. Used an untested specimen for each measurement. The width and depth of the specimen should be measured to the nearest 0.03mm at the center of the test support.
2. The support span used is determined as 16:1 support span-to-depth ratios.
3. Calculate the rate of crosshead motion using the following equation,

$$R = \frac{ZL^2}{6d} = \frac{0.01(16 \times 4)^2}{6 \times 4} = 1.707\ mm/min$$

   Where,

   R = rate of crosshead motion, mm/min

   L = support span, mm

   d = depth of beam, mm and

   Z = rate of straining of the outer fiber, 0.01 mm/mm/min
4. The loading nose and support need to be aligned so that the axes of the cylindrical surface are parallel and it is in the midway between the supports.
5. The load is applied on the specimen at calculated crosshead rate and the load deflection data is recorded.
6. When the maximum strain of outer surface of the specimen reached 0.05 mm/min, the test is terminated.

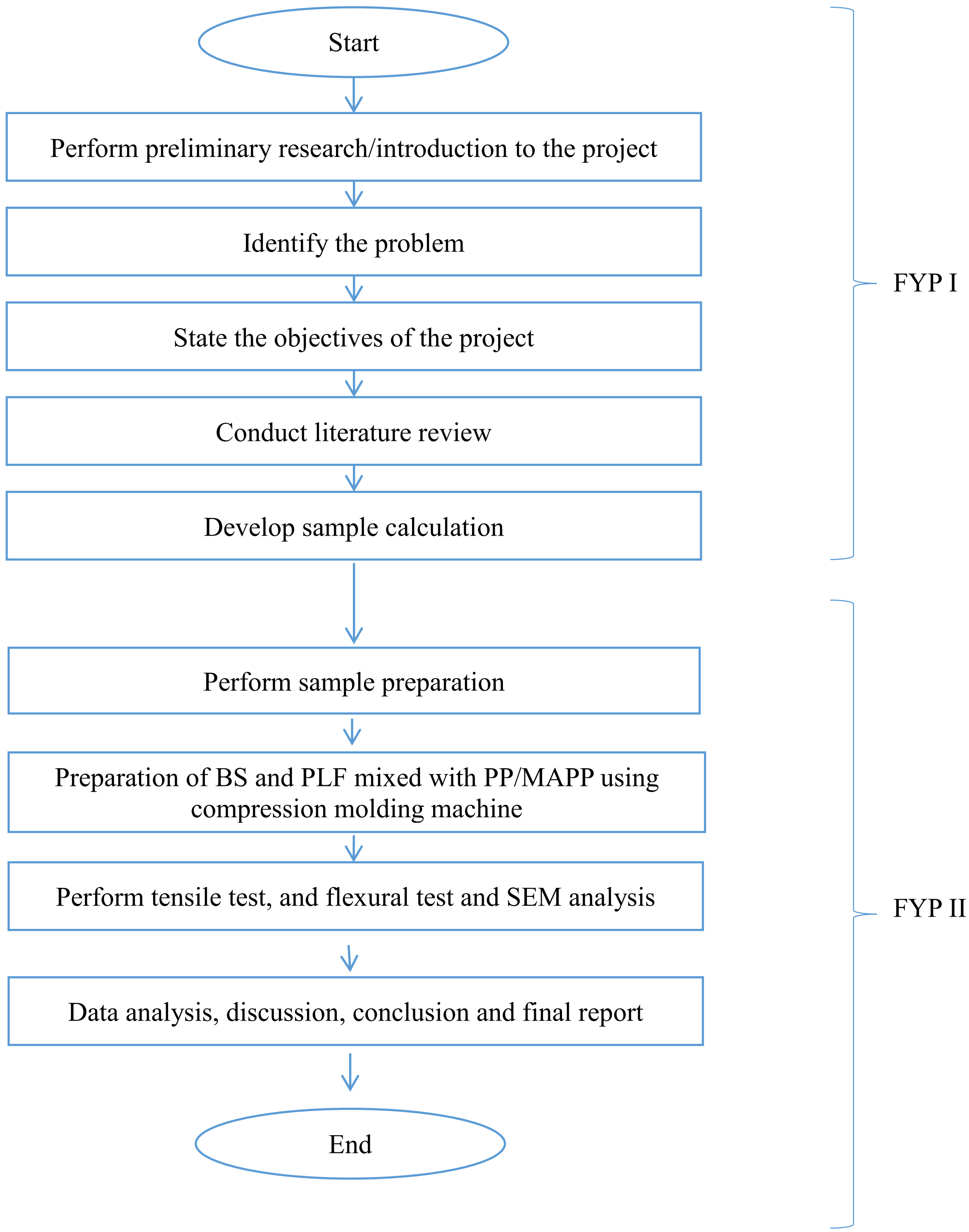
Figure 11: A specimen undergo flexural test

3.3.3.3 Morphology Study

Morphology study will be observed under Scanning Electron Microscopy machine model 7353 LEO 1430VP. The fractured surfaced of the specimen is used to illustrate the microstructure of the composite with the different composition of the fiber. It is conducted to study the bonding between the fiber and matrix.

3.4 Project Workflow

A proposed project workflow is as below:



3.5 Gantt Chart

Table 17: FYP 1 project Gantt chart and Key Milestone

Project Activities	Duration (weeks)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of project title														
Literature review/ research work														
Submission of Extended Proposal								18/2						
Proposal Defense										16/3				
Composition calculation														
Preparation material														
Submission of Interim Draft Report														
Submission of Interim Report														

Table 18: FYP 2 project Gantt chart and Key Milestone

Project Activities	Duration (weeks)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Composite preparation														
Submission of progress report														
Experimental Testing														
Pre- SEDEX														
Submission of draft final report														
Submission of Dissertation (Soft bound)														
Submission of Tehnical Paper														
Viva														
Submission of Dissertation (Hard bound)														

CHAPTER 4: RESULT AND DISCUSSION

4.1 Theoretical Result

A rule of hybrid mixture (ROHM) is used to calculate tensile strength and tensile modulus of the composites. The formula used for hybrid composite having all fiber aligned are shown in table 19.

Table 19: Formula of ROHM

Mechanical Properties	Formula
Tensile Strength	$\sigma_C = \sigma_m V_m + \sigma_{f1} V_{f1} + \sigma_{f2} V_{f2}$
Elastic Modulus	$E_C = E_m V_m + E_{f1} V_{f1} + E_{f2} V_{f2}$

Where;

σ_C = tensile strength for the composite

σ_m= tensile strength for the matrix

σ_{f1}= tensile strength for the BSF

σ_{f2}= tensile strength for PLF

V_m= volume fraction of matrix

V_{f1} = volume fraction of BSF

V_{f2} = volume fraction of PLF

E_C = tensile modulus of composite

E_m= tensile modulus for matrix

E_{f1}= tensile modulus for BSF

E_{f2} = tensile modulus for PLF

The design parameter for the calculation acquired the mechanical properties of each fiber and the matrix itself. The parameter is shown in the table 20.

Table 20: Mechanical properties for Calculation

Material	Density, ρ (g/cm³)	Tensile Strength, σ (MPa)	Tensile Modulus, E (GPa)
Polypropylene	0.9	31.0	1.15
Banana Stem Fiber (BSF)	1.3	600-750	29-32
Pineapple Leaf Fiber (PLF)	1.44	413-16277	34.5-82.5

Based on the formula and the given parameters, the expected result for tensile strength and tensile modulus for hybrid composites are calculated as example below;

Tensile strength, σ_C

$$\sigma_C = \sigma_m V_m + \sigma_{f1} V_{f1} + \sigma_{f2} V_{f2}$$

$$\sigma_C = 31\ (0.7) + 600\ (0.15) + 413\ (0.15)$$

$$\sigma_C = 173.65\ MPa$$

Elastic of Modulus, E_C

$$E_C = E_m V_m + E_{f1} V_{f1} + E_{f2} V_{f2}$$

$$E_C = 1.15\ (0.7) + 29\ (0.15) + 34.5\ (0.15)$$

$$E_C = 10.25\ GPa$$

Table 21: Theoretical result for natural fiber composites

Composite	Matrix (PP with MAPP) (wt. %)	Fiber (BSF) (wt. %)	Fiber (PLF) (wt. %)	Tensile Modulus, $\sigma_C\ (MPa)$	Elastic Modulus, $E_C\ (GPa)$
PP/BSF/PLF 1	70	30	-	201.7	9.51
PP/BSF/PLF 2	70	20	10	183.0	10.06
PP/BSF/PLF 3	70	15	15	173.7	10.25
PP/BSF/PLF 4	70	10	20	164.3	10.61

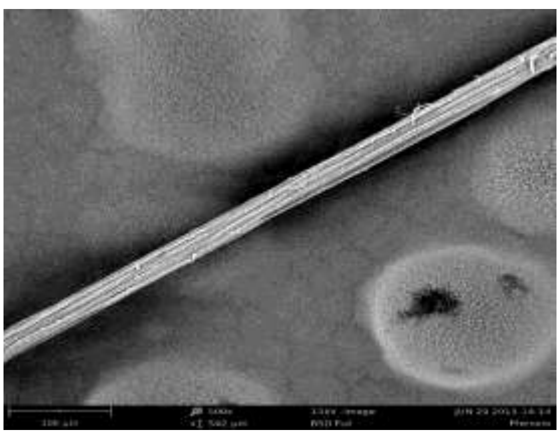
PP/BSF/PLF 5	70	-	30	145.6	11.61
PP/BSF/PLF 6	100	-	-	31.0	1.15

From table 21, it is shown that PP/BSF/PLF 1 has higher tensile strength compare to others and PP/BSF/PLF 5 has higher elastic modulus compared to others.

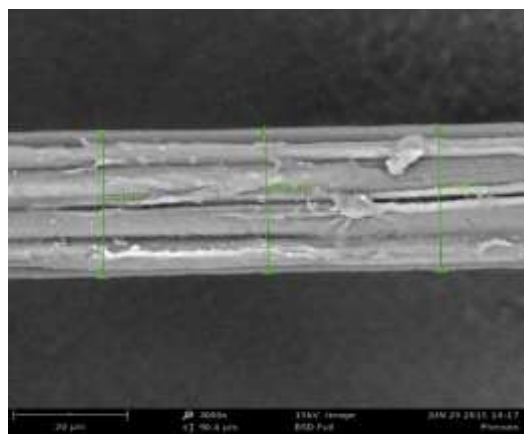
4.2 Fiber Analysis

The fiber has been analyzed using scanning electron microscopy (SEM) in order to study the surface morphology and to measure the diameter of untreated banana stem fiber (BSF) and pineapple leaf fiber (PLF). The study on the diameter and the length of the fiber influence the mechanical properties of the composites. Kwon et al. reported that the role of aspect ratio in natural fiber will predict the mechanical properties of the hybrid composites [6].

a)



b)



c)

d)

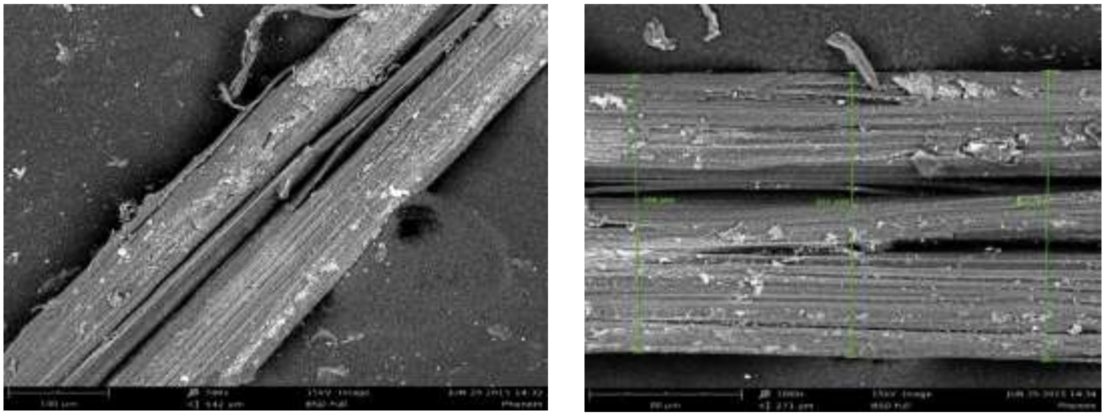


Figure 12: SEM micrographs of untreated a) raw banana fiber b) raw banana fiber with diameter measurement c) raw pineapple fiber d) raw pineapple fiber with diameter measurement

Based on the SEM micrograph in figure 12, it is shown that raw banana stem fiber (BSF) is smoother than raw pineapple leaf fiber (PLF). PLF obviously has a lot of fibrils on the surface and contains more lignin. It also shows PLF has a bigger diameter compare to BSF. As mentioned earlier, the diameter of the fiber for sure affects the role of aspect ratio in predicting the mechanical properties of the hybrid composites. Table 22 shows the role of aspect ratio for each fiber.

Table 22: Aspect ratio for each fiber in hybrid composite

	Length (mm)	Average Diameter (µm)	Aspect ratio (L/D)
Banana Stem Fiber (BSF)	140	33.03	4238.57
Pineapple Leaf Fiber (PLF)	120	200.67	598.00

Kwon at el. in his work reported that aspect ratio affected the mechanical properties of hybrid composites as has a high aspect ratio compared to PLF. Practically, the mechanical properties of composites will increase if the amount of BSF is larger than PLF in the composites. The research done by Kwon et al. indicated the one that has a higher aspect ratio played a role as primary reinforcement in the hybrid composite.

Therefore, having a higher composition of BSF in the composite will enhance the optimization of mechanical properties of hybrid composites.

4.3 Tensile Strength

Tensile test has been performed using universal tensile machine (UTM) according to ASTM D638 standards and the broken samples are shown in figure 13. The dog bone specimen is in type 1 which the average size of length is 165.00 mm, width 12.79 mm and thickness 4.33 mm is used for tensile testing. The testing is done over the five different types of banana and pineapple fibers composites. The test is performed at a speed rate about 5 mm/min and at average load of 1.185 kN.

Figure 13: Broken Specimen after tensile test

Based on figure 13, it is clearly seen that the specimens were fractured in irregular forms. The best specimen supposed to break in the middle of the length which can be seen at sample 1 while the other specimens were fractured near to the grip. It is due to void that can be clearly seen by naked eyes which appeared in the sample.

Table 23: Tensile strength of the composites

Sample	Tensile Strength (MPa)			
	Unreinforced PP + MAPP	PP + MAPP + BSF+PLF	PP + BSF + PLF	PP + BSF + PLF
1	4.264	5.919	5.373	4.426
2	4.031	7.001	0.819	3.232
3	5.241	5.217	5.331	5.357
4	3.890	6.200	5.524	2.378
5	3.086	7.764	7.777	3.866

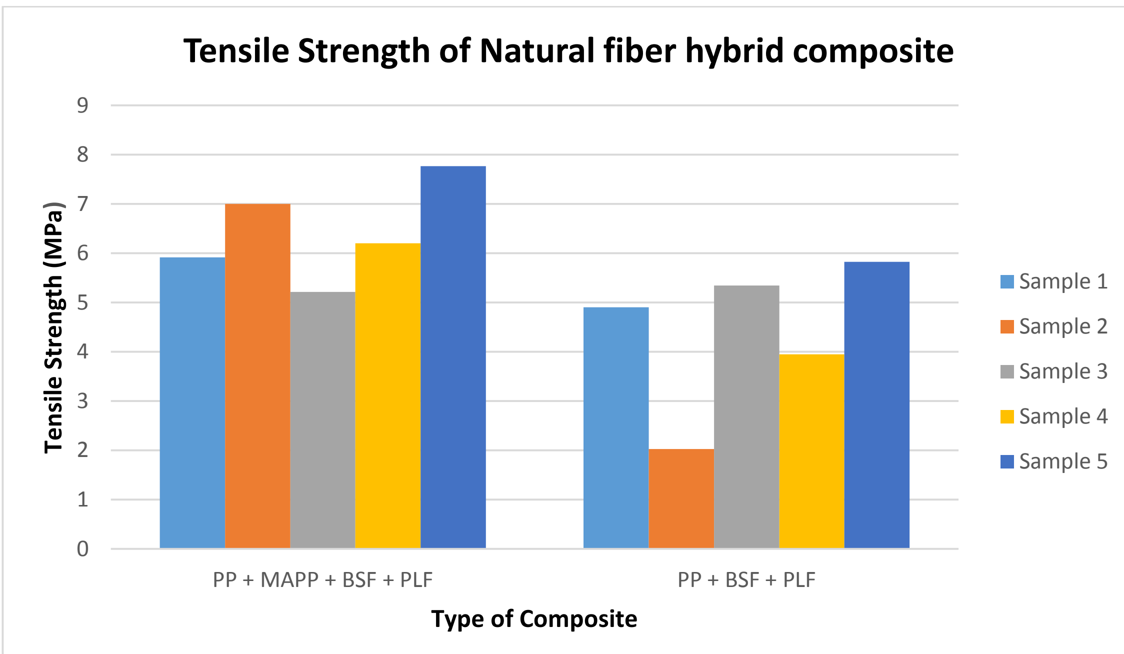


Figure 14: Bar chart of the tensile strength with different type of composites

From the bar chart depicted in figure 14, the composite that contained PP, MAPP and natural fiber shows higher tensile compared to the composite that contain PP and natural fiber only. This shows that the composites with MAPP (coupling agent) possesses better mechanical properties compare to the composites without the MAPP. The mechanical properties of the composite with MAPP shows 50% increment in tensile strength compare to the composite without MAPP. Zafeiropoulos in his study

[30] highlighted that the addition of MAPP in the composites will increase the tensile strength of the composites. It is because MAPP improves wetting of the fibers. The presence of the coupling agent chain in the composites reduces the polarity of the fibers and indirectly improves wetting of the fiber [30].

Each sample shown in figure 14 represents a different fiber loading in each composite. The fiber loading in each composites are described as in table 21. Sample 5 that contains 100% PLF has a higher tensile strength which is 7.764 MPa compared to sample 3 where it contains 50/50% BSF and PLF. The data values of the tensile strength for each composite are summarized in table 23.

4.4 Flexural Strength

Flexural test or three points bending test has been done according to ASTM D790 standard using universal testing machine (UTM) and the fractured specimens were depicted in figure 15. The result shows a smooth bending of specimen which proved that it had been done accordingly to the standards. Table 24 below summarized the value of flexural strength of all composites.

Figure 15: Fractured specimen after flexural test

Table 24: Flexural Strength of the composites

Sample	Flexural Strength (MPa) of PP + BSF + PLF				
	Batch 1	Batch 2	Batch 3	Batch 4	Average
1	45.175	44.705	44.007	32.921	41.702
2	44.777	34.312	45.354	31.787	39.058
3	44.101	40.006	48.007	42.270	43.598
4	40.996	25.872	37.491	32.371	34.183
5	48.985	44.705	43.268	27. 848	41.202
6	24.864	34.394	33.386	32.623	34.394

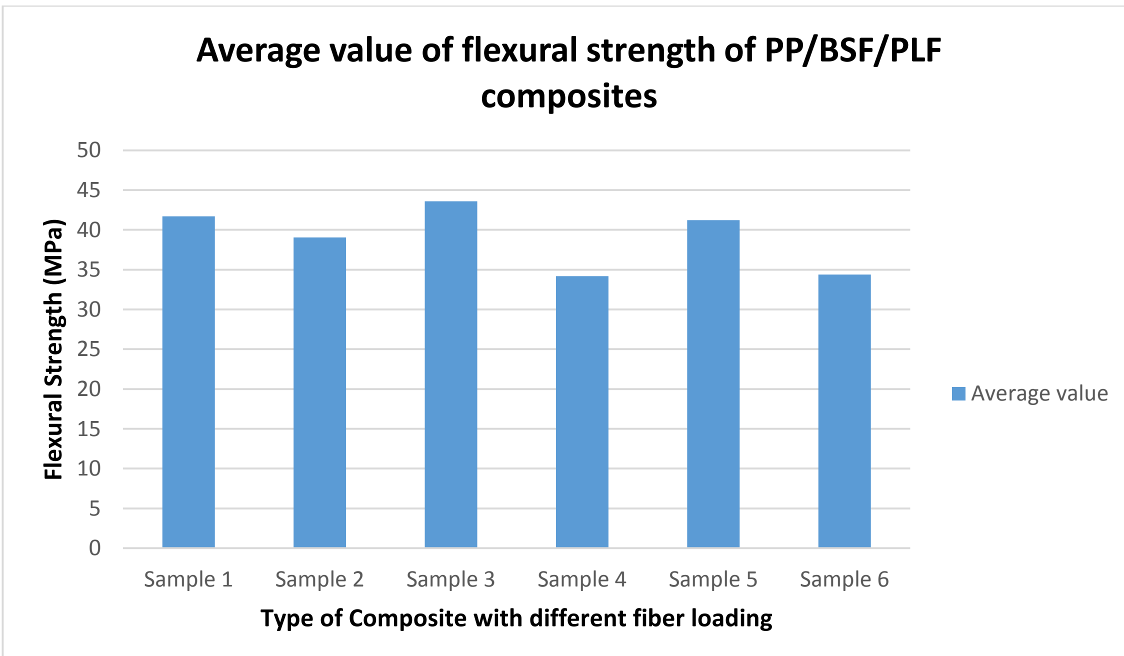


Figure 16: Bar chart of flexural strength of PP/BSF/PLF composites

The chart shows in figure 16 is the average value of flexural strength for the composites which are varied in its fiber length. The sample 3 where it consists of 50/50% BSF and PLF content yield the highest value of flexural strength compared to the other hybrid composites which is 43.598 MPa. This shows a good interfacial bonding between fiber and matrix as it possesses higher mechanical properties as compared to other hybrid composites.

From the chart in figure 16, it can be seen that the composite has higher flexural strength compared to unreinforced PP which is picturized by sample 6. Sample 1 until 5 is a composite that varied its fiber loading while sample 6 is unreinforced PP. It is proven that composites with reinforced natural fiber possess higher mechanical properties compared to single PP. Also figure 16 shows, the addition of pineapple leaf fiber into banana stem fiber will increase the strength up to 50 wt% and then it started to decrease. It is explained on the theory of the aspect ratio in which the higher content of fiber with larger aspect ratio in a composites will possess higher mechanical properties of the comosites.

4.5 Comparison of Theoretical, Experimental and Previous Research Value

Table 25: Experimental result for tensile and flexural properties of hybrid composites

Fiber content BSF/PLF	Tensile Strength (MPa)	Tensile Modulus (MPa)	Flexural Strength (MPa)	Flexural Modulus (MPa)
100/0	4.90	4770	41.70	1390
70/30	2.03	0.03	39.06	1330
50/50	5.34	5378	43.60	1350
30/70	3.95	12380	34.18	1790
0/100	5.82	0	41.20	1480

Table 26: Previous research value for tensile and flexural properties of hybrid composites *[37]*

Fiber content BSF/PLF	Tensile Strength (MPa)	Tensile Modulus (MPa)	Flexural Strength (MPa)	Flexural Modulus (MPa)
100/0	16.12	642.00	57.33	8920
70/30	17.39	662.25	58.51	9025
50/55	18.66	682.50	59.69	9130
30/70	19.93	702.75	60.87	9235
0/100	21.20	723.00	62.04	9340

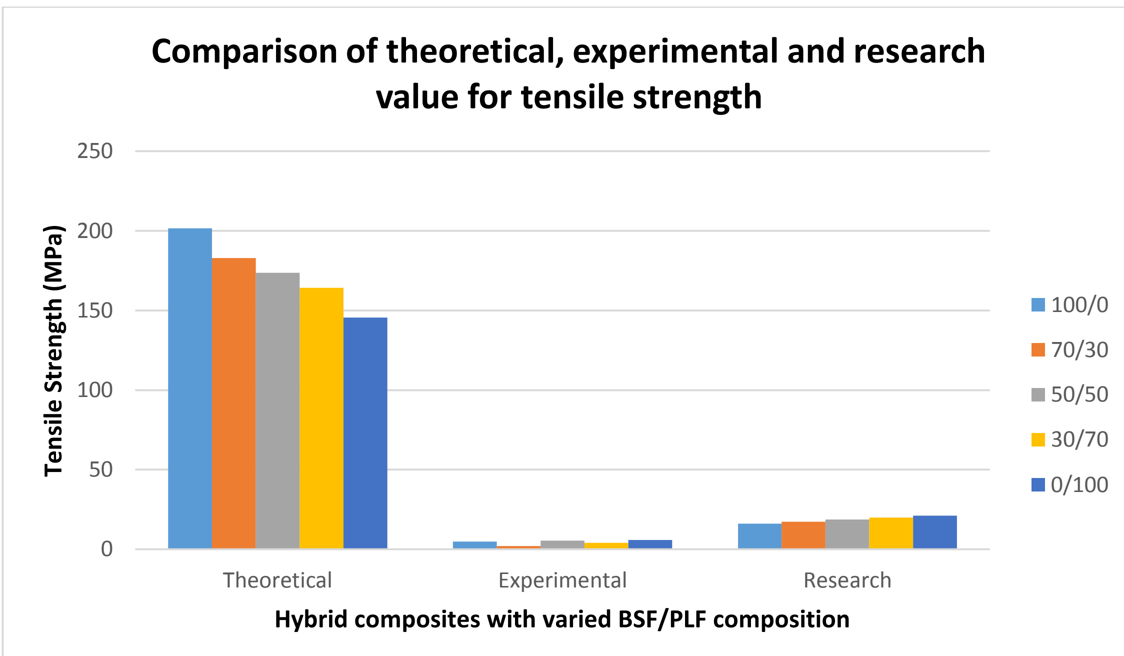


Figure 17: Bar chart of theoretical, experimental and previous research value of tensile strength

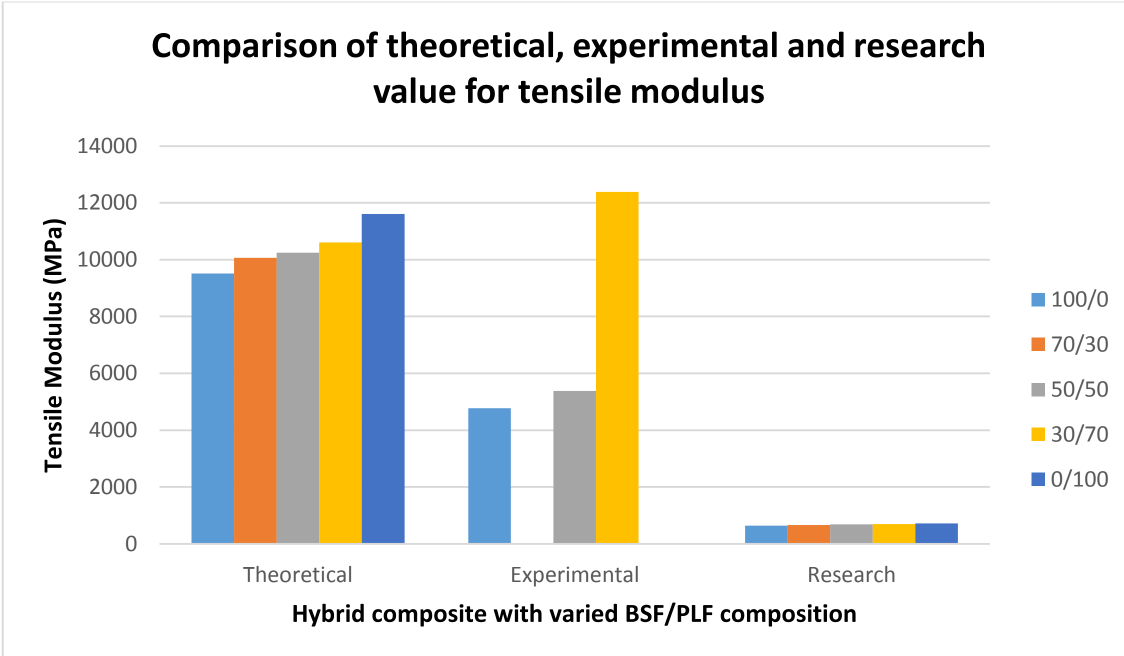


Figure 18: Comparison of Theoretical, experimental and previous research value of tensile modulus

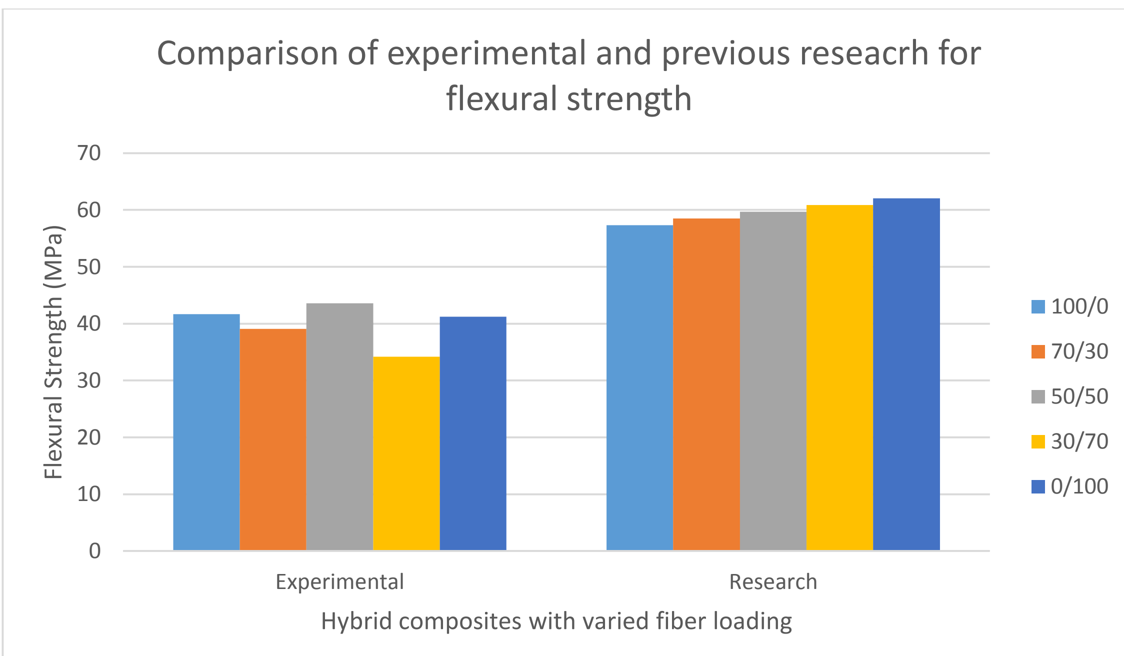


Figure 19: Comparison of experimental and previous research value for flexural strength

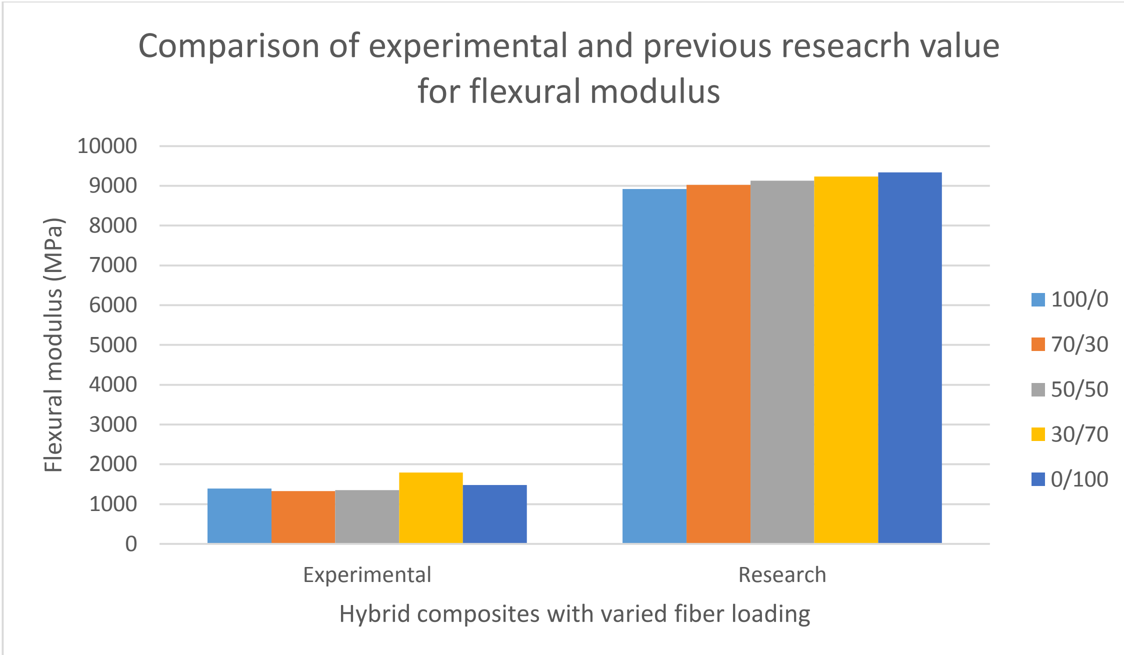


Figure 20: Comparison of experimental and previous research value for flexural modulus

Figure 18 and 19 show the comparison value of tensile strength and tensile modulus for theoretical, experimental and previous research and it is showed that the theoretical tensile strength and tensile modulus exhibit higher value compared to others. It is because, the chance of formation of micro voids during the preparation of samples influenced the tensile properties and also tensile modulus. It is observed that the tensile strength for experimental result is quite a low value compared to previous research done by Venkateshwaran [37].

Venkateshwaran et al [37] in their research used sisal in addition to banana/epoxy composite to bring the hybrid effect. Sisal is known to have a higher tensile strength compared to banana and pineapple fiber. Thus, that is the reason why the previous research possesses higher strength compare to this experimental value. However, there are some other reasons that contribute to the low value of tensile strength. It is due to void that trap inside the composites during the preparation of composite. The formation of void can be clearly seen by naked eyes. The voids gives higher tendency for the material to fail.

Figure 19 and 20 show the comparison result of experimental and previous research for flexural strength and flexural modulus. The differences between these two results are not too obvious. It is might be due to the material used and method of composites preparation. However, there is also a tendency in which the result is low because of voids trap inside the composite and it might be due to the low operating temperature of the compression moulding machine so that the material will not be fully melted. This process will cause the air bubble trapped inside the mould.

4.6 Morphology Study

The structure of the fractured surface from tensile test is observed through Scanning Electron Microscopy (SEM) analysis. All SEM micrograph shows the phenomenon of pull out fiber and observe the internal cracks, fractured surface and internal structure of the composites. It can been seen from figure below, the composites failed in the brittle manner. It is proven by researcher material that failed in a brittle mode is very rigid and have higher modulus of tensile. As observed in tensile strength test, the crack propagates at a small loads and it occurs almost instantly. It is because the composites in figure show the lack of plastic deformation on the fracture surface.

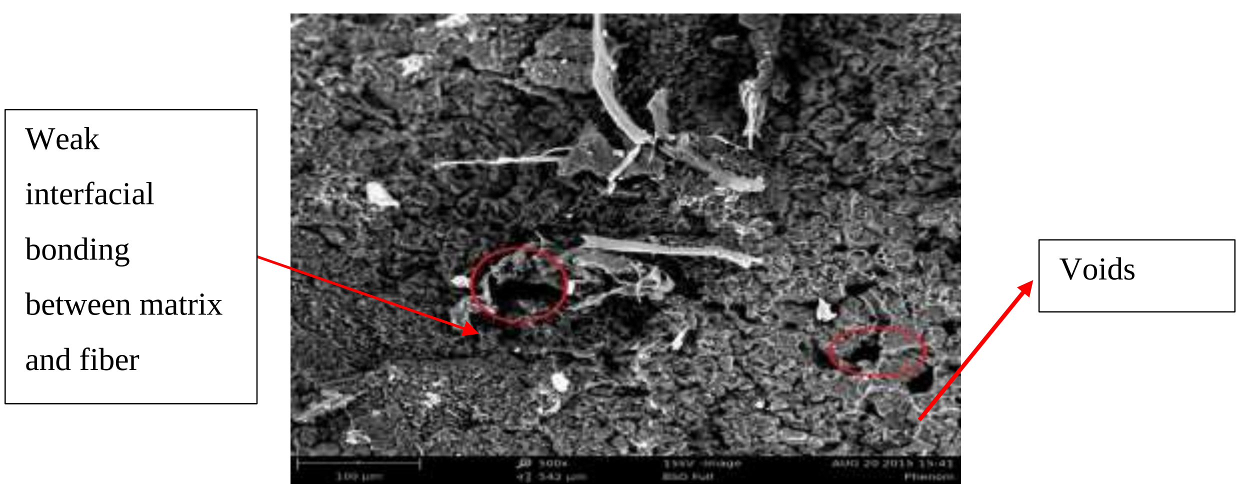


Figure 21: SEM micrograph of tensile fracture of 50/50 hybrid composite using PP/BSF/PLF

From figure 21 of SEM micrograph of tensile fracture of 50/50 hybrid composite using PP/BSF and PLF, it was observed that there are a lot of voids appeared in the composites. These voids appeared from the air bubbles that entrapped in the composites during the preparation of the composites. And, it is the strong reason to the sudden drop in its stress and strain curve provided by UTM machine. Poor interfacial bonding between fiber and matrix is clearly evident from figure 22 that resulting to the low of mechanical properties compared to the previous research.

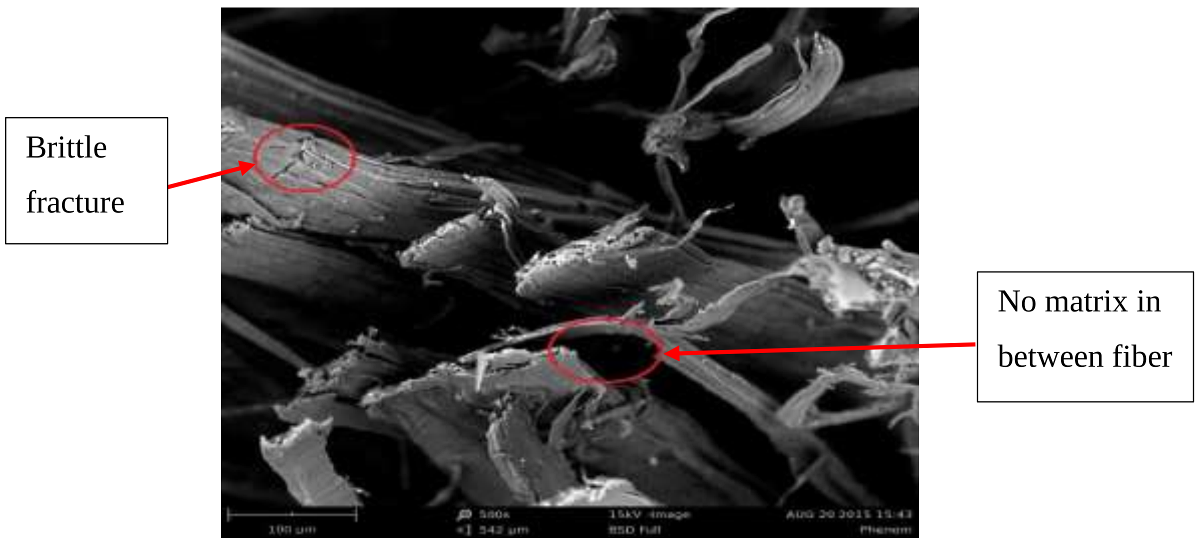


Figure 22: SEM micrograph of tensile fracture of 50/50 hybrid composites with weak bonding

Based on figure 22, the SEM analysis show the close micrograph of the tensile fracture, it is observed that there is no matrix appeared in between the fiber. The matrix does not penetrate in between the fibers to create homogenous form resulting to the weak adhesion between fibers and matrix. These is why the mechanical properties of the composites is low. Due to absence of fiber matrix interaction, the fibers tend to agglomerate into bundles and become unevenly distributed throughout the matrix.

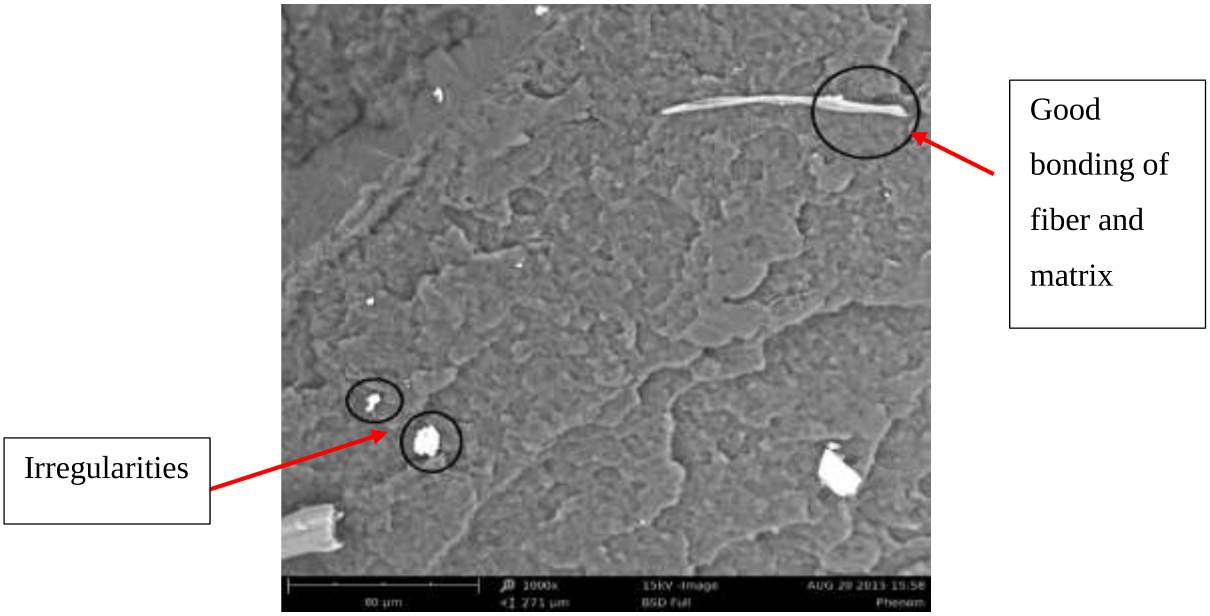


Figure 23: SEM micrograph of tensile fracture of 50/50 hybrid composite for PP/MAPP/BSF/PLF

Figure 23 show the tensile fracture microstructure of the composite that have mixed with the coupling agent. The smooth surface in the figure shows that PP and MAPP blend well, thus enhance the mechanical properties of the hybrid composites. Coupling agent is believed can improved the bonding between fiber and matrix as it treated the polar and non-polar region in the composites. Figure 23 also shows the irregularities or unwanted substance in the composites which produce low mechanical properties of the composites.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

This research was aimed to investigate the optimization of mechanical properties of the natural hybrid polymer composites using banana fiber, pineapple leaf fiber and polypropylene. MAPP was added in the composites as a coupling agent which will provide a better interfacial surface between matrix and fiber hence increase the mechanical properties of the composites. On comparing the tensile strength of the composites with MAPP had 50% more tensile strength compared to the composites without MAPP. Addition of pineapple fiber is to help in increasing the tensile and flexural strength of the fiber up to 50 wt% of fiber content. The hybridization of 50/50% BSF and PLF yield highest tensile strength and flexural strength which provided the value of 5.34 MPa and 43.6 MPa respectively. Marginal increases in tensile strength were due to void that entrapped in the composites where the composites will fail in a low stress. It was caused by the low interfacial bonding between matrix and fiber. Hybridization a natural fiber with another natural fiber did increase the mechanical properties of the composite but did not yield superior properties as hybridization by synthetic fiber. Thus, it is hoped that the development of natural fiber as reinforcement in the composites will be further improved to replace synthetic fiber.

As continuation of this study, the following aspects are recommended;

1. The fiber need to have a chemical treatment such as NaOH treatment to improve the bonding between fiber and matrix and also to remove unwanted content in fiber such lignin hence improving the mechanical properties of the composites.
2. The first layer and third layer of PP need to be melted ~~at~~ first, as it will reduce the entrapped bubble in the composites.
3. Study must be done on the short fiber to know whether mechanical properties of composites will be increased if short fiber is used instead of long fiber.
4. Water absorption and thermal properties need to be investigated to know better about the composites chemical properties.
5. Using the other type of fabrication method instead of compression moulding.

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APPENDICES

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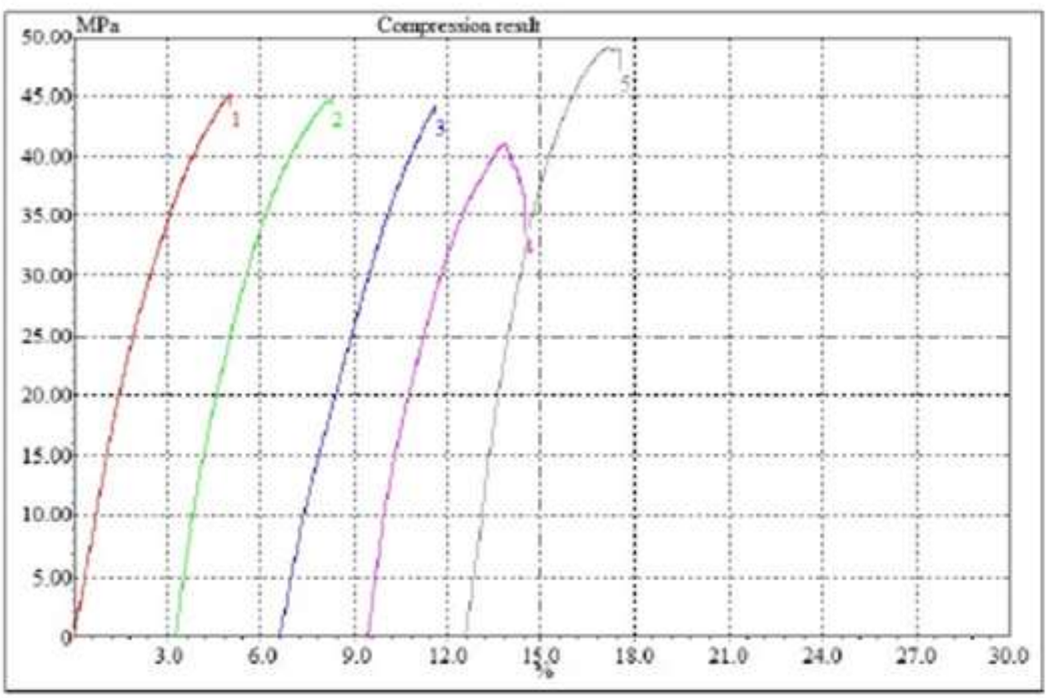
BANDAR SERI ISKANDAR
31750, TRONOH
PERAK

Material : POLYPROPHYLENE
Test Method : ASTM D790 -Procedure A

Test Speed : 1.707 mm/min

Flexural Test Report

Test No.	Span	Width	Max. Load N	Max. Load MPa	Strain %	Elastic modulus MPa
1	64.000	12.600	102	45.175	5.021	1250.477
2	64.000	12.680	115	44.777	5.021	1214.604
3	64.000	12.620	115	44.101	5.010	955.880
4	64.000	12.540	97	40.996	5.028	1211.474
5	64.000	12.510	116	48.985	5.015	1684.705
Maximum	64.000	12.680	116	48.985	5.028	1684.705
Minimum	64.000	12.510	97	40.996	5.010	955.880



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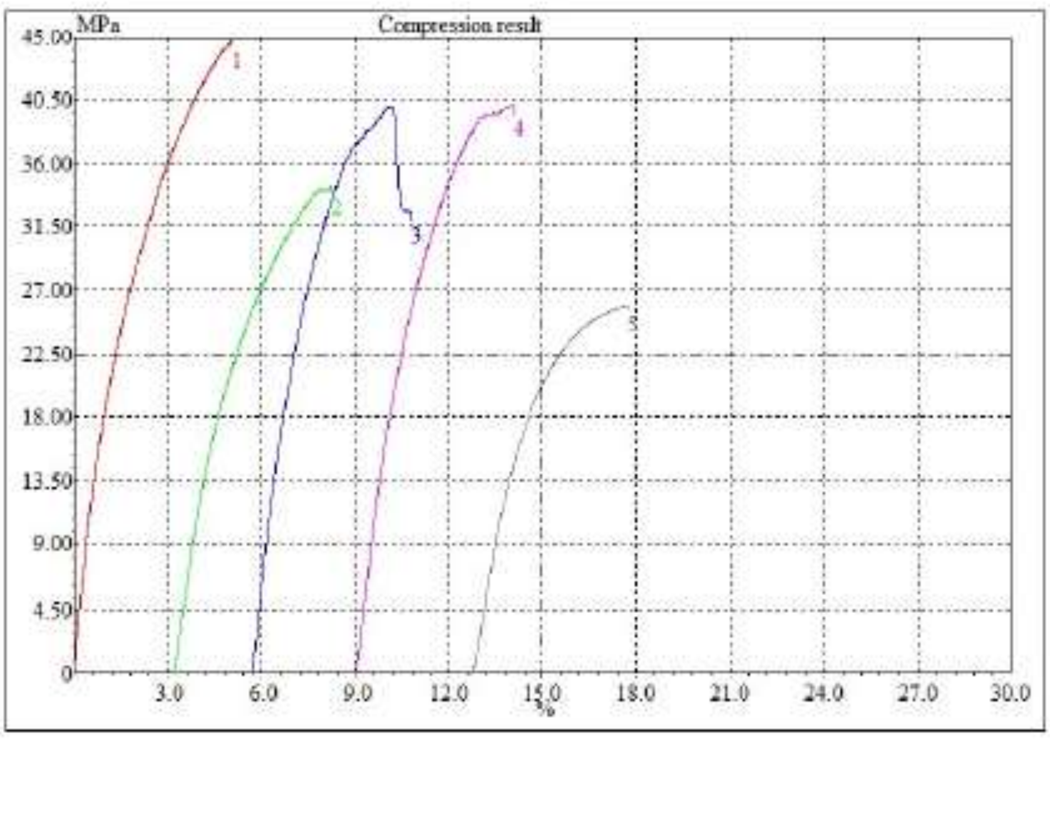
Material : POLYPROPHYLENE
Test Method : ASTM D790 -Procedure A

Test Speed : 1.707 mm/min

Flexural Test Report

Test No.	Span	Width	Max. Load N	Max. Load MPa	Strain %	Elastic modulus MPa
1	64.000	12.460	97	44.705	5.031	1305.935
2	64.000	12.530	85	34.312	5.024	1107.150
3	64.000	12.470	78	40.006	5.040	1463.318
4	64.000	12.580	87	40.131	5.040	1396.338
5	64.000	12.490	62	25.872	5.019	1056.241
Maximum	64.000	12.580	97	44.705	5.040	1463.318
Minimum	64.000	12.460	62	25.872	5.019	1056.241



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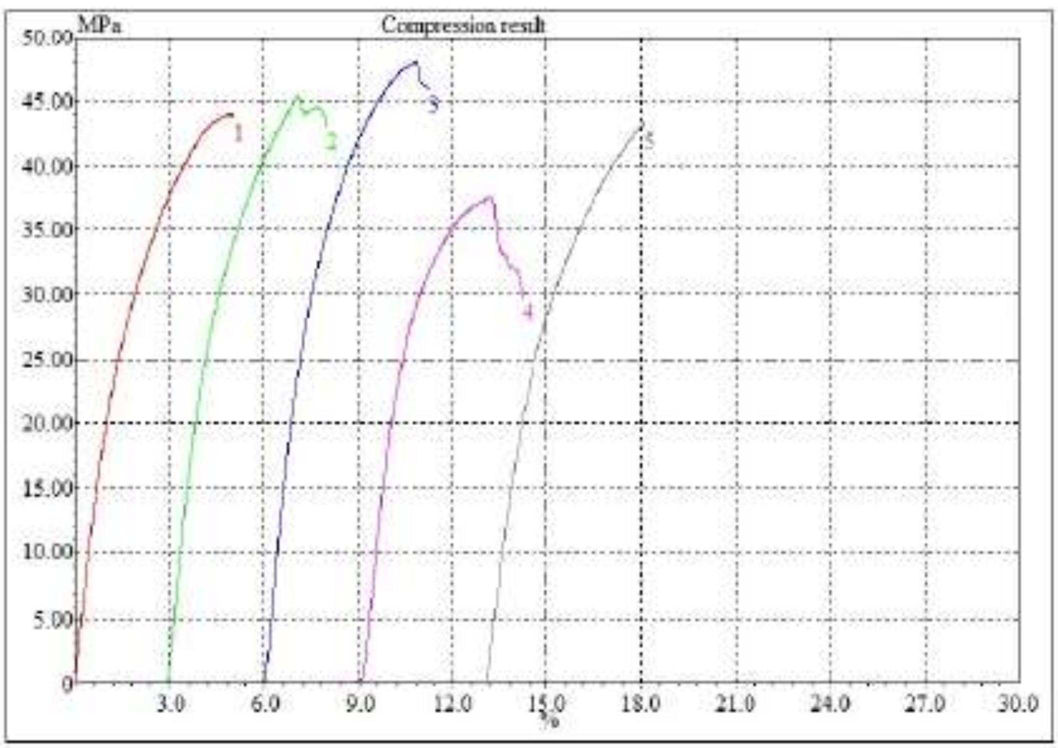
UNIVERSITI TEKNOLOGI PETRONAS

Material : POLYPROPHYLENE
Test Method : ASTM D790 -Procedure A

Test Speed : 1.707 mm/min

Flexural Test Report

Test No.	Span	Width	Max. Load N	Max. Load MPa	Strain %	Elastic modulus MPa
1	64.000	12.710	96	44.007	5.018	1637.138
2	64.000	12.560	90	45.354	5.022	1885.459
3	64.000	12.470	100	48.007	5.160	1956.767
4	64.000	12.560	79	37.491	5.144	2083.744
5	64.000	12.610	106	43.268	5.018	1480.017
Maximum	64.000	12.710	106	48.007	5.160	2083.744
Minimum	64.000	12.470	79	37.491	5.018	1480.017



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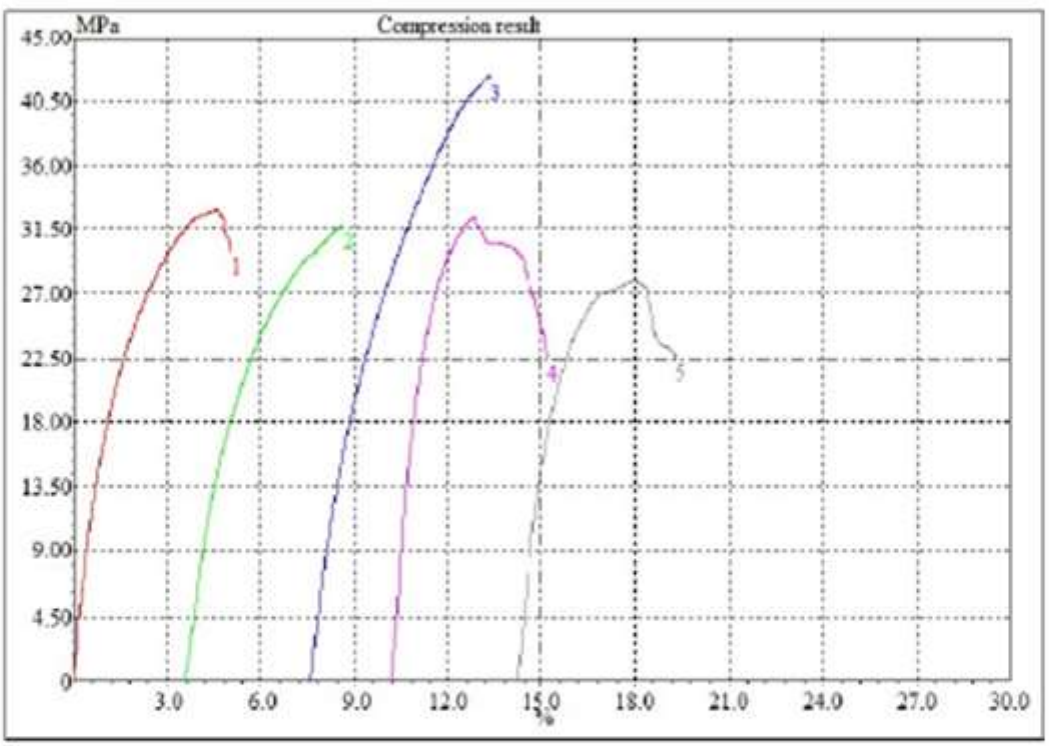
PERAK

Material : POLYPROPHYLENE
Test Method : ASTM D790 -Procedure A

Test Speed : 1.707 mm/min

Flexural Test Report

Test No.	Span	Width	Max. Load N	Max. Load MPa	Strain %	Elastic modulus MPa
1	64.000	12.610	72	32.921	5.013	1355.990
2	64.000	12.630	74	31.787	5.052	1086.685
3	64.000	12.540	111	42.270	5.757	1024.768
4	64.000	12.550	68	32.371	5.018	2463.851
5	64.000	12.500	64	27.848	5.088	1679.229
Maximum	64.000	12.630	111	42.270	5.757	2463.851
Minimum	64.000	12.500	64	27.848	5.013	1024.768



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BANDAR SERI ISKANDAR
31750, TRONOH
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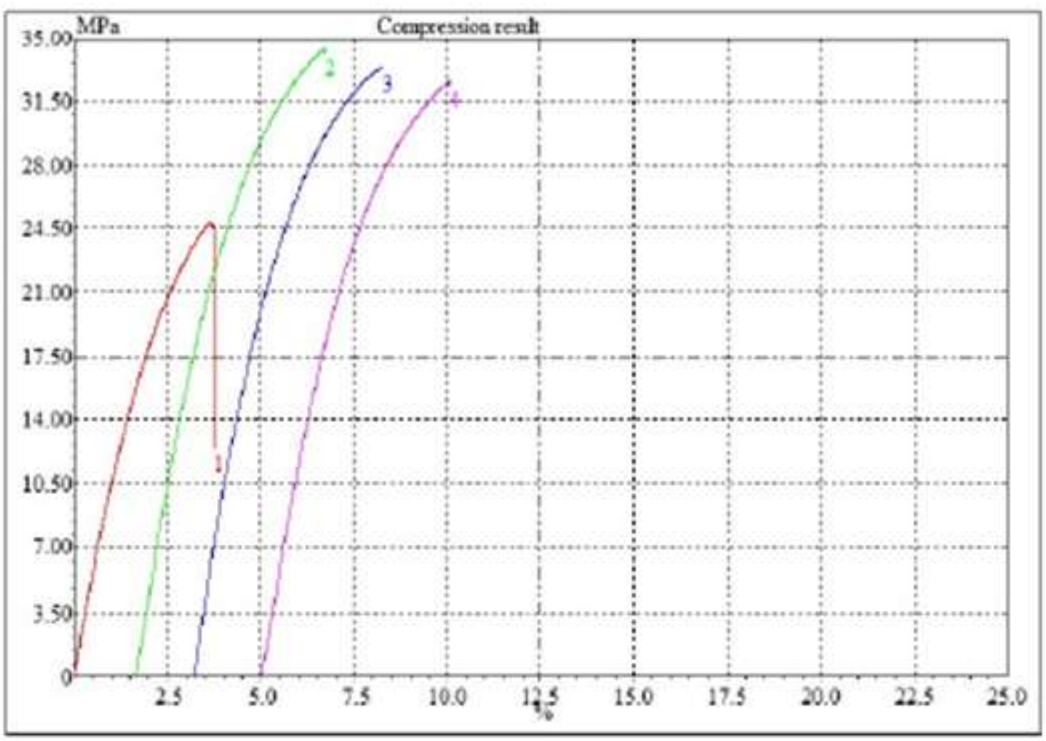
Material : POLYPROPHYLENE
Test Method : ASTM D790 -Procedure A

Test Speed : 2.986 mm/min

Flexural Test Report

Test No.	Span	Width	Max. Load N	Max. Load MPa	Strain %	Elastic modulus MPa
1	112.000	12.300	95	24.864	3.748	904.461
2	112.000	12.310	121	34.394	5.019	1031.362
3	112.000	12.220	109	33.386	5.016	1034.860
4	112.000	12.200	115	32.623	5.016	991.853
---	---	---	---	---	---	---
Maximum	112.000	12.310	121	34.394	5.019	1034.860
Minimum	112.000	12.200	95	24.864	3.748	904.461



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MECHANICAL ENGINEERING DEPARTMENT
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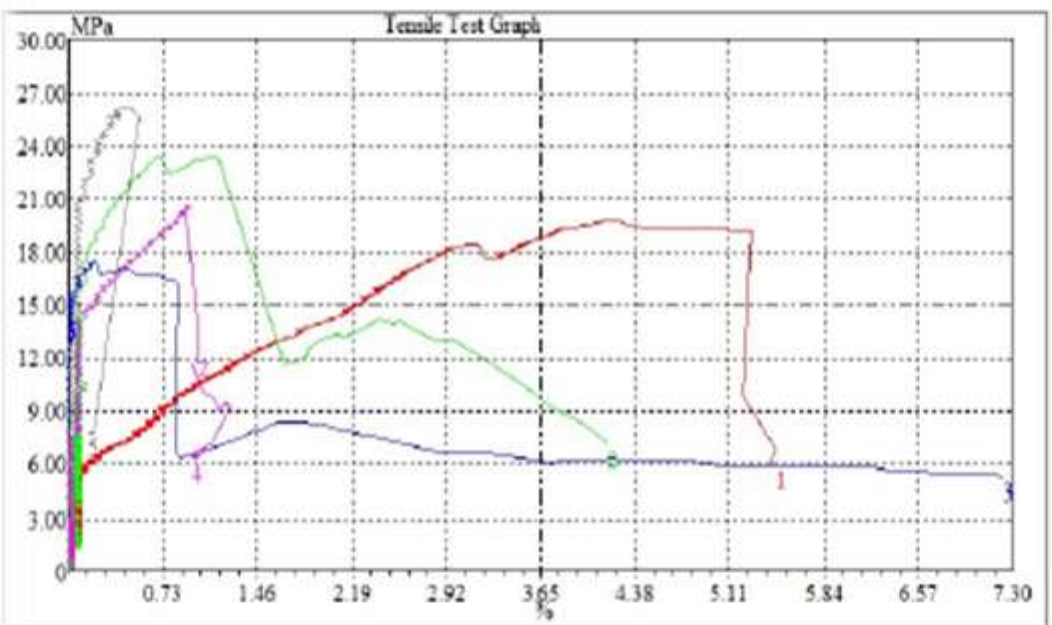
PERAK.

Tensile Test Report

Material :PP + MAPP + Fiber
Test Method :ASTM D638

Test Speed : 5.000 mm/min

Test No.	Thickness	Width	Max. Load	Elastic Modulus	Tensile Strength	Yield Strength	Elongation@Yield	Elongation@Break
			N	MPa	MPa	MPa	%	%
1	4.515	12.550	1118.963	504.734	5.919	13.260	3.115	5.467
2	4.348	12.450	1266.731	407401567.983	7.001	18.801	-	4.163
3	4.355	13.028	987.343	9714.107	5.217	17.402	-	7.223
4	4.294	12.940	1148.782	5545.658	6.200	16.908	-	0.953
5	4.140	12.990	1407.993	7931.816	7.764	26.154	0.400	0.150
Average	4.330	12.792	1185.966	281485052.860	6.420	18.505	1.758	3.591
SD(N-1)	0.135	0.270	159.014	045814331.201	0.986	4.740	1.920	2.993



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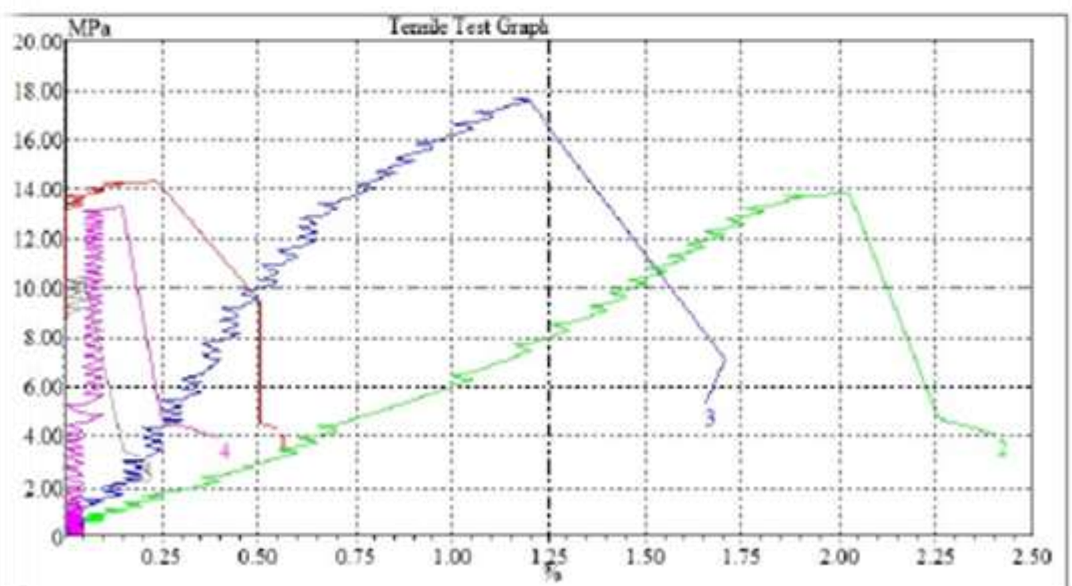
Tensile Test Report

Material :PP + MAPP + Fiber

Test Method :ASTM D638

Test Speed : 5.000 mm/min

Test No.	Thickness	Width	Max. Load	Elastic Modulus	Tensile Strength	Yield Strength	Elongation@Yield	Elongation@Break
			N	MPa	MPa	MPa	%	%
1	3.876	12.770	707.805	-	4.264	14.170	-	0.552
2	3.826	12.630	665.639	648.389	4.031	9.401	-	2.408
3	3.739	12.570	830.474	2074.013	5.241	16.189	-	1.655
4	3.863	12.850	658.404	4505.777	3.890	8.154	0.085	0.401
5	3.764	12.620	495.321	-	3.086	7.453	-	0.201
Average	3.814	12.688	671.529	2409.393	4.102	11.073	0.085	1.043
SD(N-1)	0.060	0.117	120.245	1950.441	0.776	3.879	0.000	0.949



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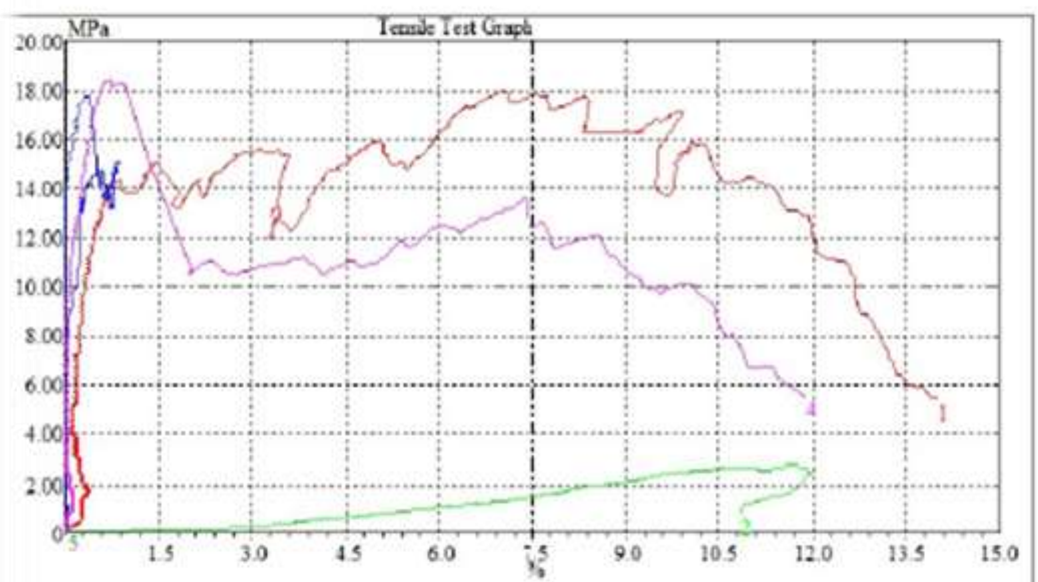
31750, TRONOH
PERAK.

Tensile Test Report

Material :PP + Fiber
Test Method :ASTM D638

Test Speed : 5.000 mm/min

Test No.	Thickness	Width	Max. Load	Elastic Modulus	Tensile Strength	Yield Strength	Elongation@Yield	Elongation@Break
			N	MPa	MPa	MPa	%	%
1	5.861	13.020	1367.107	5418.967	5.373	12.424	0.896	13.995
2	5.657	13.130	203.266	26.059	0.819	2.567	8.488	10.835
3	5.277	12.950	1214.425	8098.013	5.331	-	-	-0.049
4	4.911	13.140	1190.329	12258.092	5.524	13.734	0.645	11.888
5	4.663	13.030	9.443	-	0.140	0.139	0.049	0.050
Average	5.274	13.054	796.914	6450.283	3.437	7.216	2.519	7.344
SD(N-1)	0.499	0.080	637.718	5124.449	2.712	6.863	3.995	6.799



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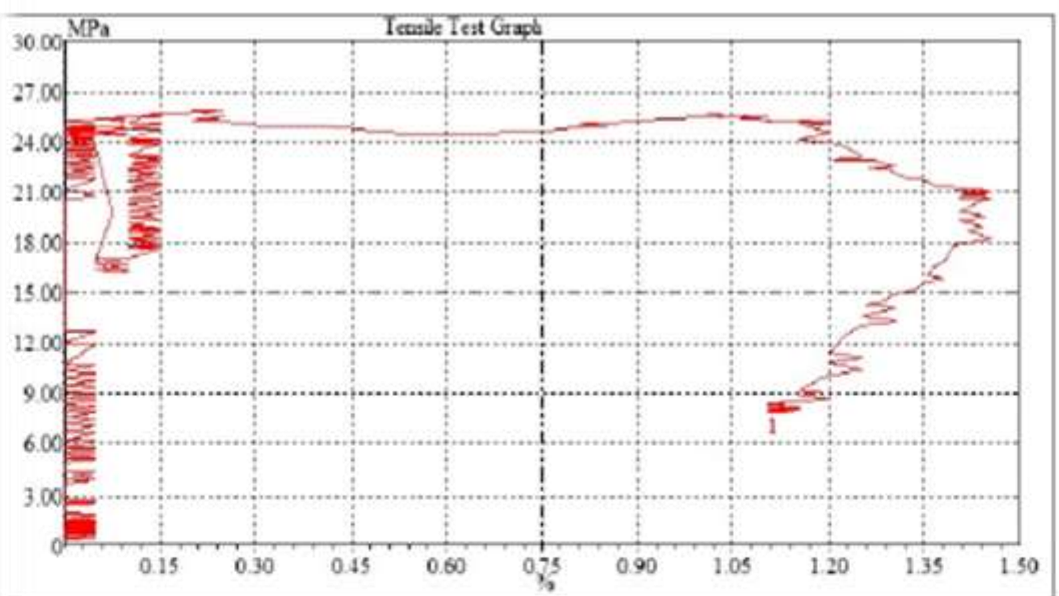
Tensile Test Report

Material :PP + Fiber

Test Speed : 5.000 mm/min

Test Method :ASTM D638

Test No.	Thickness	Width	Max. Load	Elastic Modulus	Tensile Strength	Yield Strength	Elongation@Yield	Elongation@Break
			N	MPa	MPa	MPa	%	%
1	4.663	13.030	1575.143	-	7.777	22.416	0.040	1.104
---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---
Average	4.663	13.030	1575.143	0.000	7.777	22.416	0.040	1.104
SD(N-1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000



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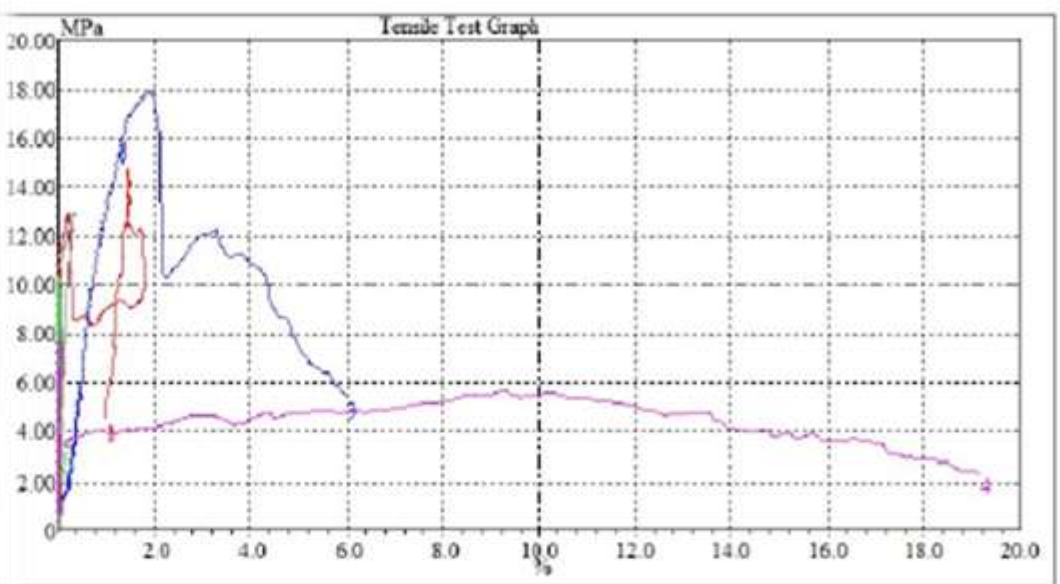
Tensile Test Report

Material :PP + Fiber

Test Method :ASTM D638

Test Speed : 5.000 mm/min

Test No.	Thickness	Width	Max. Load	Elastic Modulus	Tensile Strength	Yield Strength	Elongation@Yield	Elongation@Break
			N	MPa	MPa	MPa	%	%
1	4.853	12.990	930.830	41211.720	4.426	12.731	0.002	1.003
2	5.123	12.960	715.362	-	3.232	-	-	-
3	5.323	12.900	1230.405	2653.372	5.357	12.133	1.117	6.019
4	5.603	12.878	571.923	-	2.378	3.616	-	19.161
5	5.754	12.980	963.575	-	3.868	-	0.363	0.100
Average	5.331	12.942	882.419	21932.546	3.852	9.493	0.494	6.571
SD(N-1)	0.362	0.050	252.161	27264.869	1.135	5.099	0.569	8.788



DuPont Packaging & Industrial Polymers

The miracles of science

DuPont™ Fusabond® P613

Fusabond® resins Product Data Sheet

Description

Product Description	DuPont™ Fusabond® P613 is an anhydride modified polypropylene.

Restrictions

Material Status	• Commercial: Active
Availability	• Globally

Typical Characteristics

Uses	• Polymer Modifier
Applications	Coupling agent, short glass fiber filled PP

Typical Properties

Physical	Nominal Values	Test Method(s)	
* Density ()	0.903 g/cm³	ASTM D792	ISO 1183
* Melt Flow Rate (190°C / 1.0 kg measured)	49 g/10 min	ASTM D1238	ISO 1133
Melt Flow Rate (190°C / 2.16 kg calculated)	120 g/10 min		
Thermal	**Nominal Values**	**Test Method(s)**	
* Melting Point (DSC)	162°C (324°F)	ASTM D3418	ISO 3146

Processing Information

General

* Maximum Processing Temperature	300°C (572°F)

FDA Status Information

Fusabond® P613 resin complies with Food and Drug Administration Regulation 21 CFR 175.105 - - Adhesives. This Regulation describes adhesives that may be used as components of articles intended for use in packaging, transporting, or holding food, subject to the limitations and requirements therein.

The information and certifications provided herein are based on data we believe to be reliable, to the best of our knowledge. The information and certifications apply only to the specific material designated herein as sold by DuPont and do not apply to use in any process or in combination with any other material. They are provided at the request of and without charge to our customers. Accordingly, DuPont cannot guarantee or warrant such certifications or information and assumes no liability for their use.

Regulatory Information	For information on regulatory compliance outside of the U.S., consult your local DuPont representative.
Safety & Handling	For information on appropriate Handling & Storage of this polymeric resin, please refer to the Material Safety Data Sheet.
	A Product Safety Bulletin, Material Safety Data Sheet, and/or more detailed information on extrusion processing and/or compounding of this polymeric resin for specific applications are available from your DuPont Packaging and Industrial Polymers representative.

Read and Understand the Material Safety Data Sheet (MSDS) before using this product

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