Orientation Effect On Mechanical Properties of Kenaf Reinforced Polypropylene Composite

By

AHMAD FAIZAL BIN OTHMAN

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Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan.

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

Dr. Mohamad Zaki Bin Abdullah

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2014

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 references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AHMAD FAIZAL BIN OTHMAN

ABSTRACT

Polymer composite is widely used in many applications such as automotive, aerospace, piping system and medical tools. The advantages of polymer composite include light weight, high performance to weight ratio and minimum environmental impact. Studies on the influence of long fiber orientation on mechanical properties were rarely done. If long fibers are placed in both longitudinal and transverse directions, the mechanical properties are expected to be improved in both directions. To verify this hypothesis, this project was proposed. The objective of this project was to study the effect of kenaf fiber orientation on the tensile strength and flexural properties of the PP/kenaf composites. In this project, polypropylene was used as matrix and kenaf was used as reinforcement. The orientation of the kenaf fiber was varied. The composite was produced from two sheets of polypropylene and kenaf fiber was placed in the middle of the sheets. This processing technique was referred to compression moulding with laminate approach. The fiber in the middle was aligned into 5 orientations and each orientation underwent tensile and flexural tests. The highest tensile strength and flexural properties were obtained in unidirectional fiber orientation. Improvement of 145%, 24% and 65% were achieved in tensile strength, flexural strength and flexural modulus, respectively.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

Composite material is a material that consists of two or more combined constituent materials which have different mechanical properties. When they are combined, the composite materials will produce and form a material with different mechanical properties compared to the individual components. Polymer composite is widely used in various application including semiconductor, biomedical, automotive, and aerospace. Polymer composite technology is popular because of its unique properties such as resistant to corrosion, low heat conduction, low moisture absorption, and sufficient stiffness and strength. Kenaf fiber reinforced polymer composite is a natural fiber polymer composite (NPC) which has many advantages including low cost, abundant resources, and high specific strength.

Kenaf has become a potential natural fiber source for both industrial and manufacturer application such as automotive and construction industries due to its advantages. These advantages are of interest to the industries that require materials of light weight, high performance to weight ratio, renewability, and minimum environmental impact. One of the parameters that influence the mechanical properties of kenaf fiber composite is fiber orientation within the matrix.

1.2 Problem Statement

A lot of studies on the effect of short fiber orientation on mechanical properties were performed studies on the influence of long fiber orientation on mechanical properties were rarely done. This is due to the fact that it is proven that the mechanical properties along the longitudinal direction of fiber always higher than the transverse direction. However, if the long fibers are placed in both longitudinal and tranverse directions, the mechanical properties are expected to be improved in both directions. To verify this hypothesis, this project is proposed.

1.3 Objective

The objective of this project is to study the effect of kenaf fiber orientation on the tensile strength and flexural strength of the PP/kenaf composites.

1.4 Scope of Study

In this project, polypropylene was used as matrix and kenaf was used as reinforcement. The orientation of the kenaf was varied to prove the improvent of tensile and flexural strength. The kenaf fiber used was supplied Innovative Pultrusion Sdn. Bhd. Polypropylene was chosen as a matrix due to its corrosion resistance and heat distortion properties. Compression molding with laminate approach was used to fabricate the kenaf fiber reinforced PP composites. The specimens produced were tested and analyzed for their tensile strength and flexural properties according to their repective ASTM standards.

CHAPTER 2
LITERATURE REVIEW

2.1 Background Study

Research on natural fiber composites has started since the early 1900's but has not received much attention until late in the 1980's. Composites, primarily glass fiber but including natural reinforced composites, are found in countless consumer products including boats, skis, agricultural machinery and cars. A major goal of natural fiber composites is to alleviate the need to use expensive glass fiber ($3.25/kg) which has a relatively high density (2.5 g/cm^3) and is dependent on non-renewable sources [1]. Recently, car manufactures have been interested in incorporating natural fiber composites into both interior and exterior parts. This serves a two-fold goal of the companies; to lower the overall weight of the vehicle thus increasing fuel efficiency and to increase the sustainability of their manufacturing process. Many companies such as Mercedes Benz, Toyota and DaimlerChrysler have already accomplished this and are looking to expand the uses of natural fiber composites.

2.2 Matrix-Fiber Composites

Composites performance are influence by matrix properties. Matrix is select based on material properties such as yield strength, ultimate strength, compression, shear, failure strain of ductility and fracture toughness. Fiber is mix in the matrix in order to make the composite stronger and stiffness which material properties of matrix does not have. Polymer composite have many combination of matrix and fiber. Most common fiber are glass fiber, aramid fiber and carbon fiber.

2.3 Fiber

There are two type of fiber which synthetic and natural. Synthetic fiber are chemical based fiber such as nylon while natural fiber is based from organic material such as jute, kenaf. Fiber stronger and stiffness can be increase by changing the fiber orientation in matrix. Table 2.1 shows the properties of some selected fibers.

Table 2.1: Proprties of some fibers.

Fiber	Density (g/cm³)	Tensile Strength (MPa)	Elastic Modulus (GPa)
Cotton	1.5-1.6	400	5.5-12.6
Kenaf	1.45	930	53
Sisal	1.5	511-635	9.4-22
E-glass	2.5	2000-3500	70
Carbon	1.4	4000	230-240

Advantages of using natural fibers in composites are low cost of materials, their sustainability and light weight. Natural fibers costs as little as $0.50/kg, and can be grown in just a few months. They are also easy to grow and have the potential to be a cash crop for local farmers. Natural fibers are also significantly lighter than glass, with a density of 1.15-1.50 g/cm³ versus 2.4 g/cm³ for E-glass.

2.4 Characteristics and Properties of Kenaf Fiber

Kenaf scientific name are Hibiscus cannabinus. The stems produce two type of fiber which a coarser fiber (outer layer) and finer fiber in the core. In the experiment, kenaf is use in the composite as fiber in the matrix-fiber composite. Kenaf has a bast fiber which contains 75% cellulose and 15% lignin and offers the advantages of being biodegradable and environmentally safe. Malaysian kenaf is composed of two distinct fibers, bast and core, with a makeup of about 35% and 65%, respectively. Each fiber has its own usage; thus, separation of the fibers produces higher monetary returns over whole-stalk kenaf. Major factors involved in separation of kenaf into its two fractions include: size and amount of each portion; type and number of separation machinery; processing rate through separation machinery; moisture content of whole-stalk kenaf; humidity of ambient air. Table 2.2 shows properties of kenaf fiber [2]

Table 2.2: Properties of kenaf fiber.

Tensile Strength	930 MPa
Tensile Modulus	0.53 GPa
Elongation at Break	1.6%
Density	1450 kg/m3
Fiber Diameter, D	14-33 m
Water Absorption Percentage	17 %

2.5 Matrix – Thermoplastics

Polymer are consists of combination of many hydrocarbon unit. Polymer can be divided into two types which are thermosets and thermoplastics. Thermosets have well-bonded 3D-molecular structure after curing. It does not melt but decompose on hardening. It can retain partly cured condition over a prolonged period of time. Thus their use is very flexible. Thermoplastics have one, two or three dimensional molecular structure and soften at an elevated temperature and melt. The process of softening or melting can be reversed to regain its properties during cooling which facilitate the compression molding technique to mold the compound. They have a greater functional advantage for new avenues including replacement of metals in die casting process.

Polypropylene is a type of thermoplastics resin. It is used in product material on commercial and industrial application. The chemical designation is C_3H_6 which is hydrocarbon based. Thermoplastic composites are composites that use a thermoplastic polymer as a matrix. A thermoplastic polymer is a long chain polymer that can be either amorphous in structure or semi-crystalline. These polymers are long chain, medium to high molecular weight materials.

Advantages of thermoplastic matrices:

- Unlimited shelf life
- Short processing time
- Resistance to chemical attack
- Recyclability
- Superior impact

Disadvantages of thermoplastic matrices:

- Easy to melt
- High viscosity

2.6 Polypropylene (PP)

PP intrinsic properties of high stiffness, good tensile strength and inertness toward acids, alkalis and solvents has secured its position in a wide range of consumer and industrial products. Polypropylene are also flexible and can have very high elongation before breaking. Figure 2.1 shows the molecular structure of polypropylene.

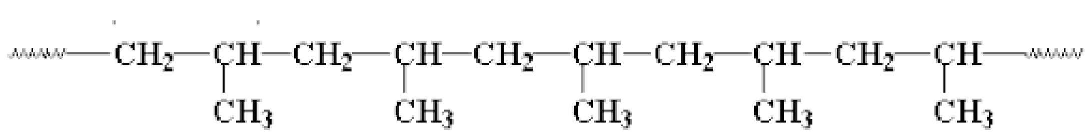


Figure 2.1: Polypropylene molecular structure.

The other advantages are:

- Homopolymer
- Good process ability
- Good stiffness

- Good impact resistance
- Copolymer
- High flow index
- Chemically coupled

Although polypropylene gives a lot of advantages, there are several difficulties for this thermoplastic such as:

- Degraded by UV
- Flammable, but retarded grades available
- Low temperature

The advantages of using PP as matrix are their low cost and relatively low processing temperature which is essential because of low thermal stability of natural fibers. Amongst eco-compatible polymer composites, special attention has been given to PP composites, due to their added advantage of recyclability.

2.7 Kenaf Fiber Reinforced Polypropylene

The research done in this study has proven the ability to successfully fabricate kenaf–polypropylene natural fiber composites. The optimal fabrication method for the compression molding process has proven to be the layered sifting of a microfine polypropylene powder and chopped kenaf fibers. Also shown through this work was that kenaf–PP composites have a higher modulus/cost and a higher specific modulus than sisal, coir, hemp, flax and E-glass [3].

The purpose of the project is study the material properties of (unwoven) bi-directional kenaf-fiber polypropylene composite. The result testing will be compare with material properties of (woven) unidirectional kenaf-fiber polypropylene composite to show the effect of woven. Whether unwoven is superior or not interm of material properties. Material testing will be conduct to prove and compare result. Tensile test, impact test and flexural test will be conduct to the composite material.

Reinforced fiber constituents in composite provide strength and certain additional purpose heat resistance, conductance resistance, corrosion resistance and also improve rigidity.

Reinforcement that gives matrix strength must be stronger and stiffer than matrix and capable of changing failure mechanism to advantage of the composite [4]. Fiber Reinforced (FR) material properties can be change by modifying the fiber orientation. There are many form possible combination. For the Fyp project, bi-directional orientation for kenaf/polypropylene are being tested to observe the mechanical properties resulting from the orientation.

From the studied of the effect of fiber orientation of flexural properties of PALF Reinforced Bisphenol composites there are there type of orientation have been tested which is unidirectional, bi-directional and inclined. The result shows that inclined orientation is the higher interm of maximum bending stress which is 105.5 MPa followed by bi-directional 102.8 MPa and lastly uni-directional 83.6 MPa. The inclined orientation have higher maximum bending stress because the higher tension load can be absorb in incline orientation [5]. Figure 2.2 show the chart of maximum bending stress v/s fiber orientation.

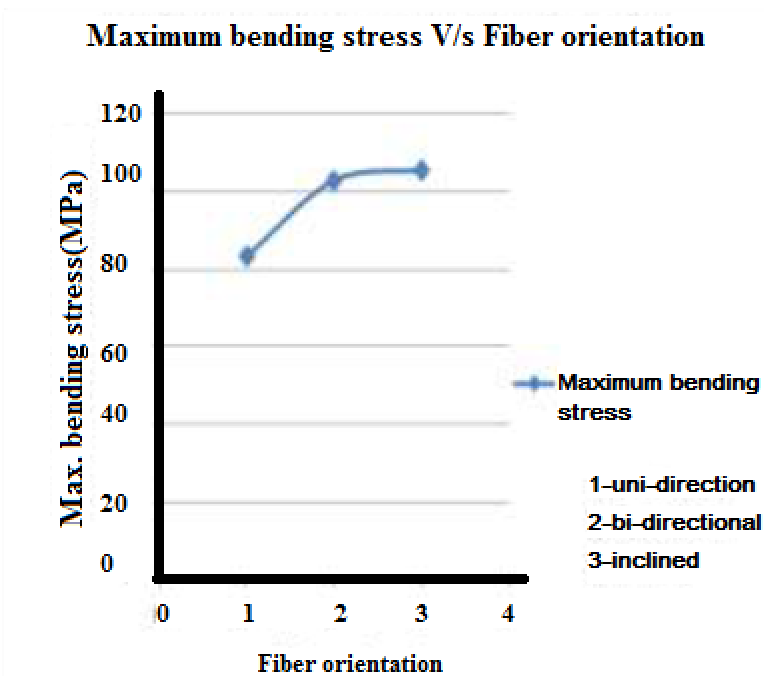


Figure 2.2: Variation of maximum bending stress with fiber [5].

Similar fiber orientation shown in Figure 2.3 [5] was studied before with kenaf/polypropylene. Figure 2.4 shows the orientation of fiber proposed for the project. Lee [6] studied the effect of kenaf fiber orientation on mechanical properties. The fiber orientation of their studies are shown in Figure 2.5.

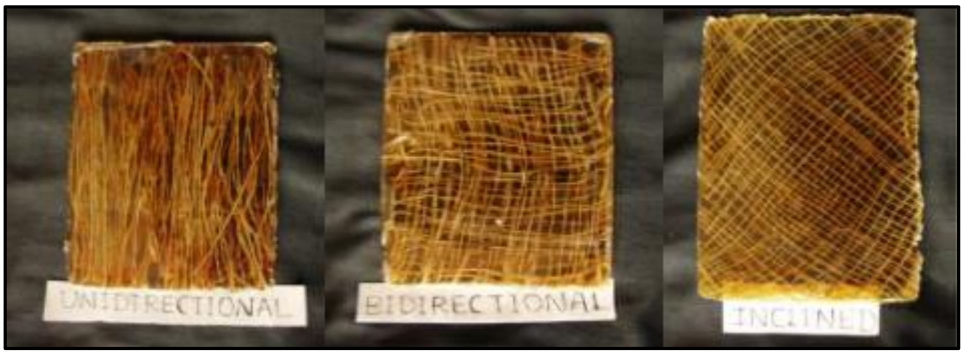


Figure 2.3: Uni-directional, bi-directional and incline orientation of pineaple leaf fiber [5].

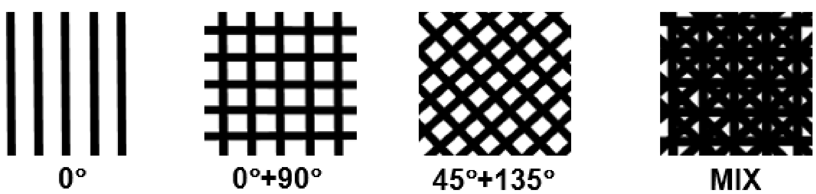


Figure 2.4: Kenaf orientation.

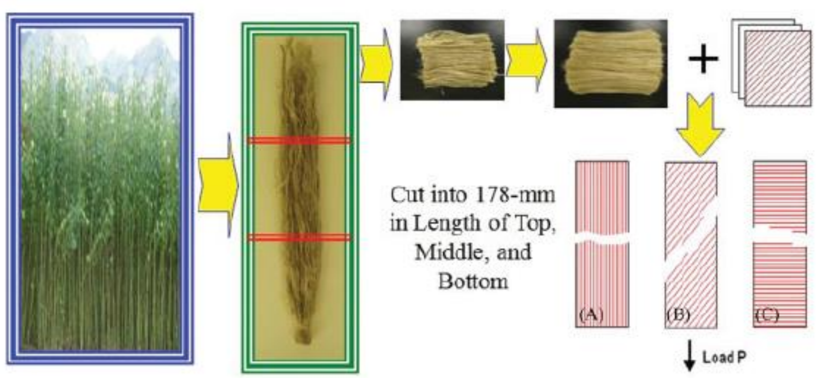


Figure 2.5: Kenaf-fiber unidirectional orientation [6].

As studies in papers of properties of unidirectional kenaf/polypropylene the ratio there are 3 ratios that have been tested which are k/PP = 30/70, k/PP = 40/60, k/PP = 50/50 with different angle of uni-directional orientation 0°, 45° and 90°. The result shows that the higher tensile strength during 0° angle is k/PP = 50/50 ratio which is 130 MPa and the lowest is k/PP = 30/70 ratio which is 110 MPa. In angle 45° and 90° there is no slightly different in tensile strength which is 10 MPa and 2 MPa [6]. With the increase of fiber ratio in the composite the tensile strength also increase. In the lab test kenaf ratio will be used is 70%.

Ochi [7] studied the effect of fiber content on mechanical properties of PLA/kenaf composites. His theoretical and experimental values of tensile strength are shown in Table 2.3. Ochi [7] found that the highest tensile strength was achieved at 70 vol% of kenaf fiber for both theoretical and experimental data. However, the theoretical data were over predicted by more than 50%.

In another research, Nishino [8] studied the effect of fiber content on tensile properties. Tensile property results of their studiesare presented in Figure 2.6. They found the tensile properties were at the highest when the fiber content was 70 vol%.

Table 2.3: Comparison of theoretical and experimental value of tensile strength and volume fraction of kenaf fiber in PLA composites [7].

Volume fraction of kenaf fibers (%)	Theoretical Strength (MPa)	Experimental Strength (MPa)	Experiment / Theory (%)
30	178.2	130.5	73.1
50	297.0	210.9	71.0
70	415.8	223.3	53.7

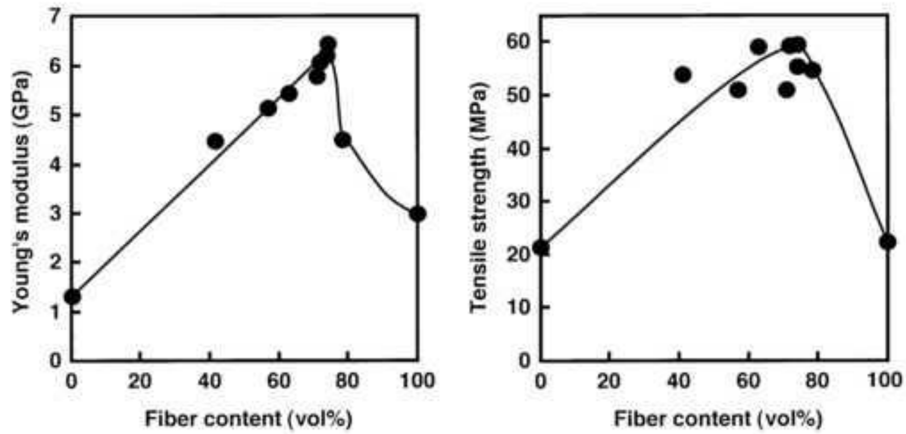


Figure 2.6: Relationship between Young's Modulus, the tensile strength, and the kenaf fiber content of PLLA/kenaf composite [8].

CHAPTER 3
METHODOLOGY

3.1 Research Methodology

In order to prepare kenaf-fiber polypropylene composite, the following steps were developed. Steps to prepare composite are shown in Figure 3.1. The composite was produced from two sheets of polypropylene and kenaf fiber was placed in the middle of the sheets.

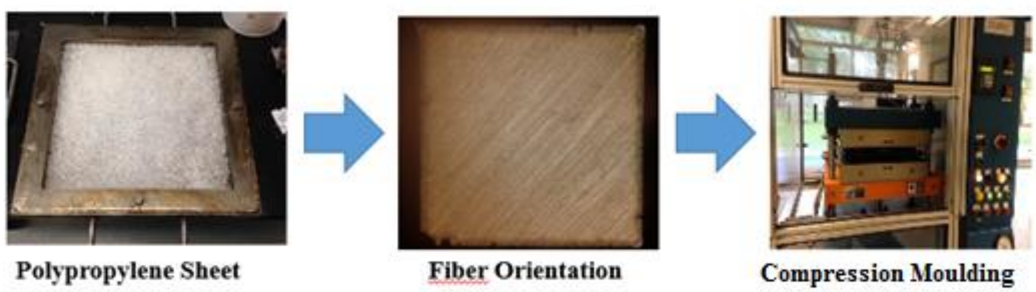


Figure 3.1: Sample preparation.

3.2 Polypropylene Sheet Preparation

Polyproylene (PP) sheet thickness that had been used in the project were 2 mm and 4 mm. To produce the PP sheet, the mould is wiped with mould release wax to ensure the sheet are easy to detach from the mould. Then PP pellets were spread evenly in the mould. The mould was inserted in the compress machine with the top mould was open to release air during preheat. During preheating, the temperature was set to 190°C and PP was preheated for 10 minutes. Then the top mould was close and compress with 12 bar pressure. The machine is running for another 15 minutes. After 15 minutes had pass the mould underwent cooling process using pneumatic air until the temperature drop to 100°C. Then the finished PP sheet is taken out. The process was repeated to produce 10 PP sheets. The compression moulding machine and mould cavity are as shown in Figure 3.2.

Figure 3.2: Compression moulding machine.

3.3 Kenaf Orientation Alignment

After producing the PP sheet, kenaf was aligned on the PP sheet. PP sheet edge are cut to bind the kenaf on the PP sheet. The edge is cut using bench saw as shown in Figure 3.3.

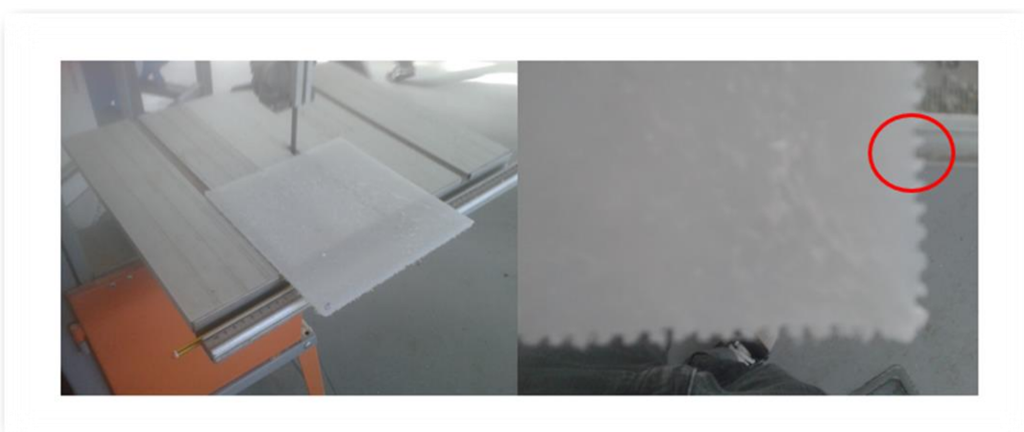


Figure 3.3: PP sheet edge cutting sample.

After all the edge were sawed. Kenaf was binded on the PP sheet and weighted on the scale to achiece 30% composition of kenaf fiber in the composite. The sheets were binded into 4 different orientations as shown in Figure 3.4.

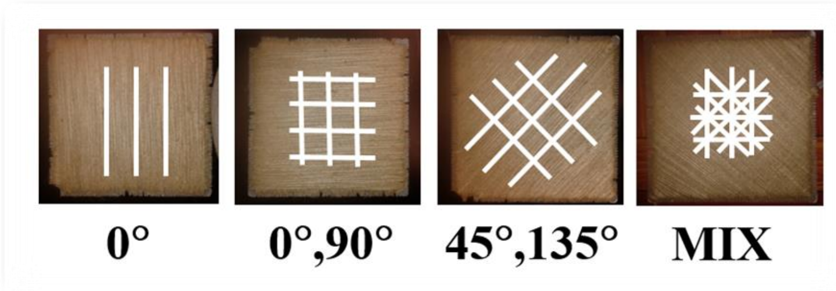


Figure 3.4: Kenaf fiber orientation.

3.4 Composite Fabrication

To produce kenaf reinforced polypropylene composite laminating process was performed using two sheets of PP and kenaf fiber in the middle as shown in Figure 3.5.

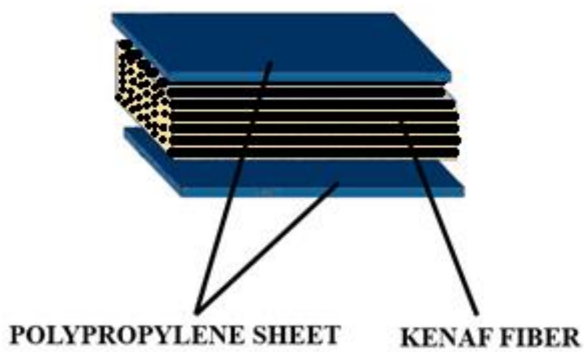


Figure 3.5: Composite laminate.

Kenaf reinforced polypropylene composite was produced by compressing the composite laminate in compress machine. The mold cavity was applied with mould release wax, then the composite was inserted in the mould. The compression moulding was set to 185°C and 2 bar pressure for 10 minutes, The pressure was added during preheat to heat top PP sheet. After 10 minutes the pressure of the machine was adjusted to 12 bar for 20 minutes.

After 20 minutes the composite was cooled until the pressure drop to 100°C then the cooling was switched to water cooling until about 60°C.

3.5 Sample Cutting

Figure 3.6 shows the tools use for sample preparation. After fabrication of the composite is done the sample will be cut into tensile and flexural sample standard for testing. The sample is being cut using bandsaw. After being cut the sample is measured and alter using filing to follow the standard. The sample for tensile andflexural specimen is mbeing measured using micrometer.

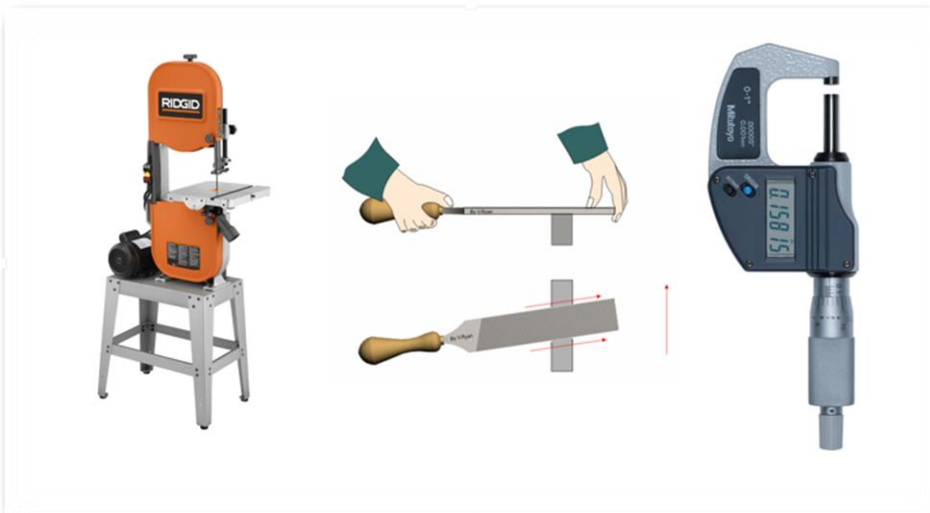


Figure 3.6: Bench saw, filing and micrometer measuring.

3.6 Tensile and Flexural Test

Table 3.1 shows the standard requirement for sample preparation. For tensile lab test. The sample is hard to cut into dog bone shape, ASTM D3039 standard is used. The sample is being cut into measurement which is recommend in the standard Table 3 to meet the requirement for the testing standard. All 25 samples were measured. Compress molding machine (CARVER INCModel: CMG3OH-15 - CPX) - this machine is a hot press machine to create test specimen. Pressure and temperature are fixed follow lab procedure. Figure 3.7 show the picture of the testing machine which are Intron Universal Tesing

Machine. Tensile test machine - Proceed to lab testing based on testing standard (ASTM D3039) to acquire lab data for tensile test.

Figure 3.8 shows the proper way to performed 3-point bending test. 3-points bending test was conducted on five specimens at roomtemperature using Universal Testing Machine. The specimens are tested according to ASTM standards D790 [23]. The recommended dimension for the thermoplastic molded material of the specimen was 127 x 12.7 x 3.2 mm.

Table 3.1: Requirement of standard for sample preparation.

Parameter	Requirement
Coupon Requirements:	
shape	constant rectangular cross-section
minimum length	gripping + 2 times width + gage length
specimen width	as needed[A]
specimen width tolerance	±1 % of width
specimen thickness	as needed
specimen thickness tolerance	±4 % of thickness
specimen flatness	flat with light finger pressure
Tab Requirements (if used):	
tab material	as needed
fiber orientation (composite tabs)	as needed
tab thickness	as needed
tab thickness variation between tabs	±1 % tab thickness
tab bevel angle	5 to 90°, inclusive
tab step at bevel to specimen	feathered without damaging specimen

[A] See 8.2.2 or Table 2 for recommendations.

Figure 3.7: Instron Universal Testing Machine.

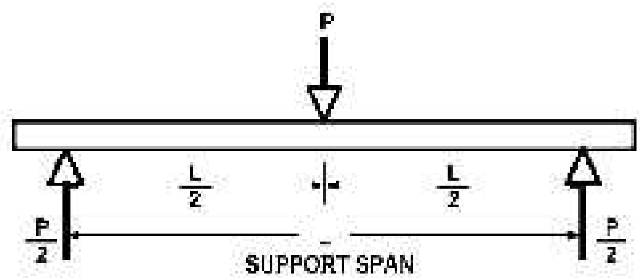


Figure 3.8: 3-point bending test.

3.7 Summary of Research Methodology

The activity start with gathering data of polymer composite material which is kenaf/polypropylene composite. Then calculation for polymer composite mixture using rule of mixture being calculate. This theory result is use to compare the material strength test such as tensile, flexural and impact test. The test specimen will be prepare using weighing machine by calculating the fraction of the material volume to get the mas needed to be insert in the mold. When the mold being hot press by the compression machine, test material is prepare this material will be tested and compare the result.

3.8 Key Milestones

Table 3.2 shows the project planning with key milestones for final year project 1. Project selection phase are done in the week 1 and week 2. On week 2 until week 5 preliminary research are done to for the project. This week is used to gather information for the project to submit extended proposal on week 6 is the due for the proposal. During week 7 to week 9 preparation of proposal defence preparation are done. On week 10 to week 12 the data gathering such as project process, material use and information for theproject are done. On week 13 project interim report first draft are submitted and on the following week 14 the final have been submitted to the supervisor.

Table 3.3 shows the project planning with key milestone for final year project 2. On week 1 to week 7 the project is started with gathering material and fabricating polypropylene sheet. On week 7, project progress report is submitted to show the project progress and confer with supervisor about problem encounter. On week 8 to week 12 project are continued, fabricating polypropylene sheet are to be laminate with kenaf fiber and mould into the compression moulding machine and cut into testing specimen. On week 10 pre-SEDEX presentation are done.On week 11 draf for final report are submitted. On week 12 technical paper and dissertation paper are submitted. On week 13 viva for the project are presented. Lastly on week 14, hardbound for dissertation are to be submitted to the supervisor.

3.9 Gantt Chart

Currently the actual time is in week 6 which is the submission of extended report. For this time the actual work are manageable and the work continues as progress. After that the proposal defence is taking place. This task considers a lot of time and effort therefore it start in FYP 1 and maybe completed by the end of the semester. Finally the FYP 1 ends with submission of interim report.

For FYP 2, continuation of on kenaf fiber – polypropylene composite specimen preparation. Then the material will be tested on testing machine. From there, the analysis is prepared by comparing the time estimation with the real work application. Then work continues with preparation of the report and oral presentation.

Table 3.2 FYP1 key milestones.

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
			30/5												
2	Preliminary Research Work														
						19/6									
3	Submission of Extended Proposal						●								
							27/6								
4	Proposal Defence														
										18/7					
5	Project work continues														
													8/8		
6	Submission of Interim Draft Report													●	
														15/8	
7	Submission of Interim Report														●
															22/8

Table 3.3:FYP2 key milestones.

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continues														
								7/11							
2	Submission of Progress Report							●							
								5/11							
3	Project Work Continue														
													12/12		
4	Pre-SEDEX										●				
											27/11				
5	Submission of Draft Final Report											●			
												4/12			
6	Submission of Dissertation (soft bound)												●		
													12/12		
7	Submission of Technical Paper												●		
													12/12		
8	Viva													●	
														16/12	
9	Submission of Project Dissertation (Hard Bound)														●
															26/12

Table 3.4: Gantt chart for FYP 1

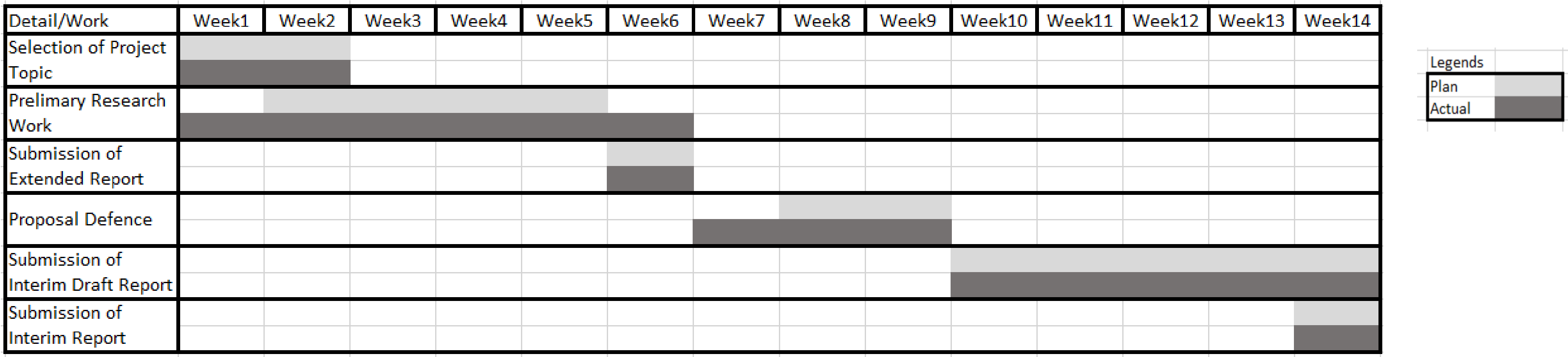
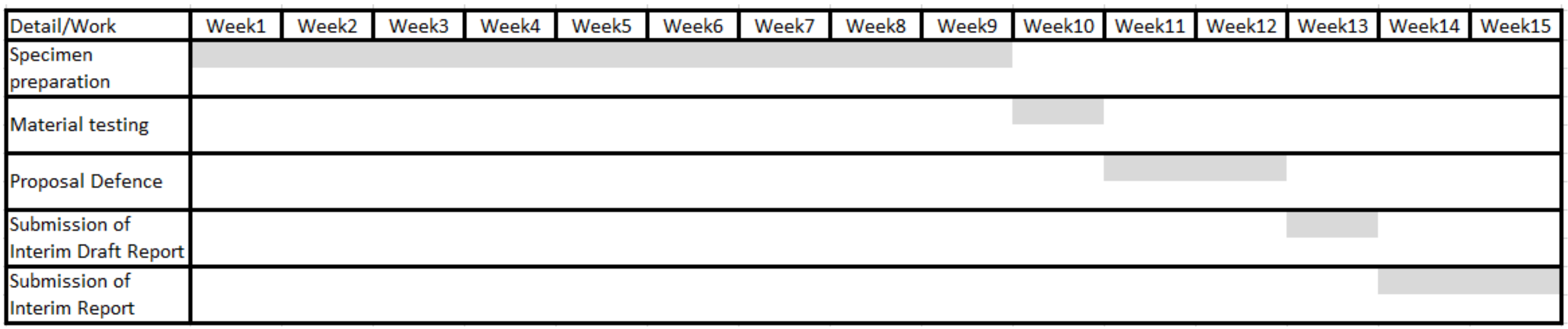


Table 3.5: Gantt chart for FYP 2



CHAPTER 4
RESULT AND DISCUSSION

4.1 Tensile Strength

There were 5 fiber orientations that were tested for tensile strength. The result are shown in Figure 4.1. Unidirectional fiber orientation or 0°orientation was the highest tensile strength. This result is expexted due to all fibers are aligned in the direction of tensile load. An improvement of 145% was achieved for unidirectional fiber compared to neat PP. The improvement for bi-directional fiber orientation was reduced to 25%. This is due to the number of fibers in the longitudinal direction is decreased to half of total fibers as compared to the unidirectional orientation composite. Another half of the fibers are facing the transverse direction. For the rest of the experiments, the tensile strengths were lower than the neat PP due to much less fiber in the longitudinal direction.

4.2 Flexural Properties

Results for flexural strength and modulus of various fiber orientation of PP/kenaf composite are shown in Figures 4.2 and 4.3, respectively. Similar to finding in tensile strength as explained in the previous section, unidirectional fiber orientation had shown the highest flexural strength and modulus. The improvement of unidirectional flexural strength and modulus were 24% and 65%, respectively, compared to neat PP. However, the flexural properties of the rest of the PP/kenaf samples were lower than neat PP. Voids and incomplete interfacial bonding between fiber and matrix may be the causes of the adverse effect.

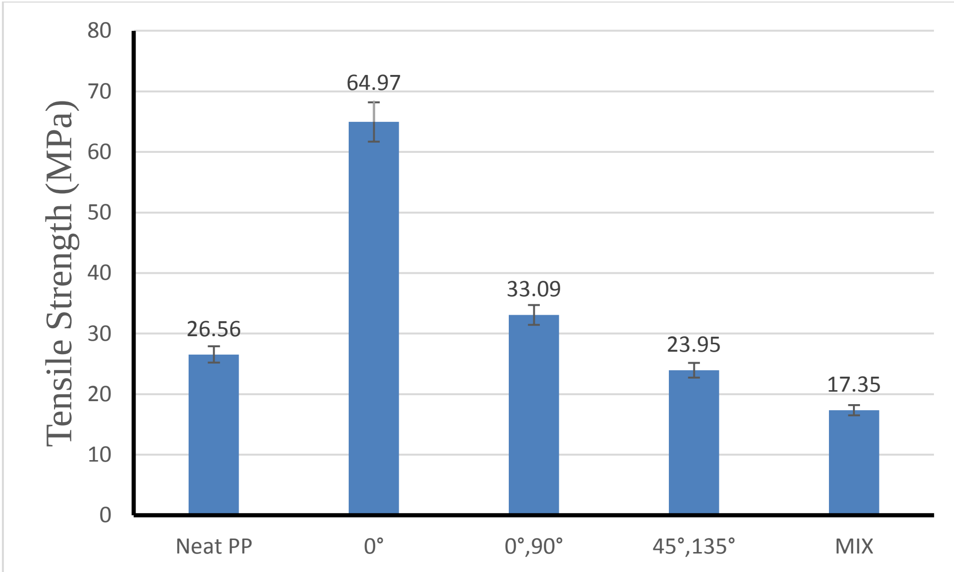


Figure 4.1: Tensile strength of PP/kenaf composite.

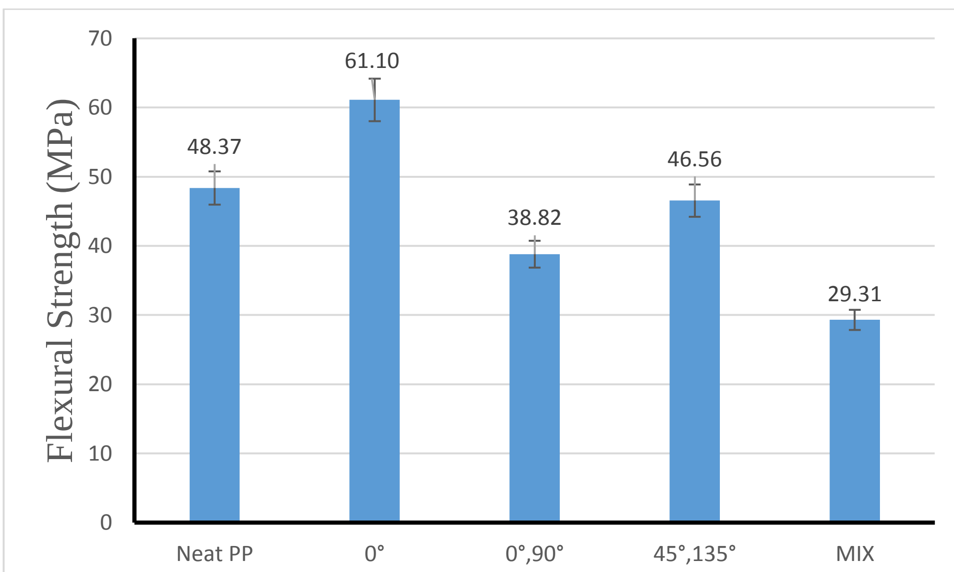


Figure 4.2: Flexural strength of PP/kenaf composite.

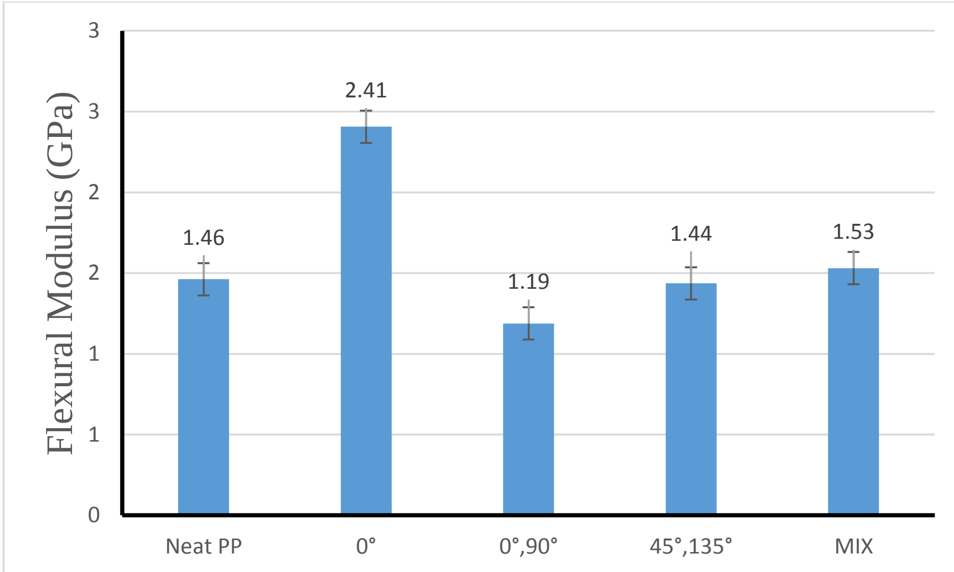


Figure 4.3: Flexural modulus of PP/kenaf composite.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

After specimens were prepared, testing of tensile strength and flexural proeperties was done. Tensile strength and flexural properties were successfully achieved in this project. Improvement of 145% was achieved in tensile strength of unidirectional kenaf fiber compared to neat PP. However, tensile strength of bi-directional fiber orientation was reduced to 25% compared to neat PP. Improvements of 24% for flexural strength and 65% for flexural modulus were achieved in unidirectional kenaf fiber compared to neat PP. The flexural properties were improved in unidirectional kenaf fiber but reduced for the rest of experiments compared to neat PP.

5.2 Recommendation

As expected unidirectional fiber orientation produced the highest tensile and flexural properties. While some applications require unidirectional orientation, the other applications may require bi-directional or multi-directional orientation. To benefit from bi-directional and multi-directional orientations, fabric composite such as woven, knitted and braided composites should have been fabricated. Therefore, mechanical property testing on fabric composites is recommended to explore their potentials.

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