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EFFECT OF FIBER LENGTH ON MECHANICAL PROPERTIES OF PALF REINFORCED BISPHENOL: A COMPOSITE

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ABSTRACT
Composites are becoming an essential part of today's materials because they offer advantages such as low weight, corrosion resistance, high fatigue strength, faster assembly etc. Composites are used as materials ranging from making, aircraft structures to golf clubs, electronic packaging to medical equipments. Composites are generating curiosity and interest in students all over the world, use of natural fibers as reinforcement in polymeric composites for technical application has been a research subject of scientist. Among several natural fibers, Pineapple leaf fibre (PALF) is one that has good potential as reinforcement in polymer composite. PALF was extracted from raw pineapple leaf; it was then chemically treated and dried in hot air oven to hinder the water content. In the present work the composite specimens are prepared by using Bisphenol-A (BPA) as a matrix and the short PALF fiber with length < 15 mm and 30% volume fraction as reinforcement. The composites were prepared by hand lay-up technique. The objective of the present work is to investigate the mechanical properties such as tensile strength, flexural strength, impact strength of Short PALF reinforced Bisphenol-A composite. The composites reinforced with the fiber length of 2mm, 4mm, 6mm, 8mm, 10mm, 12mm & 14mm was subjected to mechanical analysis to check the fisibility of utilizing PALF reinforced Bisphenol-A composite for mechanical applications. From this experimental study, it was observed that the fiber length greatly influences the mechanical behavior of PALF reinforced Bisphenol-A composites.

KEYWORDS: PALF, BPA, Fiber length, Tensile strength, flexural strength, Impact strength

INTRODUCTION
Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials. Natural fibers are plant based which are lignocelluloses in nature and composed of cellulose, hemicelluloses, lignin, pectin and waxy substances. Cellulose gives the strength, stiffness and structural stability for the fibre, and is the major framework components of the fiber. Pineapple Leaf Fibre (PALF) is one such fiber source known from a long time obtained from the leaves of pineapple. Pineapple leaves from the plantations are being wasted as they are cut after the fruits are harvested before being either composted or burnt. Additionally, burning of these beneficial agricultural wastes causes environmental pollution. Over the past decade, cellulosic fillers have been of greater interest, since they give improved mechanical properties to composite material compared to those containing non-fibrous fillers. Bisphenol-A (BPA) resin is a thermo set resin with good thermal and

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environmental stability, high strength and wears resistance. This combination of properties permits the application of BPA in polymer-based heavy duty sliding bearings. For these purposes, BPA usually is compounded with reinforcements like glass or carbon fibers and ceramic mineral oxides and inorganic fillers. The use of fibers in polymeric composites helps to improve tensile and compressive strengths, tribological characteristics, toughness (including abrasion), dimensional stability, thermal stability, and other properties.

MATERIALS AND METHODOLOGY

Pineapple Leaf Fibre (PALF) is one such fiber source known from a long time obtained from the leaves of pineapple plant (Ananascomosus) from the family of Bromeliaceous. Bisphenol-A (BPA) is an organic compound which belongs to the group of diphenyl methane derivatives and Bisphenol. The chemical formula is $(CH_3)_2C\ (C_6H_4OH)_2$. BPA is used to make certain plastics and epoxy resins; it has been in commercial use since 1957.

2.1 MATERIALS:

PALF extracted from leaf of pineapple plant by biological method supplied from Sri Lakshmi Group; Guntur, Andhra Pradesh. Bisphenol-A resin was supplied from Shree fibro chemicals, Pune.

2.2 CHEMICAL TREATMENT:

Extracted fibers subjected to Alkali treatment or mercerization using sodium hydroxide (NAOH) is the most commonly used treatment for bleaching and cleaning the surface of natural fibers to produce high-quality fibers. Modifying natural fibers with alkali has greatly improved the mechanical properties of the resultant composites. Firstly 5% NAOH solution was prepared using sodium hydroxide pellets and distilled water. Pineapple leaf fibers were then dipped in the solution for 1hour. After 1 hour fibers were washed with 1% HCl solution to neutralize the fibers. Then it is washed with distilled water. It was then kept in hot air oven for 3hours at 65-70°c. Then fibers were chopped to different fiber length.

2.3 MANUFACTURING OF COMPOSITE:

A polypropylene (PP) mould having dimensions of 211 X 119 X 5 mm^3 is used for composite fabrication. The mass fraction for the prepared mould is calculated using equation of volume fraction of the fiber and density of fiber. The mould was first cleaned with wax so that the laminate easily comes out of the die after hardening. Then around 15 to 20 ml of promoter and accelerator are added to Bisphenol and the color of the resin changes from pale yellow to dark yellow with the addition of these two agents. The laminates of different fibers lengths of short PALF are prepared using hand layup method. This method of manufacturing is a relatively simple method compared to other methods like vacuum bag molding, resin transfer molding, autoclave molding etc. Fig 2.3.1 shows the PALF reinforced laminated composites with fiber length of 2, 4, 6, 8 and 14mm respectively.

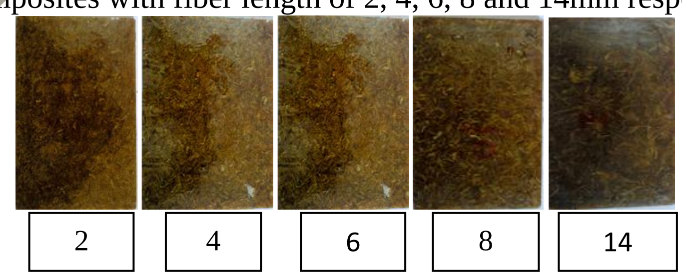

Figure 2.3.1: PALF reinforced composites of different fiber length

The mass fraction for the prepared mould and for desired volume fraction of fiber is calculated using equations:

Volume fraction of fibers (VF) = vf / vc ………. (2.1)

Density of the fiber (ρ) = mf / vf ……… (2.2)

Were vf = Volume of the fiber, vc= Volume of the composite, mf = Mass fraction of the fiber.

2.4 CUTTING OF LAMINATES IN TO DESIRE DIMENSIONS:

A WIRE HACKSAW blade was used to cut each laminate into smaller pieces, for various experiments:

TENSILE TEST- Sample was cut into dog bone shape (165*13*5) mm.

FLEXURAL TEST- Sample was cut into flat shape (125*14.5*5) mm, in accordance with ASTM standards.

IMPACT TEST- Sample was cut into flat shape (65*12*3.2) mm, in accordance with ASTM standards.

Fig2.4: shows tensile specimen, flexural specimen, impact specimen after cutting to desired specimen from Wire Hacksaw

MECHANICAL TESTS

The mechanical testing has been done on the composite laminate specimens as per the guidelines given in ASTM standards for the respective tests. The mechanical tests are usually performed to identify the strength parameters of any kind of materials considered or prepared under the studies. The Flexural test and Tensile test were performed in the Computerized Universal Testing Machine with load cell of 1 kN and using crosshead speed of 5 mm/min, impact strength test were performed in the computer integrated IZODE test machine. All the tests were carried out in SMSMPITR, Akluj.

3.1 TENSILE TEST:

Tensile test is a measurement of the ability of a material to withstand forces that tend to pull it apart and to what extent the material stretches before breaking.

TEST TYPE:

According to ASTM D638, tensile testing has been carried out. The specimen with the gauge length of 115 mm was considered for the investigation of tensile properties

EXPERIMENTAL SETUP

Machine Data: universal testing machine with load cell of 1 kN
Loading rate: 5 mm/min
Specimen used: Rectangular bar
Specimen dimension: 165mm*13mm*5mm

Fig 3.1: Specimen undergoing tensile test

As the tensile test starts, the specimen elongates; the resistance of the specimen increases and is detected by a load cell. This load value (F) is recorded until a rupture of the specimen occurred. Instrument software provided along with the equipment will calculate the tensile properties for instance tensile strength, yield strength and elongation at break. Below are the basic relationships to determine these properties:

- Tensile strength = $\frac{\text{Force (load).}}{\text{Cross section area}}$ ……………………..eq-2.3
- Tensile strength at yield = $\frac{\text{Maximum load recorded}}{\text{Cross section area}}$ ………eq-2.4
- Tensile strength at break = $\frac{\text{Load recorded at break}}{\text{Cross section area}}$ ………eq-2.5

3.2 FLEXURAL TEST (3 POINT LOADING):

Flexural strength also known as modulus of rupture is a mechanical parameter for brittle material defined as the material's ability to resist deformation under load. The flexural strength represents the highest stress experienced within the material at its moment of rupture. This test method determines the flexural properties of specimen under defined condition

TEST TYPE:

There are two methods that cover the determination of flexural properties of material: three-point loading system and four point loading system. As described in ASTM D790, three-point loading system applied on a supported beam was utilized.

EXPERIMENTAL SETUP:

Machine Data: Flexural Testing Machine
Loading rate: 5 mm/min

Specimen used: Rectangular bar
Specimen dimension: 120 mm X 14.5 mm

Fig 3.2: Specimen undergoing flexural test

3.3 IMPACT TEST:

The impact properties of the material are directly related to the overall toughness which is defined as the ability to absorb applied energy. Area under the stress-strain curve is proportional to the toughness of a material. Nevertheless, impact strength is a measure of toughness. In this last two decades, there are four types of impact tests, for example: the pendulum impact tests, high-rate tension test, falling weight impact test and instrumented impact test. In this research, pendulum impact test – Notched Izode Impact Test was utilized.

TEST TYPE:

According to ASTM D256-56, impact test has been carried out. The test method is the cantilever beam or Izod type test in which specimen is held as a cantilever beam (usually vertical) and is broken by a blow delivered at a fixed distance from the edge of the specimen clamp. The test requires a notched specimen.

EXPERIMENTAL SETUP:

Machine Data: Izod Impact Testing Machine
Specimen used: Notched Rectangular bar
Specimen dimension: 63.5 mm X 14.5 mm X 2.5 mm

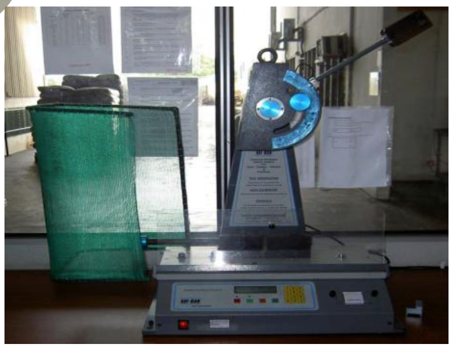

Fig 3.3: Impact Test Specimen under Test

RESULTS AND DISCUSSION

4.1 TENSILE TEST RESULT AND DISCUSSION:

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. The tensile test is carried out on standard size specimen by applying load and the elongation of the specimen over the span distance is measured. The Young's modulus (E), Ultimate Tensile strength (UTS) and the maximum load obtained are tabulated in Table 4.1.1 to 4.1.7, and graphically represented in the graphs in the fig 4.1.1, 4.1.2.

Table 4.1.1 : tensile properties of 2mm fiber reinforced composite

Sr. no	Maximum load(KN)	Tensile strength(MPa)	Young's modulus(MPa)	% elongation at break
1	1.02	15.6	2340.12	0.96
2	1	15.3	2310.54	1.03
3	0.98	15.07	2300.20	1.01
4	0.90	13.8	2100.72	0.98
5	0.87	13.3	2120.30	0.86
Average	**0.954**	**14.61**	**2234.37**	**0.968**

Table 4.1.2 : tensile properties of 4mm fiber reinforced composite

Sr. no	Maximum load(KN)	Tensile strength(MPa)	Young's modulus(MPa)	% elongation at break
1	1.02	15.6	2380.12	1.14
2	1	15.3	2320.54	1.08
3	1.04	16	2410.35	1.02
4	0.98	15.07	2300.20	0.95
5	1	15.3	2310.54	0.97
Average	**1.008**	**15.45**	**2344.35**	**1.032**

Table 4.1.3 : tensile properties of 6mm fiber reinforced composite

Sr. no	Maximum load(KN)	Tensile strength(MPa)	Young's modulus(MPa)	% elongation at break
1	1.21	18.6	2600.93	1.35
2	0.90	13.8	2220.88	1.09
3	1.16	17.8	2510.58	1.20
4	1.02	15.6	2330.79	1.12
5	1.04	16	2400.22	1.05
Average	**1.066**	**16.36**	**2412.68**	**1.162**

Table 4.1.4 : tensile properties of 8mm fiber reinforced composite

Sr. no	Maximum load(KN)	Tensile strength(MPa)	Young's modulus(MPa)	% elongation at break
1	1.20	18.4	2580.36	1.60
2	1.16	17.8	2510.23	1.25
3	1.10	16.9	2450.35	1.05
4	1.15	17.6	2500.32	1.13
5	1.12	17.2	2495.63	1.09
Average	**1.146**	**17.58**	**2507.37**	**1.224**

Table 4.1.5 : tensile properties of 10mm fiber reinforced composite

Sr. no	Maximum load(KN)	Tensile strength(MPa)	Young's modulus(MPa)	% elongation at break
1	1.21	18.6	2620.53	1.65
2	1.20	18.4	2580.36	1.55
3	1.15	17.6	2500.86	1.18
4	1.16	17.8	2510.75	1.1
5	1.20	18.4	2574.69	1.23
Average	**1.184**	**18.16**	**2557.43**	**1.34**

Table 4.1.6 : tensile properties of 12mm fiber reinforced composite

Sr. no	Maximum load(KN)	Tensile strength(MPa)	Young's modulus(MPa)	% elongation at break
1	0.90	13.8	2220.59	1.11
2	1.02	15.6	2350.15	1.05
3	1	15.3	2320.45	1.02
4	1	15.3	2300.89	0.85
5	0.98	15.07	2295.89	0.88
Average	**0.98**	**15.10**	**2297.59**	**0.98**

Table 4.1.7: tensile properties of 14mm fiber reinforced composite

Sr. no	Maximum load(KN)	Tensile strength(MPa)	Young's modulus(MPa)	% elongation at break
1	1.02	15.6	2350.96	1.01
2	1	15.3	2310.56	0.96
3	1.02	15.6	2348.29	0.98
4	0.98	15.07	2300.17	0.88
5	0.87	13.3	2170.53	0.82
Average	**0.978**	**14.9**	**2296.10**	**0.93**

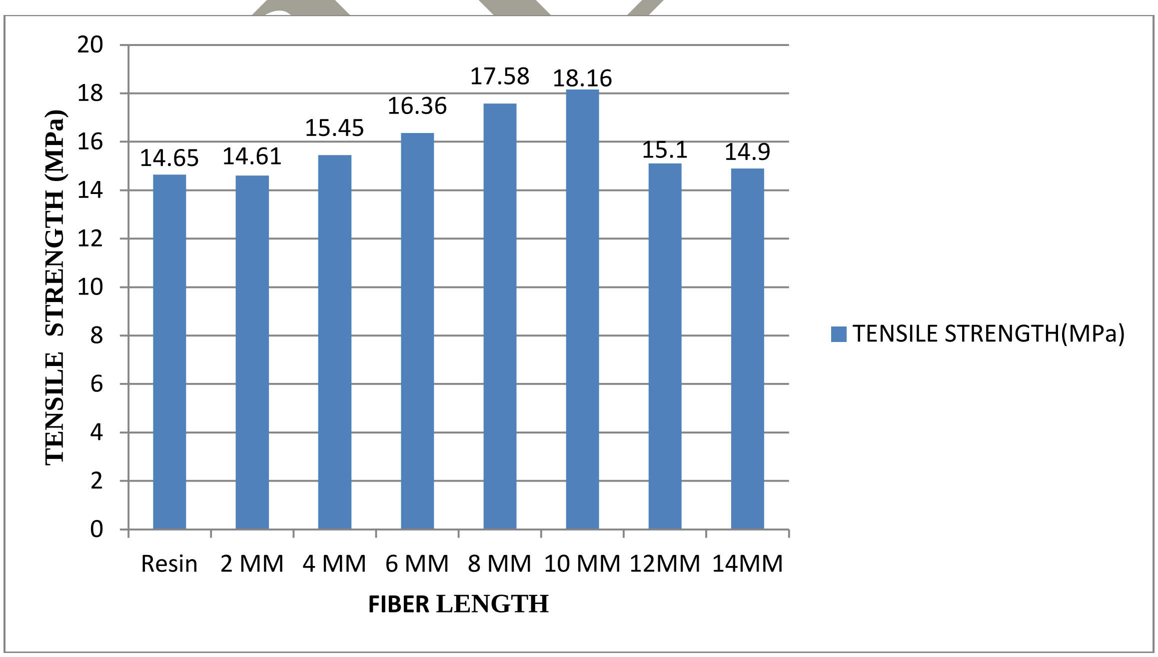

Fig 4.1.1: Tensile strength of the composite material

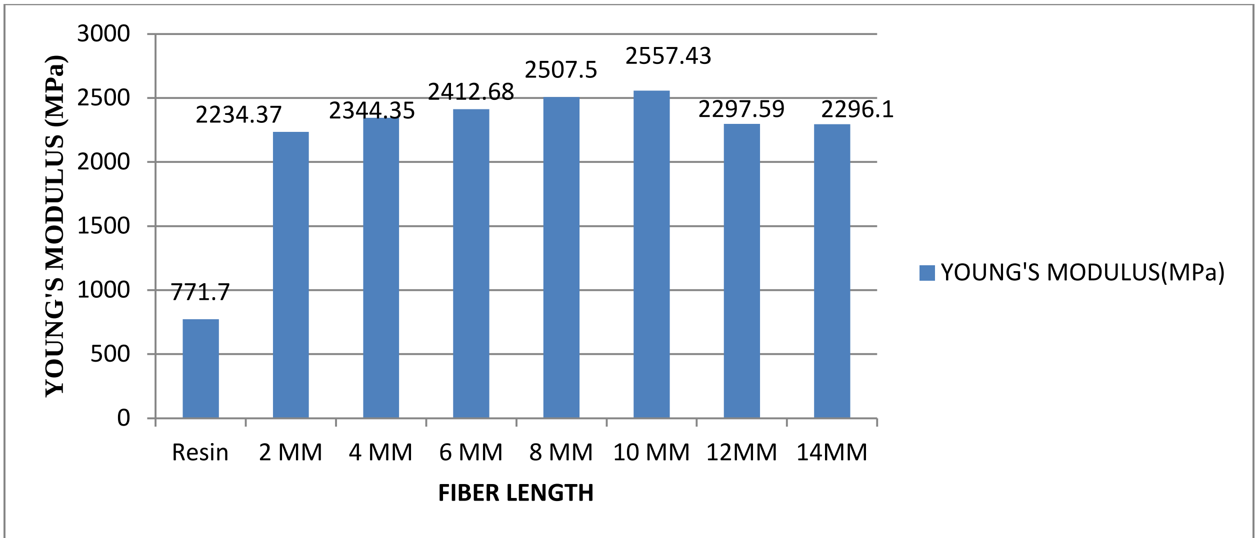

Fig 4.1.2: Tensile modulus of the composite material

In tensile test, the most properties can be represented by Young's modulus and tensile strength. Figure 4.1.1 shows that tensile strength increased with fibre length, decreased after optimum fiber length reached and experienced more for fiber length of 10mm that was 18.16. After fiber length of 10mm,the modulus dropped to 14.90MPa from 18.16MPa.too short the fibers or too long the fibers, the fibers tends to entangle from the matrix when the forces are applied, due to which the interfacial bonding strength decreases, which results in decrease in trend of tensile strength and tensile modulus. In the present study the tensile strength and modulus increased till optimum fiber length reached then it tends to decrease. Figure 4.1.2 shows that Young's Modulus increased with fibre length, decreased after optimum fiber length reached and experienced more for fiber length of 10mm, that was 2557.43MPa.

4.2 FLEXURAL TEST RESULTS AND DISCUSSION:

In flexural test, the most important properties considered to study are flexural strength and flexural modulus. The three point bending /flexural test has been conducted on the short PALF-reinforced composite fiber with their varying length of 2,4,6,8,10,12 and 14 mm in each cases and the results obtained are tabulated in Table 4.2.1-4.2.7.the flexural property is one of the important parameter in composite mainly useful to quantify in structural applications. Flexural strength and flexural modulus of 5 samples each composite are taken and the average of their flexural strength and modulus is used for discussion.

Table 4.2.1: Flexural properties of 2mm short fiber reinforced composites

Sr. no	Maximum load(KN)	Flexural strength(MPa)	Flexural 's modulus(MPa)
1	200.12	34.89	2425.10
2	197.45	34.43	2419.50
3	192.50	33.56	2350.16
4	196.10	34.19	2420.60
5	191.90	33.46	2390.96
Average	**195.61**	**34.106**	**2401.26**

Table 4.2.2: Flexural properties of 4mm short fiber reinforced composites

Sr. no	Maximum load(KN)	Flexural strength(MPa)	Flexural 's modulus(MPa)
1	200.12	34.89	2425.10
2	197.45	34.43	2419.50
3	192.50	33.56	2350.16
4	196.10	34.19	2420.60
5	191.90	33.46	2390.96
Average	**195.61**	**34.106**	**2401.26**

Table 4.2.3: Flexural properties of 6mm short fiber reinforced composites

Sr. no	Maximum load(KN)	Flexural strength(MPa)	Flexural 's modulus(MPa)
1	225.21	39.2	2525.10
2	220.01	38.36	2466.20
3	212.14	36.99	2439.96
4	215.26	37.53	2445.27
5	217.10	37.85	2591.13
Average	**217.94**	**37.986**	**2493.53**

Table 4.2.4: Flexural properties of 8mm short fiber reinforced composites

Sr. no	Maximum load(KN)	Flexural strength(MPa)	Flexural 's modulus(MPa)
1	260.76	45.46	2612.50
2	255.89	44.62	2586.10
3	259.13	45.18	2590.96
4	245.24	42.76	2578.13
5	250.13	43.61	2538.20
Average	**254.23**	**44.326**	**2581.170**

Table 4.2.5: Flexural properties of 10mm short fiber reinforced composites

Sr. no	Maximum load(KN)	Flexural strength(MPa)	Flexural 's modulus(MPa)
1	273.76	47.73	2675.89
2	265.85	46.35	2650.17
3	278.05	48.48	2690.26
4	257.39	44.88	2600.12
5	277.40	48.37	2605.13
Average	**270.49**	**47.162**	**2644.314**

Table 4.2.6: Flexural properties of 12mm short fiber reinforced composites

Sr. no	Maximum load(KN)	Flexural strength(MPa)	Flexural 's modulus(MPa)
1	212.14	36.94	2460.96
2	213.65	37.25	2472.10
3	220.45	38.44	2486.96
4	210.13	36.64	2455.12
5	209.45	36.52	2445.92
Average	**213.164**	**37.163**	**2464.21**

Table 4.2.7: Flexural properties of 14mm short fiber reinforced composites

Sr. no	Maximum load(KN)	Flexural strength(MPa)	Flexural 's modulus(MPa)
1	193.16	33.68	2220.45
2	191.25	33.34	2315.15
3	190.13	33.15	2355.05
4	195.45	34.08	2365.15
5	192.13	33.50	2323.15
Average	**192.42**	**33.55**	**2315.79**

Flexural strength and flexural modulus for the unreinforced Bisphenol-a resin and re-in forced Bisphenol-a resin composite are shown in figure 4.2.1 and 4.2.2. Figure 4.2.1 the flexural strength of un-reinforced Bisphenol-resin 33.02MPa and after reinforcing its strength increased to 33.02,32.67,34.12,37.98,44.32,47.16 and 37.16 in the case of 2mm, 4mm, 6mm, 8mm,10mm and 12mm.fig shows that flexural strength increased with fibre length, decreased after optimum fiber length reached, till 10mm fiber length there is increased linear variation of the strength and experienced more for fiber length of 10mm and flexural strength dropped for 12mm and 14mm, from maximum of 47.16 for 10mm to 33.55 for 14mm. On the other hand, the fig 4.2.2 shows the graph of fiber length vs. flexural modulus. The flexural modulus of the unreinforced Bisphenol-a resin was obtained from 3-point bending strength test and result was 743.28 MPa. The value of flexural strength increased with fiber length 0.4% for 2mm, 3.2% for 4mm, 13% for 6mm, 25.49% for 8mm, 29.9% for 10mm, 11.14% for 12mm, 1.57% for 14mm when compared with the un-reinforced Bisphenol-a resin (0 wt% PALF) which as a flexural modulus of 743.38MPa. The value of flexural modulus increases with fiber incorporation to resin, From the obtained result 10mm fiber length re-inforced composite considered to be the optimum fiber length, after the results obtained since it as high flexural strength and flexural modulus this can be reasoned because of the optimal length short fiber which allowed the composite to have high force transfer along the length of the composite, which is important parameter in composites mainly useful to quantify in structural application.

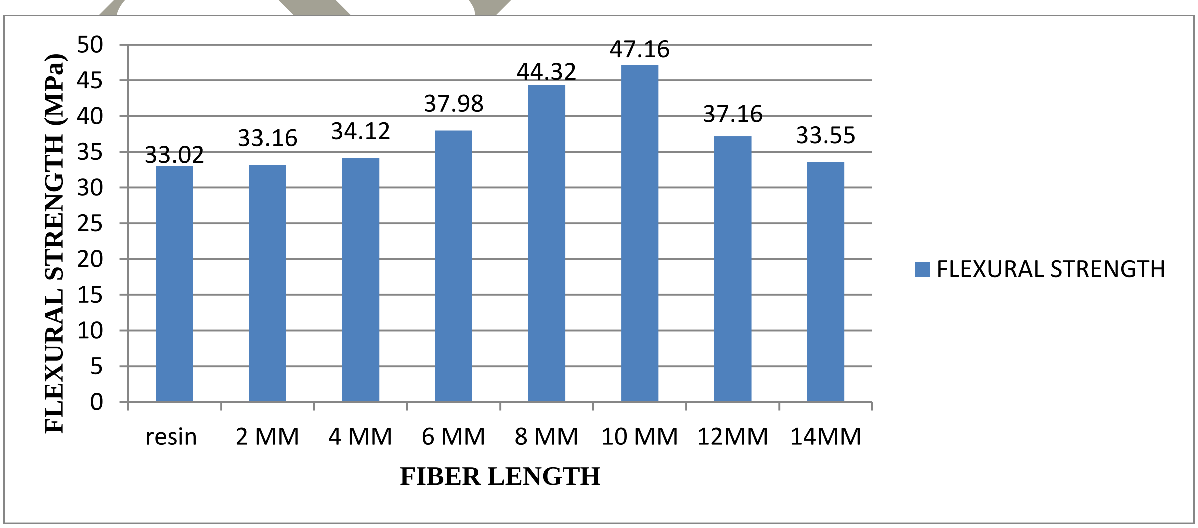

Fig 4.2.1 : flexural strength of the composite material with varying length

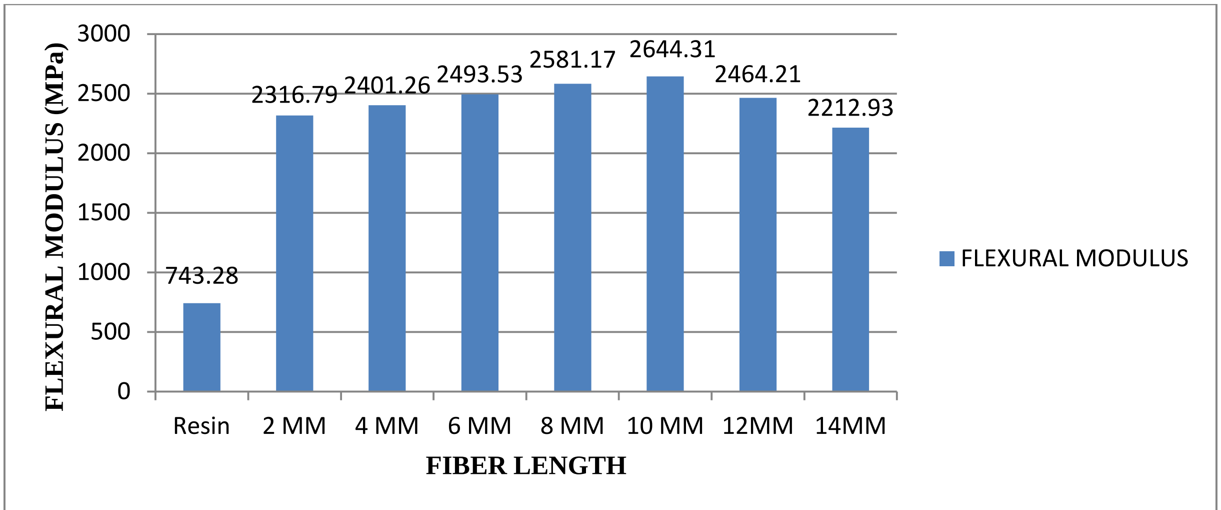

Fig 4.2.2 : flexural modulus of the composite material with varying length

4.3 IMPACT TEST RESULTS AND DISCUSSION

The Izode impact test is conducted on the chosen composite specimens of varied length 2, 4,6,8,10,12 and 14 mm. The obtained Impact strengths are tabulated in below Table. Impact strength is the ability of a material to absorb energy under a shock load or the ability to resist the fracture under load applied at high speed. Impact behavior is one of the most widely specified mechanical properties of the Engineering materials. The variations of impact strength with respect to fiber loading (weight fraction) is as shown in table's 4.3.1-4.3.7.

Table 4.3.1: Experimental results of the 2mm short fiber impact strength of composite material

Sr. no	Impact strength (KJ/m)
1	2.36
2	2.36
3	2.98
4	3.36
5	3.06
Average	2.268

Table 4.3.2: Experimental results of the 4mm short fiber impact strength of composite

Sr. no	Impact strength (KJ/m)
1	2.36
2	2.24
3	2.28
4	2.38
5	2.30
Average	2.312

Table 4.3.3: Experimental results of the 6mm short fiber impact strength of composite material

Sr. no	Impact strength (KJ/m)
1	3.51
2	2.14
3	2.11
4	2.07
5	2.58
Average	2.482

Table 4.3.4: Experimental results of the 8mm short fiber impact strength of composite material

Sr. no	Impact strength (KJ/m)
1	2.47
2	3.14
3	2.68
4	3.44
5	2.43
Average	2.832

Table 4.3.5: Experimental results of the 10mm short fiber impact strength of composite material

Sr. no	Impact strength (KJ/m)
1	2.36
2	2.36
3	2.98
4	3.36
5	3.06
Average	2.824

Table 4.3.6: Experimental results of the 12mm short fiber impact strength of composite material

Sr. no	Impact strength (KJ/m)
1	2.51
2	2.48
3	2.45
4	2.52
5	2.43
Average	2.47

Table 4.3.7: Experimental results of the 14mm short fiber impact strength of composite material

Sr. no	Impact strength (KJ/m)
1	2.31
2	2.25
3	2.20
4	2.22
5	2.26
Average	2.248

From the above table 4.3.1-4.3.2 it can be observed that the impact strength of the un-reinforced Bisphenol-a resin has been increased significantly after PALF-reinforcement. It can be observed form the table that the highest value of Izode impact strength is obtained for 8mm specimen which is 2.832kJ/m.

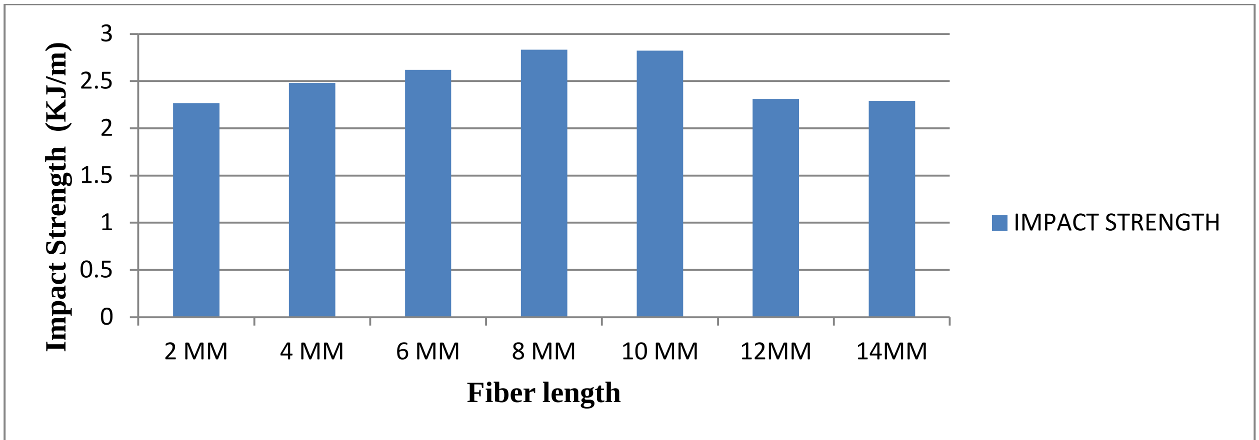

Fig 4.3.1: impact strength of the composite material with varying length

2 mm PALF showed an increment in impact strength by 11.5%,length of 4mm PALF, the impact strength showed an increment of 13.4%, length of 6mm PALF, the impact strength showed an increment of 19.35%, length of 8mm PALF, the impact strength showed an increment of 29.32%, length of 10mm PALF, the impact strength showed an increment of 29.1%, length of 12mm PALF, the impact strength showed an increment of 19.2%, whereas for 14mm PALF, the impact strength was 11.03% higher than the unreinforced Bisphenol Resin (0 wt% PALF) which as a impact strength of 2 kJ/m.fig 5.6 shows the impact strength of the composite material with varying length.

CONCLUSION

The results of this present study showed that a useful composite with good properties could be successfully developed using treated PALF as reinforcing agent for the Bisphenol-A matrix. From this, several conclusions can be drawn regarding to mechanical properties of composite to the effect of fibre arrangements, namely tensile, flexural and impact properties.

As the Bisphenol-A resin reinforced with 2mm,4mm,6mm,8mm,10mm,12mm&14mm, the young's modulus was increased by 65.49%,66.96%,68.74%,69.24%,69.80%,66.42% and 66.36% respectively. The young's modulus of 10mm, 8mm composite was best because there is a great bond between the matrix and resin material, and have a more load bearing capacity when compared with other fiber length and it considered as the optimum fiber length. The tensile strength of the resin was increased by 5.11%, 10.57%, 16.95%, 19.6%, 3.11% and 2.013% after reinforcement 2mm, 4mm, 6mm, 8mm, 10mm, 12mm and 14mm varying fiber length in to the composite.

The flexural modulus and flexural strength of resin were increased after the reinforcement of fibers in to the resin. Out of seven types of fiber lengths, namely, 2mm, 4mm, 6mm, 8mmm, 10mm, 12mm and 14mm lengths, 10mm fiber reinforced composite given the highest flexural modulus and flexural strength which were 71.89% and 29.9% respectively. This was because of the presence of great bond between the fiber and the matrix material in the case of 10mm fiber reinforced composite which transferred more load.

Impact properties also indicate the rise of impact strength of resin after fibers reinforcement. 8mm composite had given highest impact strength that was about 29.32% more than that of resin. Once again, the presence of great bond between the fiber and the matrix in 10mm fiber reinforced composite played the important role in increasing the strength by capable of transferring the more load.

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