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Experimental Investigation and Analysis of Mechanical Properties of Palm fibre reinforced Epoxy composites and Sisal fibre reinforced Polyester composites

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The objective of this paper was investigated to evaluate tensile, flexural and Impact properties of Palm fibre reinforced Epoxy composites (PFRP) and compared with Sisal fibre reinforced Polyester composites (SFRP). Untreated chopped Palmyra Palm fruit fibrewas used as reinforcement in Epoxy resin matrix and chopped sisal fibre was used as reinforcement in Polyester resin matrix. The chopped palm fibrereinforced composite were prepared in volume fractions (V_f) such as 10 %, 20 % and 30 % of specimens by using Epoxy and the chopped sisalfibre reinforced composite were prepared in volume fractions (Vf) such as 10 %, 20 % and 30 % of specimens by using Polyester. The specimens are tested for their mechanical Properties strictly as per ASTM procedures. Static analysis is performed by FEA based software ANSYS R15 with design constraints as Equivalent stress, Shear stress and deflection.The experimental result and analysis shows that the fibrevolume fraction increases the tensile, flexural, Impact strength and modulus of the fibre reinforced composites

Keywords: Palm fibre, Sisal fibre, epoxy resin, polyester resin, volume fractions, tensile property, flexural property, impact property, ANSYS.

1 Introduction: Nature created materials is the natural fibres which are abundantly available, eco-friendly and have renewable in their behavior. The cultivation and on growing harvesting and primary processing conditions to extract the fibre will dictate the homogeneity. Natural fibres are light in weight which is extremely advantageous but dueto its low density can be disadvantageous in processing since the fibre tends to emerge from the matrix specificallyliquid resins. Moisture absorbing tendency is another bottleneck to the natural fibres which resulted in the delaminationof the composites. Hence right extraction method of fibre and suitable processing method to manufacturethe composites by reinforcing the fibre are the vital foremost tasks in dealing with Natural Fibre Reinforced Polymer Composite [1]. Simple manual water treatment process used to extract roselle and sisal fibers and performed experiments on roselle/sisal–polyester composites. Tensile and flexural strength results were compared with the Hirsch theoretical model [2]. Tensile strength, modulus, flexural strength, modulus and impact strength for alkali treated/MAPP composites by 4.5, 17, 17.2, 9 and 10 % better in case of borassus fruit fibre reinforced polyester composites [3]. Short discontinuous fiber was better stress distribution between the fibers and matrix than the continuous fibers. The importance of the short fiber composites was also discussed [4]. The Palmyra palm fibres extracted from stem and chemical treated. The result shows palm yran fibres up to 50 mm length in the polyester composites have increasing trend of flexural strength thereafter it is decreasing and 50 mm fibre length, the composites exhibited maximum tensile strength of 42.65 MPa and thereafter it is decreasing **[5].** Chemically treated on palmyra palm leaf stalk fibre reinforced polyester composites are an improvement in tensile strength by 60 % and modulus by 60 % respectively with the reinforcement of mercerized and benzoyl – treated fibre composites respectively whereaspermanganate – treated fibre composites shown increase in flexural strength, modulus by 70 % and 110 % respectively, impact strength for mercerized and permanganate treated fibre composites improved by 55 % and 42 % in comparison to the untreated fibre composites respectively **[6].** Before preparation of reinforcement in polyester matrix sisal fibers were subjected to alkali, thermal, benzoyl chlorideand potassium permanganate treatment **[7].** Adopting the various chemical treatment processes observed that the structural stability and adhesion properties in the reinforced composite were improved **[8].**Jute fibre has high tensile strength, modulus, high cellulose content and availability due to which it is used as potential reinforcement in polymer matrix **[9].** The tensile and flexural properties of the unidirectional Roystonearegia fiber–epoxy composites enhanced by alkali treatment **[10 -17].**

Table (1): Properties of selected natural and manmade fibers [adapted from 12, 16].

Fiber	Density (g/cm^3)	Elongation (%)	Tensile strength (MPa)	Elastic modulus (GPa)	Refs.
Cotton	1.5–1.6	7.0–8.0	400	5.5–12.6	[14,15]
Jute	1.3	1.5–1.8	393–773	26.5	[14]
Flax	1.5	2.7–3.2	500–1500	27.6	[13]
Hemp	1.47	$2–4^{0}$	690	70	[13]
Kenaf	1.45	1.6	930	53	[13]
Ramie	N/A	3.6–3.8	400–938	61.4–128	[16]
Coir	1.2	30	593	4.0–6.0	[17]
Softwood kraft pulp	1.5	4.4	1000	40	[17]
E-glass	2.5	0.5	2000–3500	70	[17]
S-glass	2.5	2.8	4570	86	[17]
Aramid (Std.)	1.4	3.3–3.7	3000–3150	63.0–67.0	[17]
Carbon (Std. PAN-based)	1.4	1.4–1.8	4000	230–240	[17]

Table (2): Properties of Palmyra and Sisal.

Properties	**Palmyra**	**Sisal**
Density(kg/m^3)	1090	1500
TensileStrength (MPa)	180-215	511-635
Tensilemodulus(GPa)	7.4-60.4	9.4-22
% Elongation	7-15	2.0-2.5

2 Experimental details:

2.1 Materials: Palmyra Palm fibers were extracted from the fruit of the Palmyra palm tree.The extracted Palmyra Palm fibers are immersed in water for four consecutive days to remove the primary and secondary walls of the plants by biodegradable process. After four days, the extracted palm fibres are taken out from the wateragain cleaned with distilled water. The water content present inside of the fiber is removed by keeping in the hot air oven for 60 min at 160 ˚C **[11].** The dried fibers are chopped into specified lengths to prepare the composites. Sisal fibers are purchased from local sources. Purchased fibers are chopped into specified lengths to prepare the composites

2.2 Epoxy and Hardener: The matrix used to manufacture the composite specimen is epoxy Epotec YD 128 of density 1.16 g/cm^3 and it is mixed with hardener Triethylenetetramine (TETA) of density 0.978 g/cm^3 are purchased from Aditya Birla Chemicals Ltd. (Epoxy Division). The ratio of mixing epoxy and hardener is 10:1. The primary function of the resin is to transfer stress between the reinforcement fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage.

Table (3): Properties of Epoxy

properties	Epotec YD 128
Epoxide Value	5.15 – 5.40
Density @25ºC	1.16 g/cm^3
Moisture content	0.1 % max.
ECH content	10 ppm max.
Non-volatile content	100 %
Flash point	> 150ºC

2.3 Polyester resin: Unsaturated polyester resin is a thermoset, capable of being cured from a liquid or solid state when subject to the right conditions. It is usual to refer to unsaturated polyester resins as 'polyester resins', or simply as 'polyesters'. There are two principle types of polyester resin used as standard laminating systems in the composites industry. Orthophthalic polyester resin is the standard economic resin used by many people. Isophthalic polyester resin is now becoming the preferred material in industries such as marine where its superior water resistance is desirable

2.4 Preparation of Specimens: Palm fibre/epoxy composites with varying volume fraction of fibre (V_f) were manufactured by compression molding machine (Heating facility RT-350˚C, Press capacity 30T). A steel die of 300 mm x125 mm x 3 mm was used to fabricate the composites. The volume fraction of 10%, 20%, 30% chopped palm fibre was mixed with epoxy resin. Epoxy resin andfibrestirred thoroughly to ensure homogenous mixing. Then composite mixer was poured inside the die cavity and the die was closed by applying force of 2 tons by hydraulic compression to produce a composite sheet of 3 mmthickness.The mold was kept under pressure for 4 hrs at room temperature. Composite sheet was removed and mold release agent was already sprayed on inside the die cavity for remove composite sheet. The specimens were cut to the as per ASTM standard. Simultaneously same procedure for was followed to prepare sisal fibre/polyester composites.

Figure (1): Fibre extracted from Source

Figure (2): Specimen Preparation.

Figure (3): PFRP and SFRP Specimens as per ASTM standards.

3. Mechanical testing: Tensile properties of the Palm/Epoxy and Sisal/Polyester reinforced composites were determined using Deepak DTRX – 20KN tensile tester with a cross head speed of 5 mm/min, operated at room temperature. Tests were conducted as per ASTM D638 **[18]**. Averages of 3 specimens were used in each test. Flexural tests were conducted as per ASTM D790 **[19]** standards using Deepak

DTRX – 20KN universal testing machine, with a cross head speed of 2 mm/min. The test specimens of size 127x12.7x3 mm were cut from Palm/Epoxy and Sisal/Polyester reinforced composites. Three specimens were tested in each composite and average values are reported. Impact tests were conducted as per ASTMD256 [20] standards using Deepak Digital impact tester. It was used for determining the impact properties of the composites. Un-notched rectangular specimens of size 63.5x13x3 mm were cut from Palm/Epoxy and Sisal/Polyester reinforced composites. Three specimens were tested in each composite for their impact properties. The morphology of the composites surface was examined with a ZEIS scanning electron microscope.

4. Results and Discussion:

4.1 Experimental results: A typical Load vs. Displacement graph of PFRP, SFRPand combined PFRPSFRP composites was recorded during tensile test as per ASTM D638 standard. Graph was drawn from these recorded values are shown in Figure (4, 5 and 6).

Figure (4) shows the load increases to reach the peak value at 1365 N in case of 30 % volume fraction palmfibre. But the load increases to reach the peak value at 1138.8 N for 20 % volume fraction palmlfibre. 30 % volume fraction takes higher load to fracture specimens due to maximum volume of fibre compare with 20 % volume fraction. And also 30 % volume fraction experienced maximum displacement at peak load around the value of 2.7074 mm; In 10 % volume fraction specimen tends to break at 1068.6 N. Similarly Figure (5) shows the load increases to reach the peak value at 1271.4 N in case of 30 % volume fraction sisal fibre. But the load increases to reach the peak value at 1224.6 N for 20 % volume fraction sisal fibre. 30 % volume fraction takes higher load to fracture specimens due to maximum volume of fibre compare with 20 % volume fraction. And also 30 % volume fraction experienced maximum displacement at peak load around the value of 2.5217 mm. In 10 % volume fraction specimen tends to break at 1049 N. Figure (6) shows combined curve of PFRP and SFRP, from these curve 30 % PFRP composites takes maximum load to fracture the specimen as well takes maximum displacement. Compare both PFRP and SFRP composites 30 % Volume fractions takes more load and deflection.

Table (4): Mechanical properties of Palm/epoxy and sisal/polyester composites

Sample	Fiber(V_f) %	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (KJ/m^2)	Tensile modulus (GPa)	Flexural modulus (GPa)
PFRP	10	27.4	53	4.9	0.75	4.93
	20	29.2	55.8	5.7	0.81	5.27
	30	35	58.5	6.4	0.89	7.63
SFRP	10	26.9	45.4	3.7	1.00	4.51
	20	31.4	55.2	4.8	0.88	5.62
	30	32.6	57.3	6.1	0.80	5.83

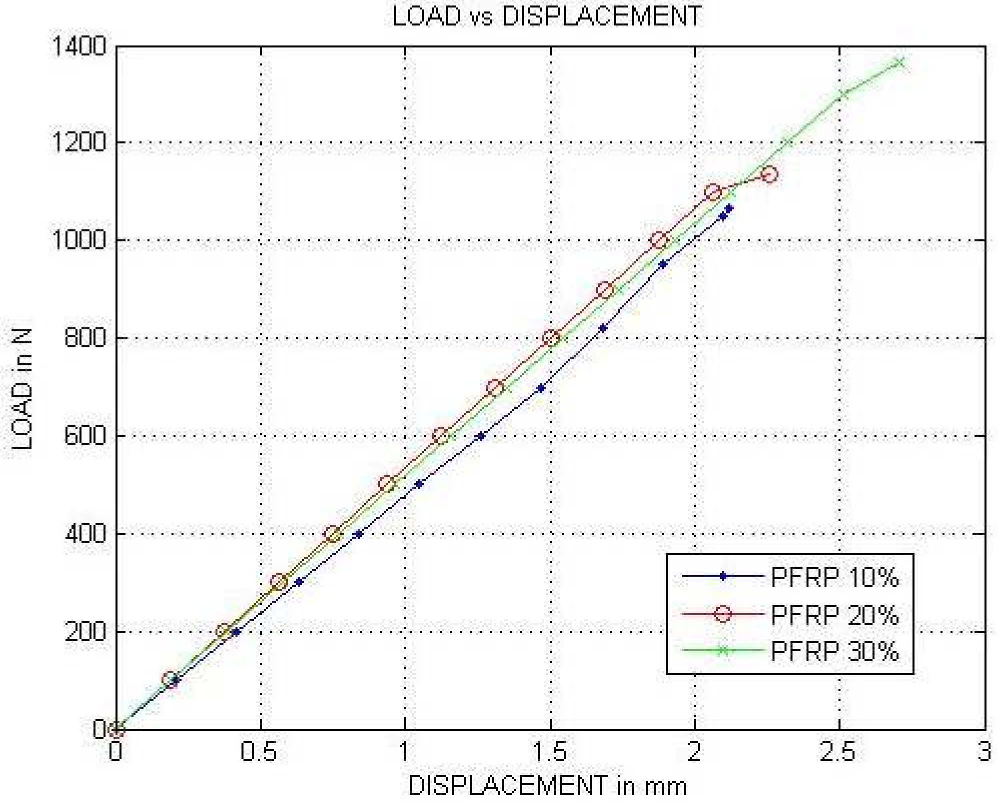


Figure (4): Load vs Displacement of PFRP Composites

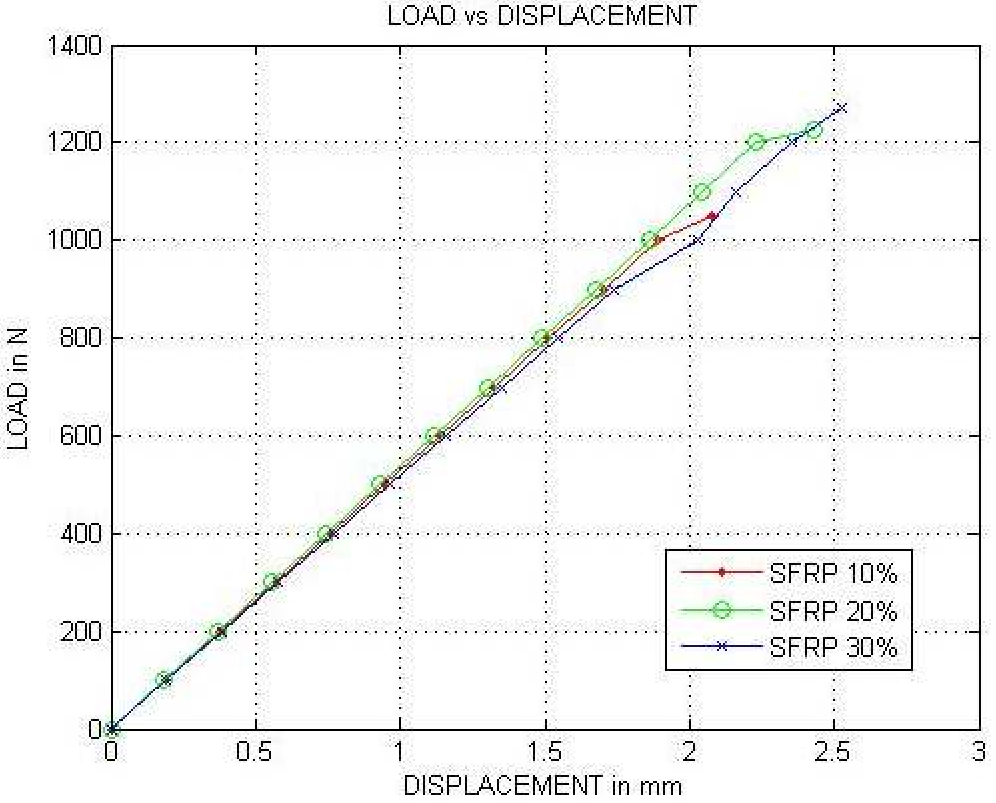


Figure (5): Load vs Displacement of PFRP Composites

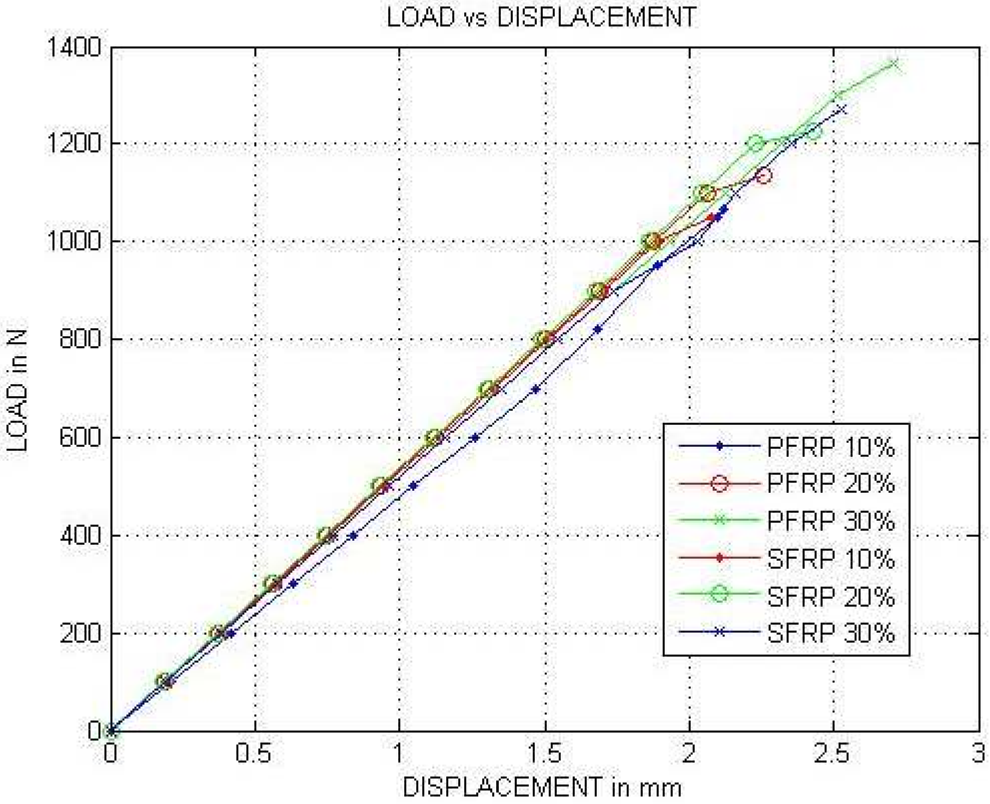
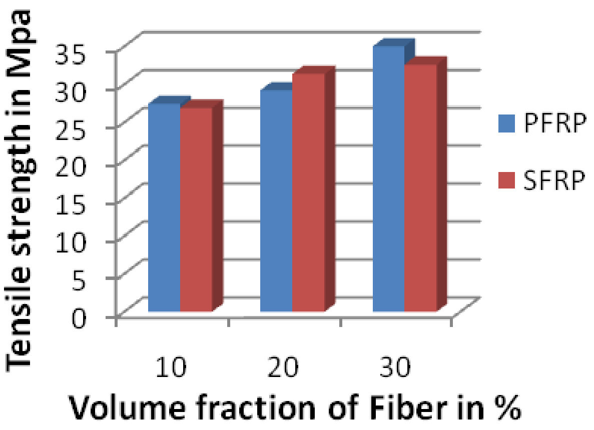


Figure (6): Load vs Displacement comparison of SFRP and PFRP Composites



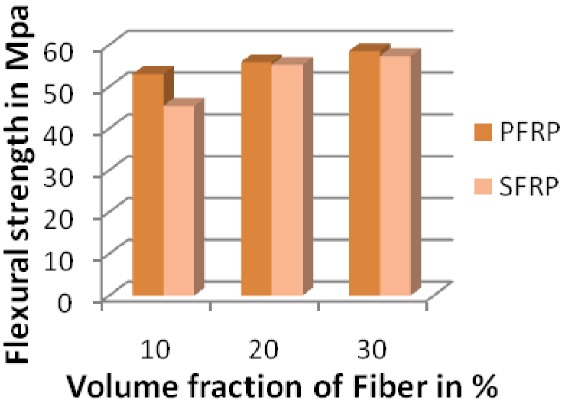
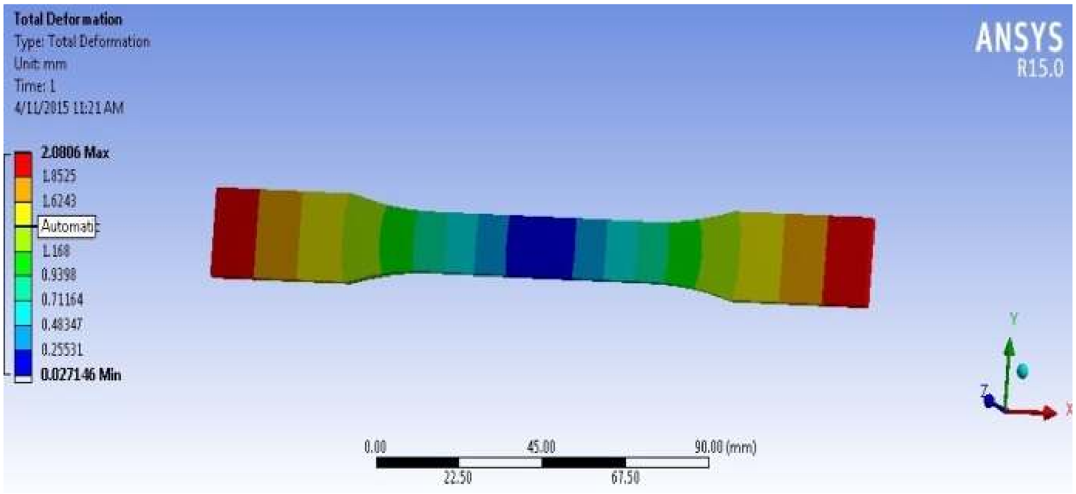


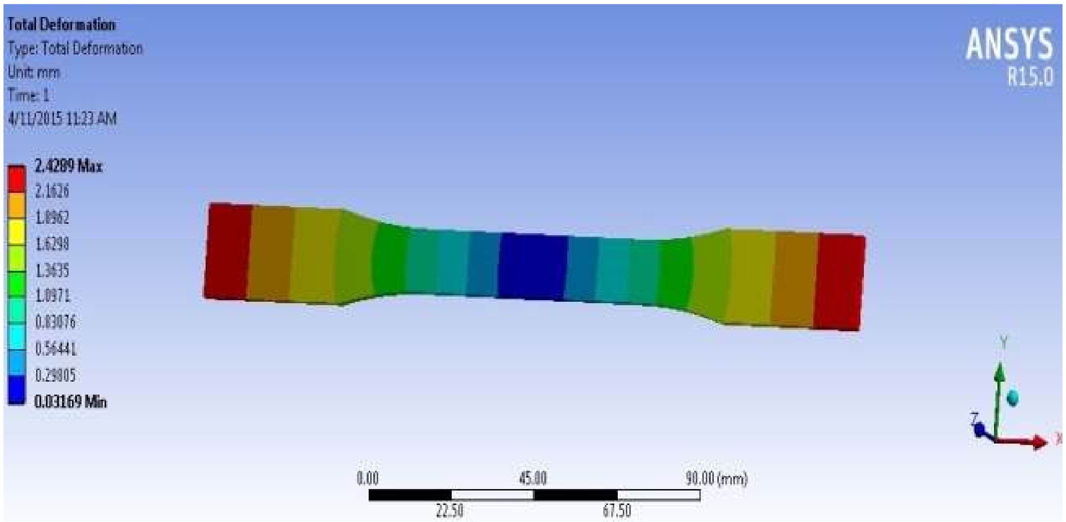
Figure (7): Tensile Strength vs volume fraction Figure (8): Flexural strength vs volume fraction

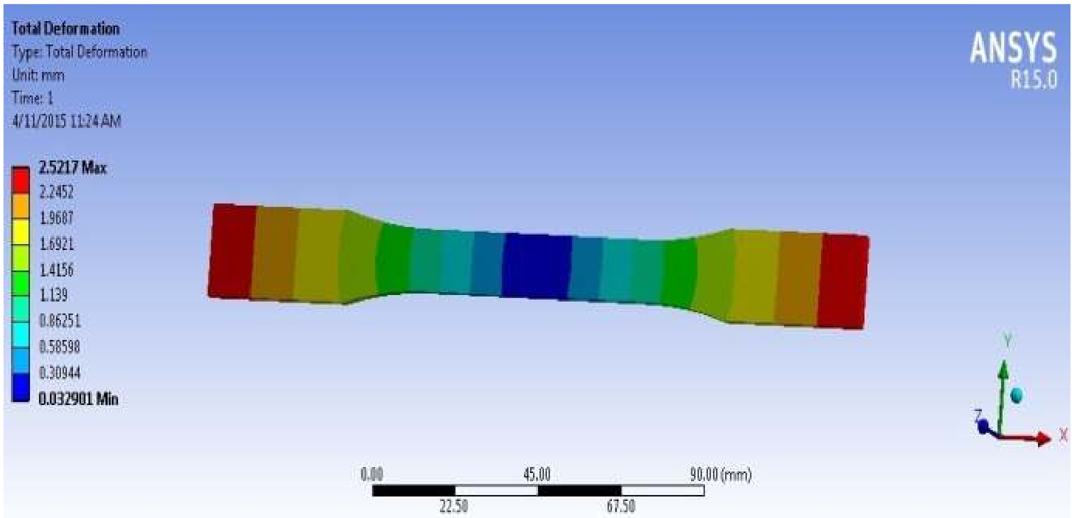
From Figure (7) shows tensile strength vs. volume fraction of PFRP and SFRP. Tensile strength of 30% volume fraction is higher than that of 20 % and 10 %. In 20 % volume fraction, Tensile strength of SFRP composites are high value but 30 % volume fraction, PFRP composite is high tensile strength. Similarly in flexural strength of 30 % volume fraction is higher than that of 20 % and 10 %. In 10 %, 20 % and 30 % volume fraction, flexural strength of PFRP composites are high value. Similarly In Impact strength 30 % volume fractions is better than 20 % and 10 %.

Table (5): Comparison Results sisal/polyester and Palm/epoxy composites.

Composite	**Volume Fraction V_f(%)**	**Loads (N)**	**Total Deformation (mm)**	**Equivalent Stress (MPa)**	**Max Shear stress (MPa)**
SFRP	10	1068.6	2.0806	27.615	4.5005
	20	1138.8	2.4249	32.261	5.2636
	30	1365.0	2.5217	33.494	5.4647
PFRP	10	1049.1	2.1183	28.136	4.5975
	20	1224.6	2.2587	30.001	4.8948
	30	1271.4	2.7074	35.960	5.8670



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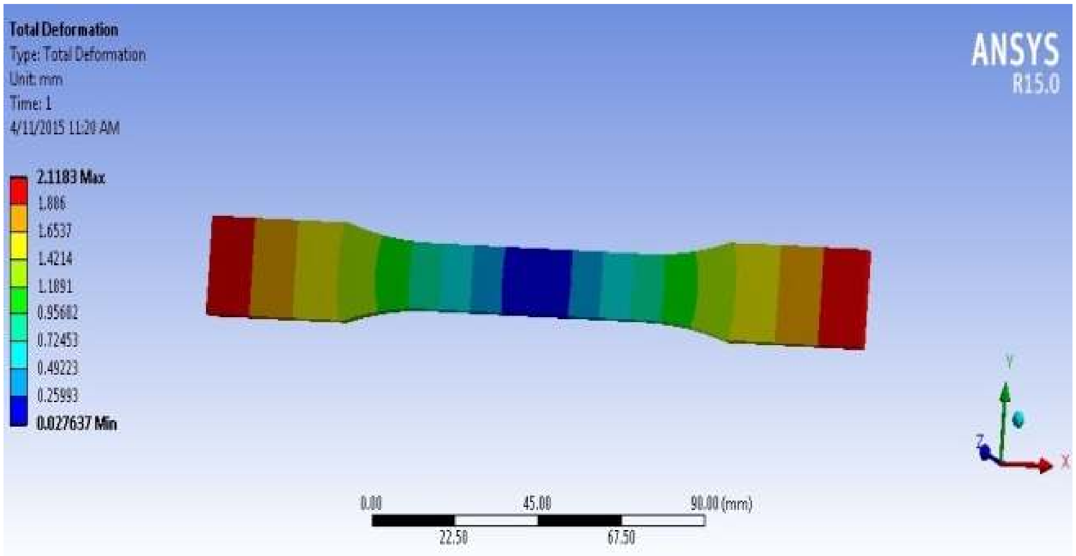
1.139
0.86251
0.58598
0.30944
0.032901 Min
ANSYS
R15.0
Y
Z
X
0.00
45.00
90.00 (mm)
22.50
67.50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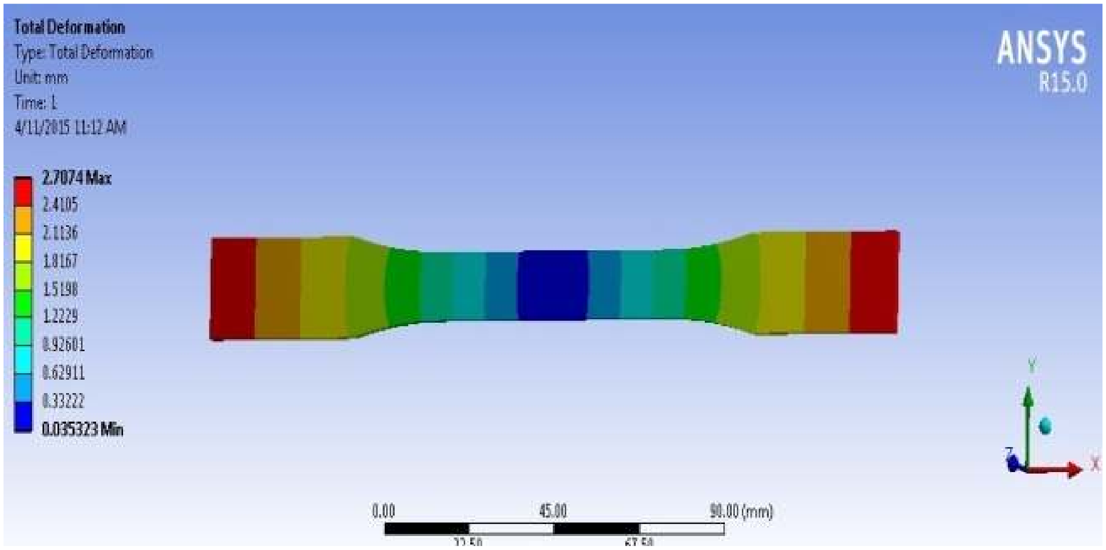
1.6537
1.4214
1.1891
0.95682
0.72453
0.49223
0.25993
0.027637 Min
ANSYS
R15.0
Y
Z
X
0.00
45.00
90.00 (mm)
22.50
67.50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1.2229
0.92601
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ANSYS
R15.0
Y
Z
X
0.00
45.00
90.00 (mm)

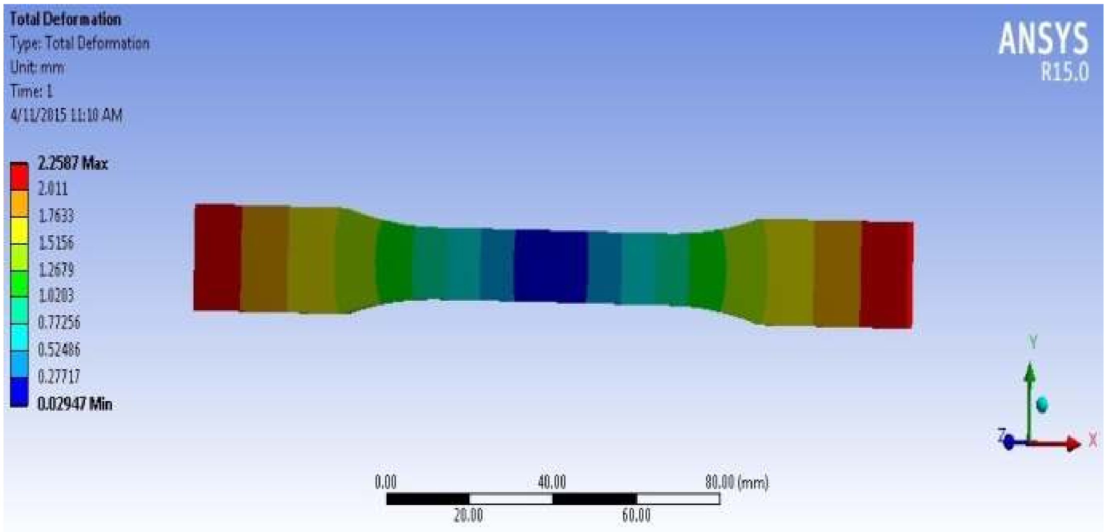
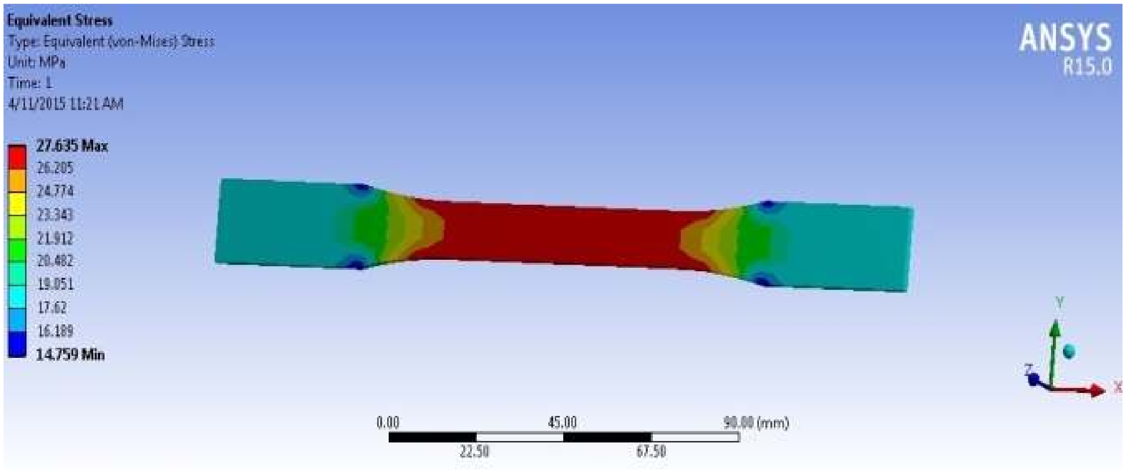
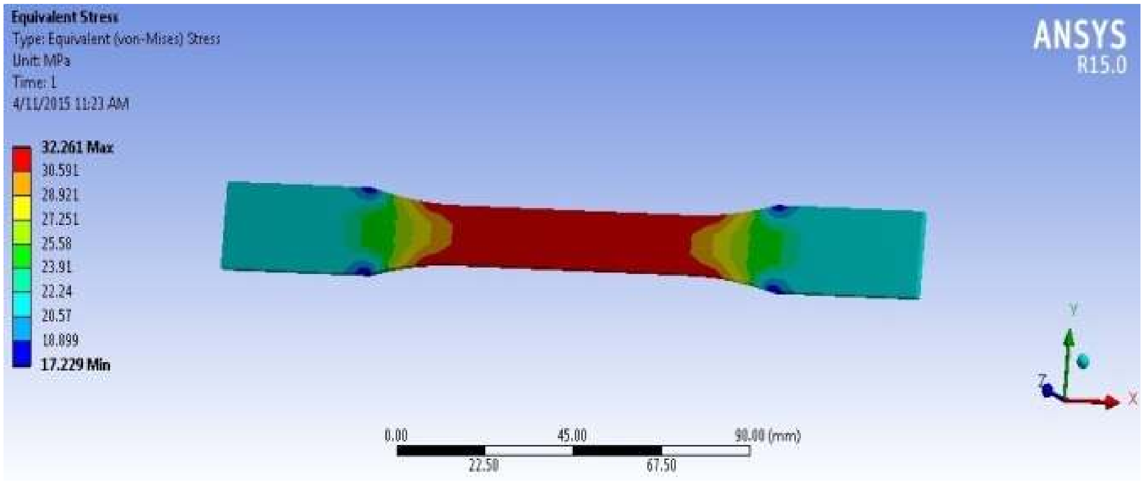
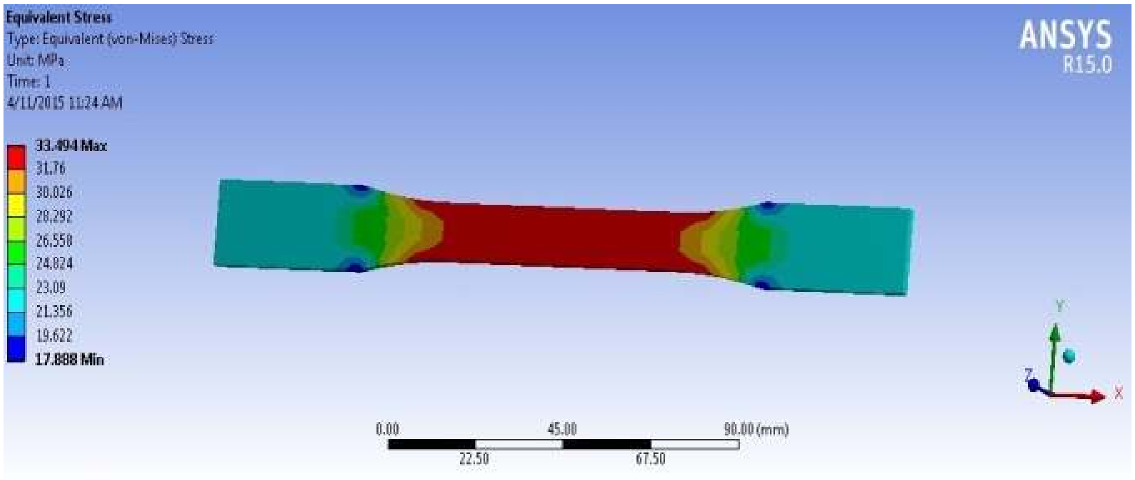


Figure (9): Total deformation of SFRP and PFRP at 10 %, 20 % and 30 % volume fraction of fibre.



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23.09
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ANSYS
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Z
X
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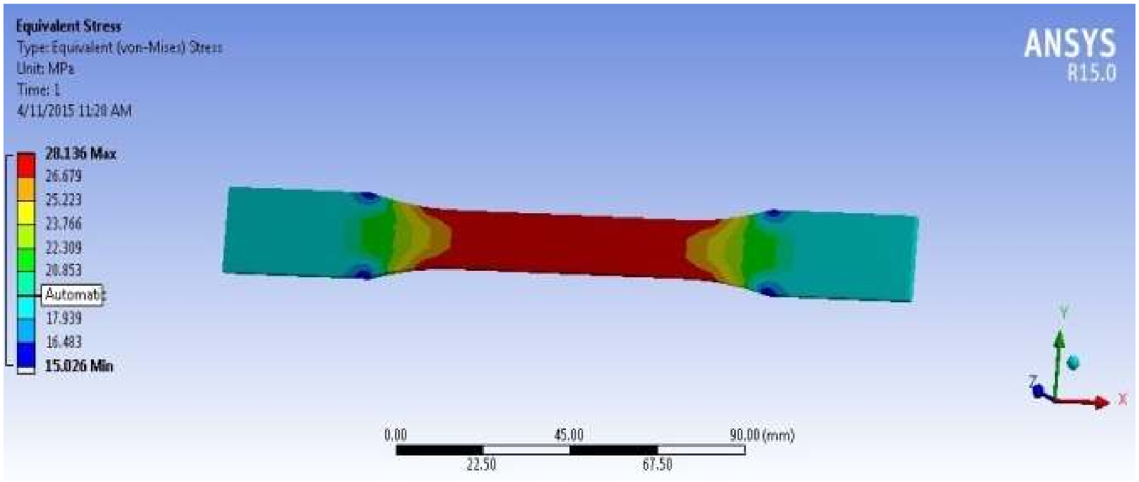
45.00
90.00 (mm)
22.50
67.50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Automati
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Z
X
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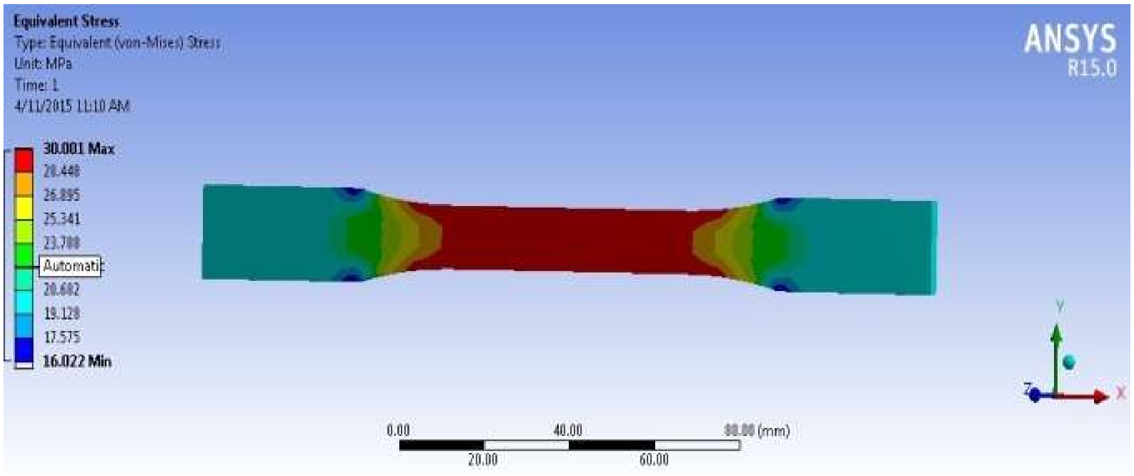
45.00
90.00 (mm)
22.50
67.50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80.00 (mm)
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60.00

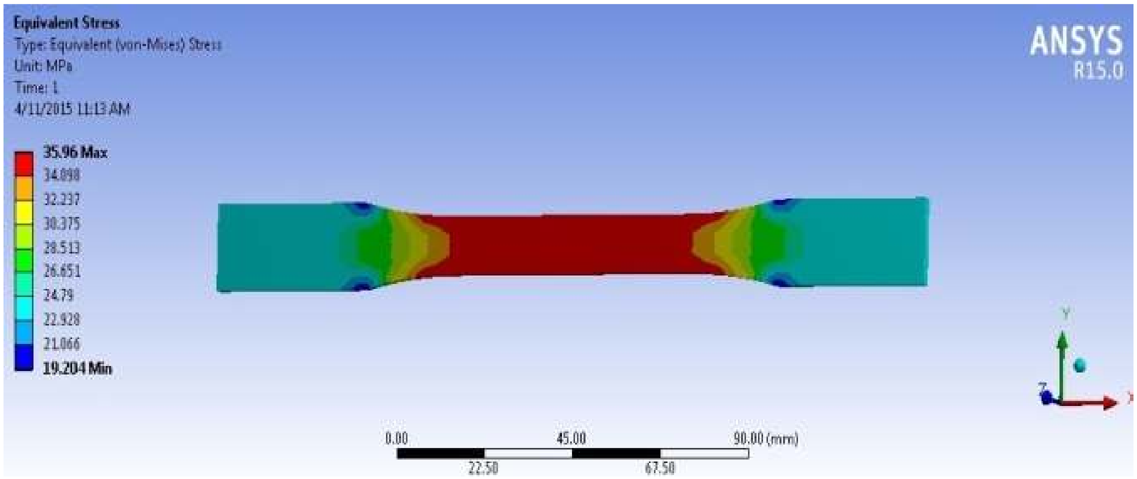
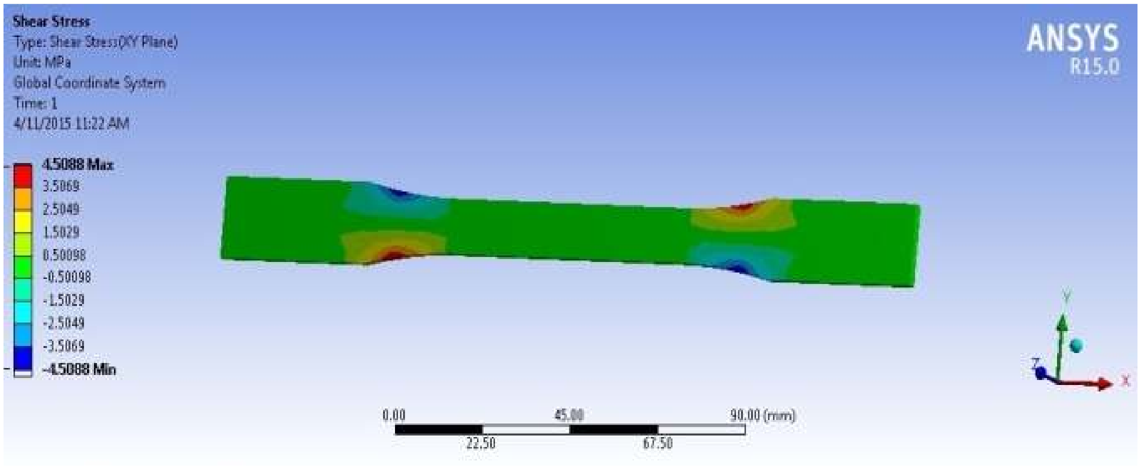
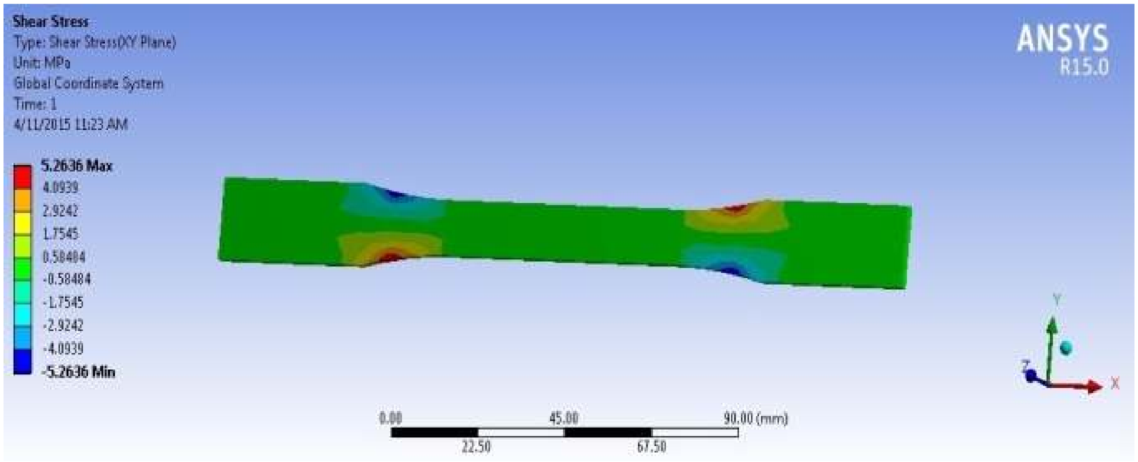
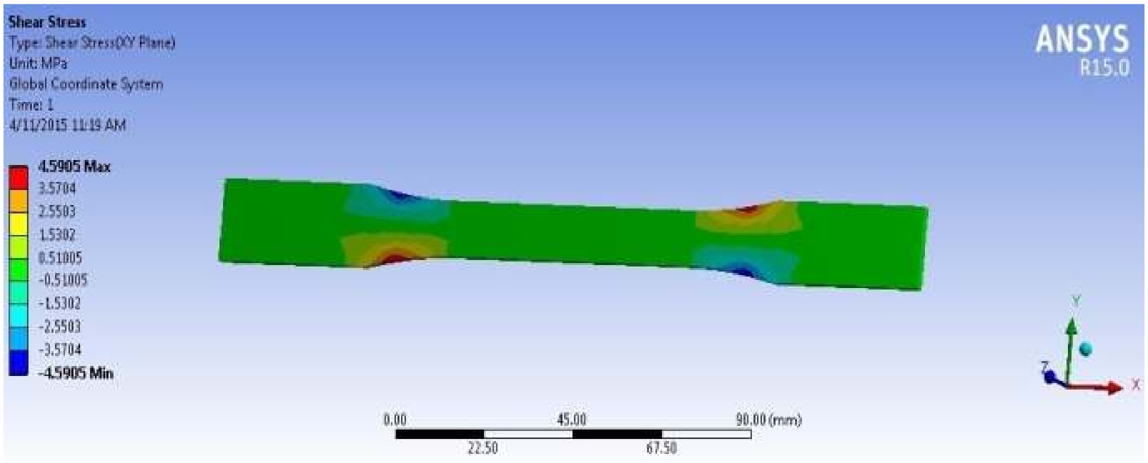


Figure (10): Equivalent stress of SFRP and PFRP at 10 %, 20 % and 30 % volume fraction of fibre.







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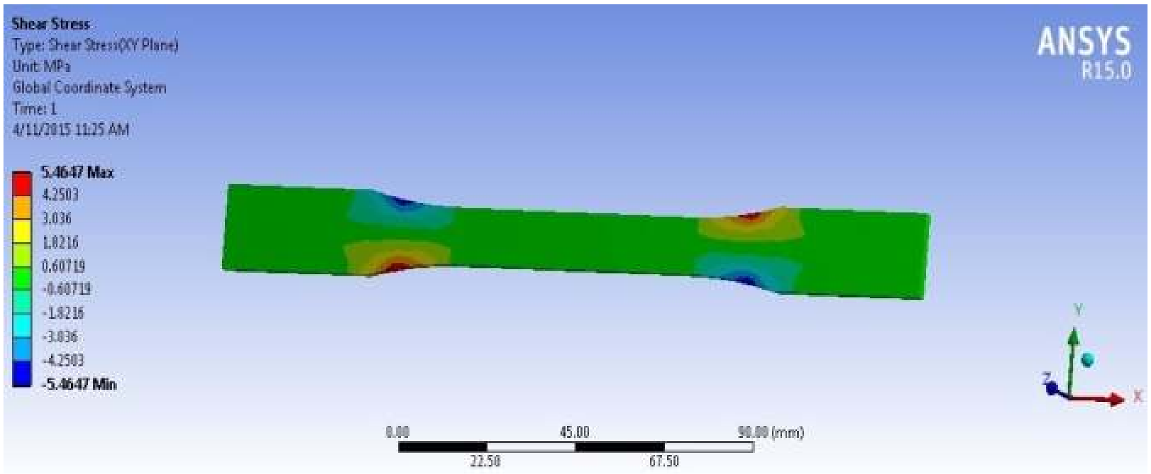

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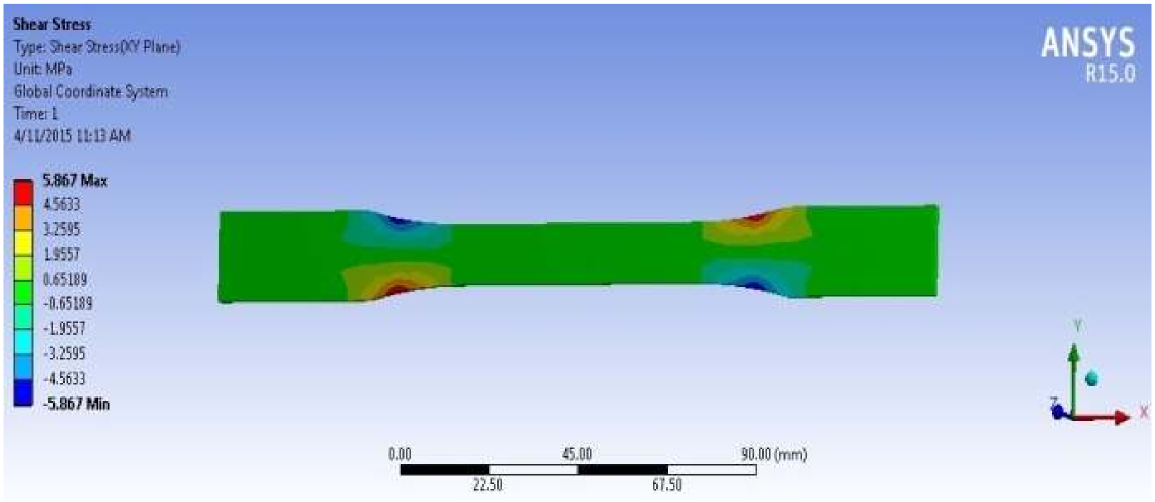

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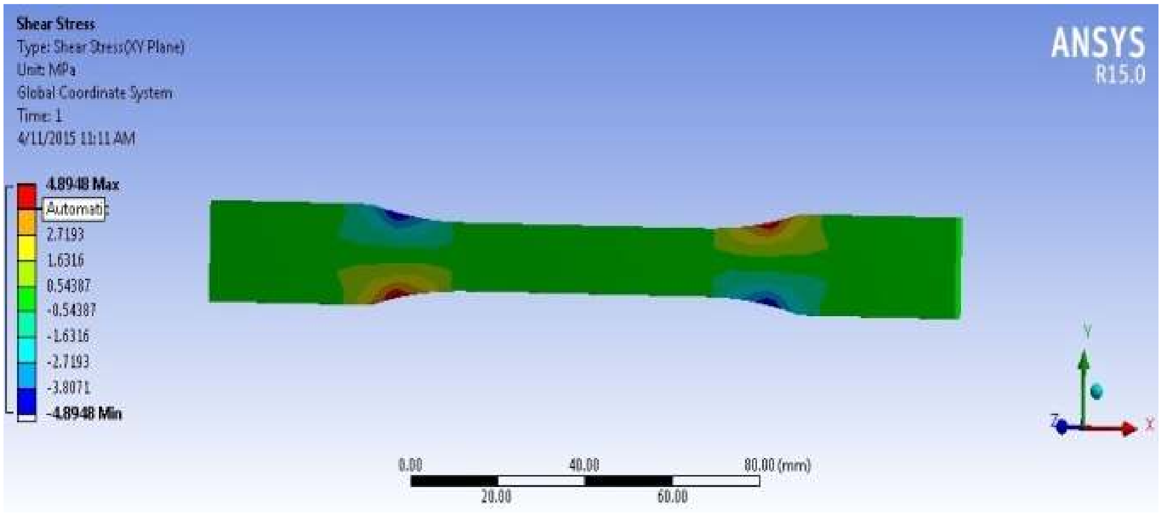

Figure (11): Maximum shear stress of SFRP and PFRP at 10 %, 20 % and 30 % volume fraction of fibre.

4.2 Finite Element Analysis (FEA): Finite element analysis of present work is done in ANSYS R15 Workbench. Thus the finite element modeling of the PFRP and SFRP composites for tensile specimens was developed with the static loading conditions using the orthotropic elasticity data in Ansys. It was modeled by using the CREO software. The FEA results in Figure (9, 10 and 11) show deflection and equivalent stress and shear stress for PFRP and SFRP composites respectively.

The Table (5) indicates the deflection in SFRP is lower compared to PFRP results having deflection around 2.7074. Similarly Equivalent stress and Shear stress in SFRP is lower compared to PFRP results having Equivalent stress around 35.960 MPa and shear stress around 5.8670 MPa. Compared both SFRP and PFRP, 30 % volume fraction have a better strength than 10 % and 20 %.

5. Conclusion: The study presents experimental investigation and Analysis of Mechanical Properties of Palm fibre reinforced Epoxy composites and Sisal fibre reinforced Polyester composites. Based on the experimental and analysis results the following conclusions were drawn.

- Increase in volume fraction of fibre in composites tends to increase the tensile strength, Flexural strength and Impact strength.
- Maximum load required to fracture, increase in volume fraction of fibre.
- Tensile strength, Flexural strength and Impact strength of 30 % volume fraction are higher than 10 % and 20 %.
- Tensile strength, Flexural strength and Impact strength of PFRP composites are considerably higher than SFRP composites.
- FEA shows maximum deflection, Equivalent stress and shear stress are 2.7074 mm, 35.96 MPa and 5.867 MPa for PFRP composites.

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