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Experimental and analytical investigation on mechanical properties of sisal fibre reinforced polyester composite

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Abstract - *Composite materials have occupied major part in current era due to its light weight, good stiffness, high specific strength and flexible nature. In the present scenario, environmental regulations and social concern are forcing the industries to explore new and eco-friendly materials that can replace non-degradable materials for a clean and green environment. Polymer composites based on natural fibres are developed by replacing synthetic fibres for applications in automotive and electronic fields. This study is aimed at investigating the mechanical properties of polyester resin reinforced with different weight fractions (10% and 20%) of sisal fibre by experimentally and ANSYS simulation. Static analysis is performed by FEA based software ANSYS 16.2 with design constraints as equivalent stress and deflection. From the results obtained, it is evident that increase in fibre content significantly improves the mechanical properties.*

Keywords – *sisal fibre, polyester resin, weight fraction, mechanical properties, compression moulding, ANSYS.*

I. INTRODUCTION

Composite materials are produced by combining two dissimilar materials into a new material that may be better suited for a particular application than either of the original materials alone. Polymer composites have been increasingly applied as structural materials in the aerospace, automotive and chemical industries, providing lower weight alternatives to traditional metallic materials. The role of polymer as a matrix in a fibre-reinforced composite is to transfer stresses between the fibres to provide a barrier against an adverse environment and to protect the surface of the fibres from mechanical abrasion [1]. Natural fibres present many advantages compared to synthetic fibres which make them attractive as reinforcements in composite materials. They come from abundant and renewable resources, which ensures a continuous fibre supply and a significant material cost saving to the plastics industry. Unlike brittle fibres, such as glass and carbon fibres, cellulose fibres are flexible and will not fracture when processed over sharp curvatures [9]. Natural fibres from renewable natural resources offer the potential to act as a biodegradable reinforcing materials alternative for the use of synthetic fibres. Natural fibres offer various advantages such as low density, low cost, biodegradability, acceptable specific properties, better thermal and insulating properties, and low energy consumption during processing [2]. Natural vegetable fibres, characterized by a rapid renewability, are environmentally friendly materials at all stages of their life cycle; that is to say, during extraction, production, processing, and disposal. Composites containing vegetable fibres such as sisal present soundproofing properties, the ability to absorb vibrations, and good impact properties due to their better elasticity, especially when modified with crushed fibres. Sisal reinforced polyester composites may be considered ecological materials because when burnt they produce less $CO2$, CO, and toxic gases than their unreinforced counterpart; also, one has to consider the benefits of all oxygen emissions from the sisal plantation [3].

II. EXPERIMENTAL

There are numerous methods for fabricating composite components. In this study manufacturing of composite is done by compression moulding process. compression moulding is a composite manufacturing process normally used to produce composite components in high production volume such as automotive components. There are two types of compression moulding process, i.e. Cold compression and hot compression mouldings.

2.1. Materials

Sisal fibres were purchased from Chandraprakash company, kolkatas India. Isophthalic polyester resin, cobaltnapthenate (accelerator), methyl ethyl ketone peroxide (curing agent) were procured from Surat, Gujrat, India. The properties of sisal fibre and isophthalic polyester resin used were given in Tables 1 and 2 respectively[4].

Table 2.1 Properties of sisal fibre

Diameter(mm)	0.22
Density (g cm^{-3})	1.45
Cellulose (%)	65-78
Hemicellulose(%)	10-14
Pectin(%)	10
Lignin(%)	9.9
Elongation at break (%)	2.5
Tensile strength (MPa)	314
Young's Modulus (MPa)	13600

Table 2.2 Properties of isopthalic polyester resin

Apprarance	Pale yellow color
Viscosity(cps)	650
Density(g cm^{-3})	1.15
Elongation at break(%)	4.79
Tensile strength(MPa)	29.8
Young's modulus(MPa)	915

2.2. Fabrication of composites

Fabrication was done by using compression moulding techniques. The fibres were chopped to the 30 mm length, washed with water, dried in air and used. The mould was polished and mould-releasing agents were applied. The fibres were arranged in the form of unidirection layer in mould. Isophthalic polyester resin was mixed with 1 wt% cobalt napthenate and 1 wt% methyl ethyl ketone peroxide. In compression moulding the resin mixture was poured into the unidirectional sisal until it is completely soaked. The mould was closed and pressed at a pressure of 10 kg/cm2 at room temperature. The curing was done for 12 h. For the fibre-reinforced composites, fabricated by compression moulding, the samples have been coded as C10 and C20: where 'C' represents compression moulding and '10' '20' represents the fibre content.

2.3. Mechanical property measurements

Tensile properties of pure polyester and sisal polyester composite were determined according to ASTM D638 and ASTM D3039 standard respectively. The measurements were done using a universal testing machine (Tiniusion olsen at chandubhai S. Patel Institute of Technology Changa, India) at a crosshead speed of 5 mm/min at room temperature. Flexural properties were determined in three point bend mode according to ASTM D790 standard at a speed of 5 mm/min. The measurements were performed at room temperature using a universal testing machine (Tinusion olsen). Izod impact measurements will do using IMPats-15 (Sartorius chandubhai S. Patel Institute of Technology Changa, India) impact tester at room temperature. The impact strength was determined by striking the bar shaped specimen with a hammer as per ASTM D256 [5].

2.3.1. Tensile testing of sisal fibres

The tensile strength of sisal fibres was measured in accordance with ASTM D 3822. Each fibre specimen was cut with a gauge length of 100 mm. Then the fibres are tested at a cross head speed of 5 mm/min. The test was carried out for 5 specimens to get a valid average. Tensile strength, Tensile modulus, Percentage elongation and Maximum extension of fibres were obtained. The diameter of the fibres was measured using a 3D microscope at five different locations along the gauge length and the average cross sectional area was calculated by assuming that the fibres were cylindrical in shape.

2.3.2. Testing of isopthalic polyester resin

The tensile strength of polyester was measured in accordance with ASTM D 638. Each fibre specimen was cut with a gauge length of 100 mm. The polyester at a cross head speed of 5 mm/min was tested. The test was carried out for 5 specimens to get a valid average. Tensile strength, Tensile modulus, Percentage elongation and Maximum extension of polyester resin were obtained. The thickness of the polyester was measured using a vernier caliper at five different locations of five different specimen was 5mm.

2.3.3. Tensile testing of sisal fibre reinforced polyester (SFRP) composite

The unidirectional composite specimens were made as per the ASTM D 3039 to measure the tensile properties. The gauge length, width and thickness of the specimens were 138, 15 and 6 mm respectively. The tensile modulus and the maximum composite stress were calculated by five identical samples were prepared for each weight fraction of fibre and all the specimens were tested at a strain rate of 5 mm/min using an UTM.

2.3.4. Flexural testing of sisal fibre reinforced polyester composite

Three point bend tests were performed in accordance with ASTM D 790to measure flexural properties. The samples were 96 mm gauge length by 12.7 mm wide by 6 mm thick. A three point bend test is chosen because it requires less material for each test and eliminates the need to accurately determine center-point deflections with test equipment. The flexural modulus and the maximum composite stress were calculated by five identical samples were prepared for each weight fraction of fibre and all the specimens were tested at a strain rate of 5 mm/min using an UTM. The density of the fibre and its composites were measured using picnometric procedure.

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III. RESULTS AND DISCUSSION

The stress as a function of percentage strain for sisal fibre reinforced polyester composites at 10% and 20%weight fraction of fibre is shown in Figure3.3 and Fig 3.4 respectively. The plot shows that the stress increases linearly with respect to strain for all composites specimen. Ultimate tensile strength and modulus of sisal fibre reinforced composites at 10% and 20% weight fraction of fibre, are presented in Figure3.3 and Fig 3.4. It is observed that the tensile strength and tensile modulus of all fibre reinforced composites considered in the present study increase with weight fraction of fibre.

3.1 Experimental results

A typical Stress vs. Strain and Load vs. Displacement graph of sisal fibre, pure polyester, 10% SFRP and 20% SFRP composites was recorded during tensile test and flexural test. Graph was drawn from these recorded values are shown in Figure 3.1 to Figure 3.6.

Figure 3.1 shows the load increases to reach the peak value at 13.6 N in case of only sisal fibre. But the maximum tensile strength, young's modulus and maximum extension of the sisal fibre reach to 357MPa, 17400MPa and 3.52 respectively.

Figure 3.2 to Figure 3.4 shows the load increases to reach the peak value at 4610 N in case of 20% weight fraction sisal fibre. But the load increases to reach the peak value at 3410 N for 10 % weight fraction sisal fibre. 20 % weight fraction takes higher load to fracture specimens due to maximum weight of fibre compare with 10 % weight fraction. And also 20 % weight fraction experienced maximum displacement at peak load around the value of 3.81 mm. Tensile strength of 20% weight fraction is higher than that of 10 % and pure polyester. Similarly in flexural strength of 20 % weight fraction is higher than that of 10 % and pure polyester.

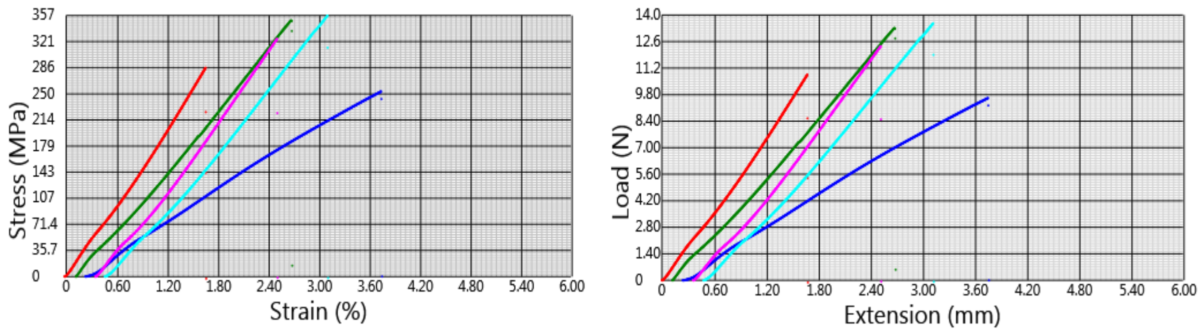

Figure 3.1.Tensile strength of sisal fibre

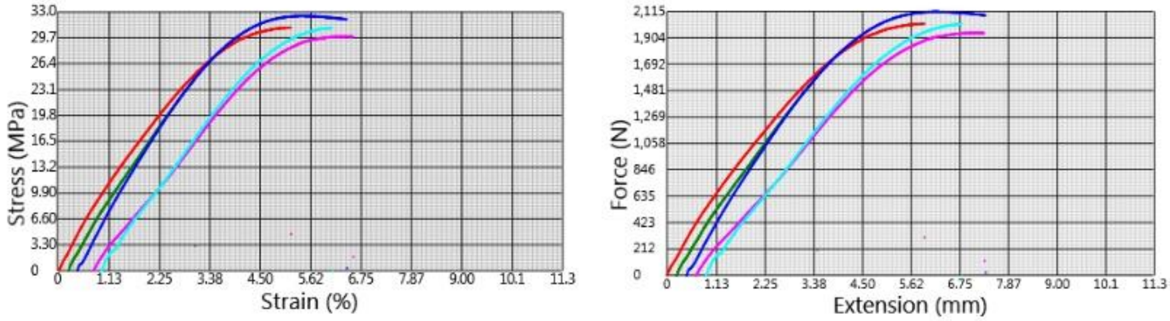

Figure 3.2. Tensile strength of plain polyester

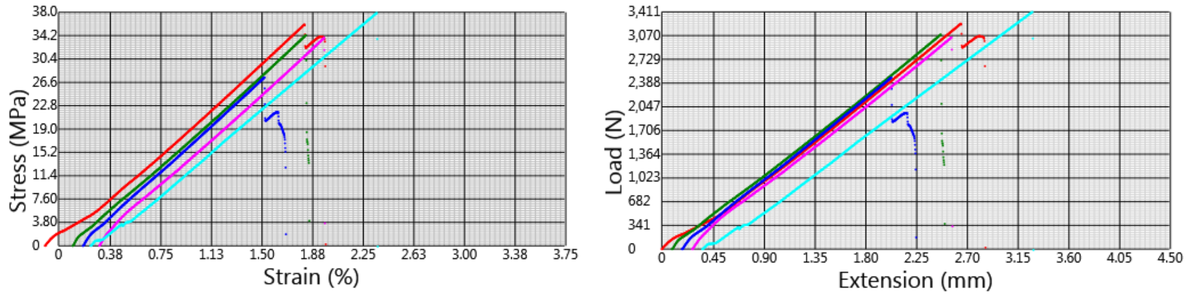

Figure 3.3. Tensile strength of 10% sisal polyester composite

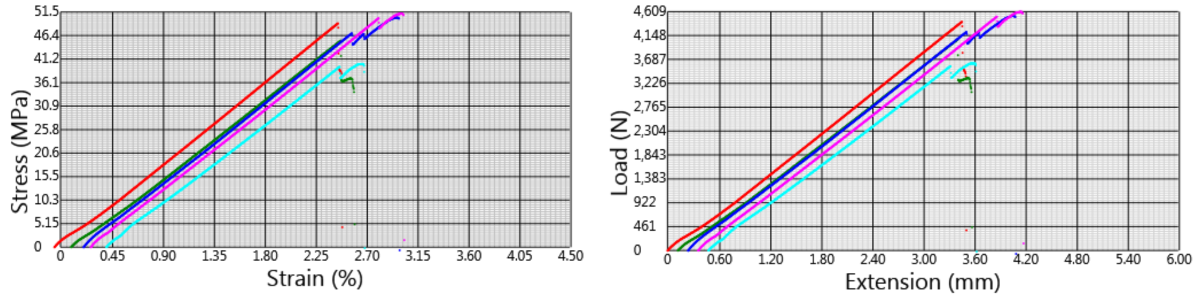

Figure 3.4. Tensile strength of 20% sisal polyester composite

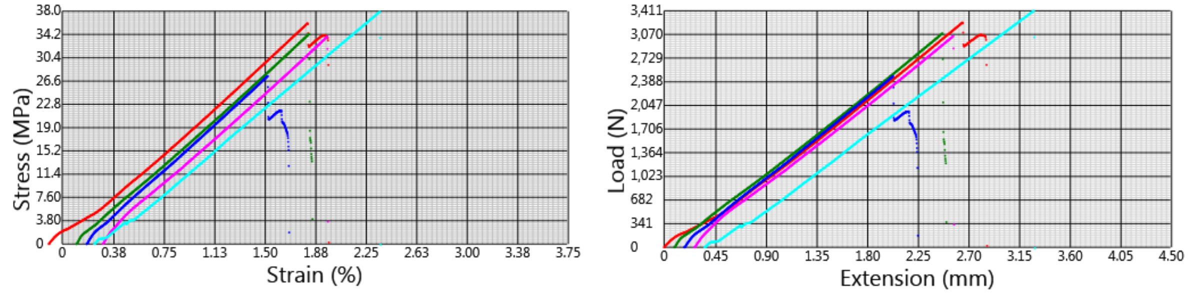

Figure 3.5. Flexural strength of 10% sisal polyester composite

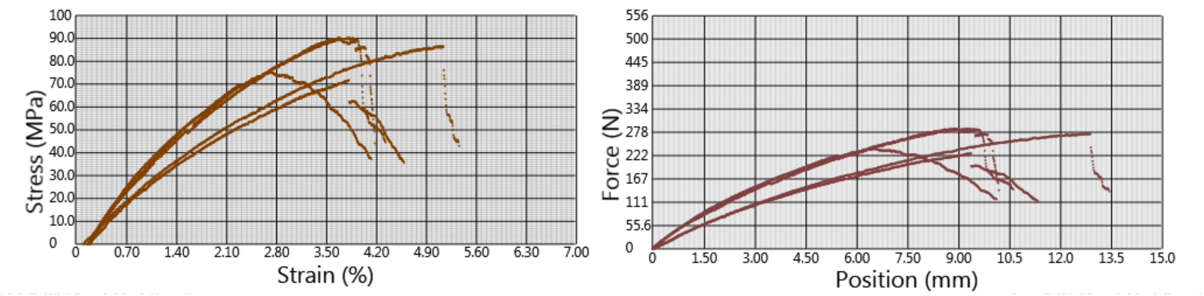

Figure 3.6. Flexural strength of 20% sisal polyester composite

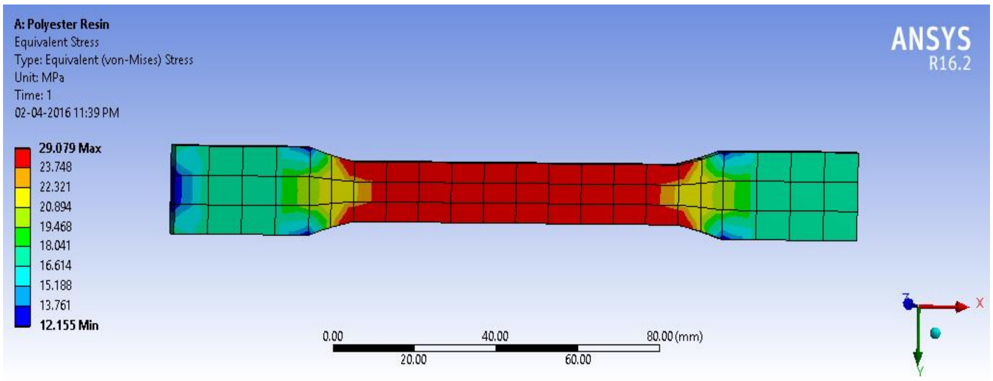

Figure 3.7 Equivalent stress of polyester resin

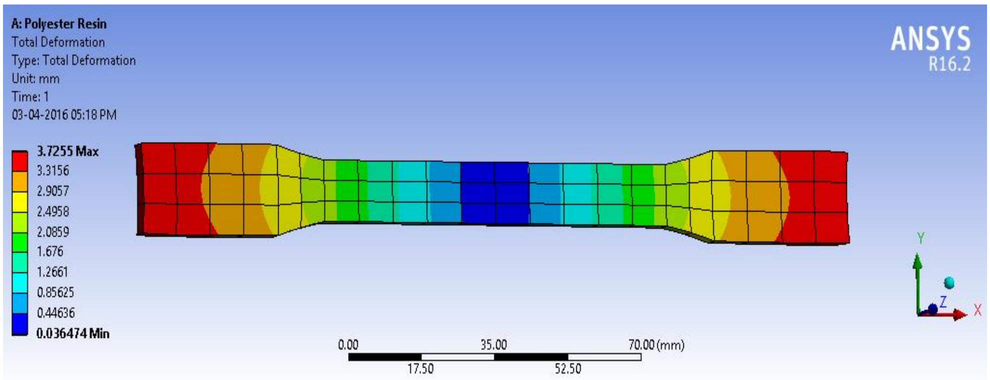

Figure 3.8 Total deformation of polyester resin

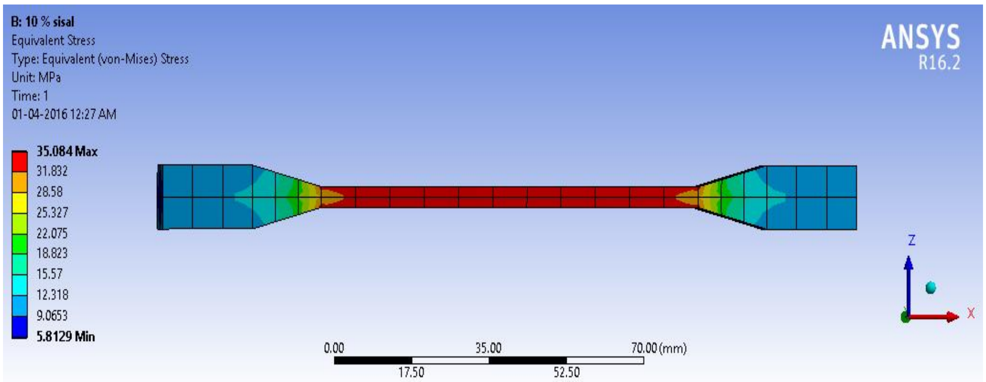

Figure 3.9 Equivalent stress of 10% sisal polyester composite

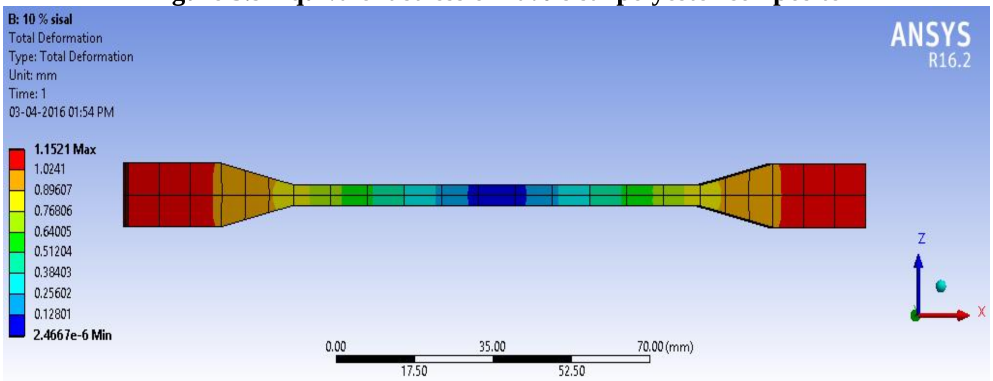

Figure 3.10 Total deformation of 10% sisal polyester composite

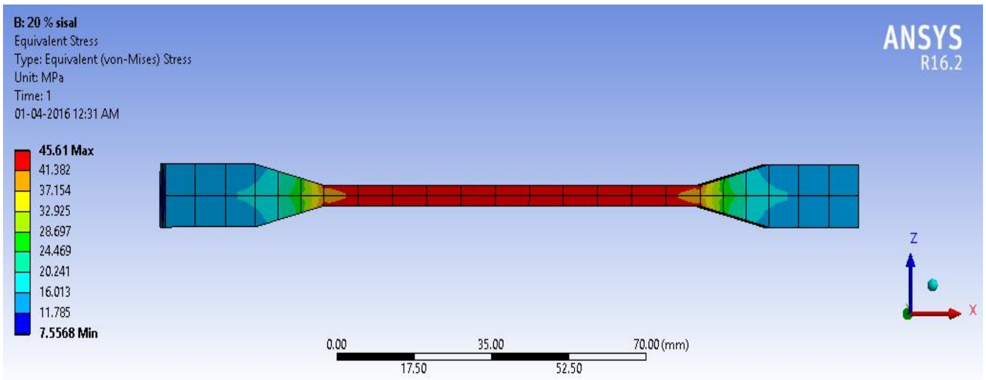

Figure 3.11 Equivalent stress of 20% sisal polyester composite

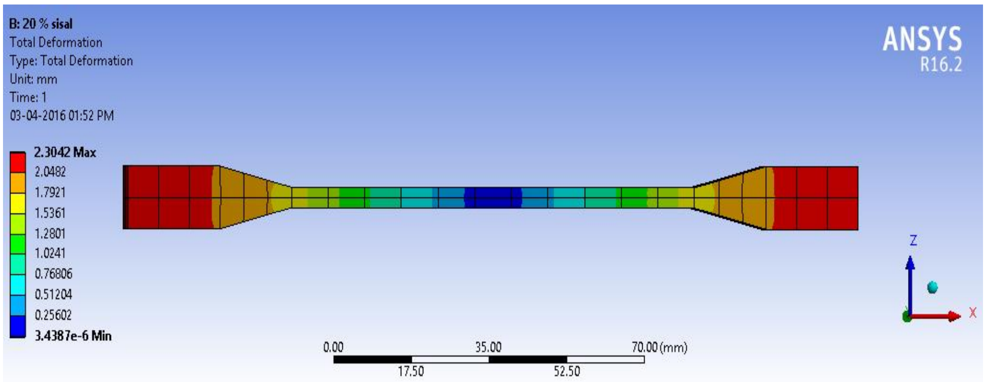

Figure 3.12 Total deformation of 20% sisal polyester composite

3.2 Simulation using ANSYS

Finite element analysis of present work is done in ANSYS R16.2 Workbench. Thus the finite element modeling of the sisal fibre reinforced polyester 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. From the experimental model, the load to be applied on the specimen is values are determined for the polyester composites reinforced with natural fibres at various weight fractions (10% and 20%). The results calculated from experimental approach are compared with ANSYS simulation for the polyester composites reinforced with different weight fractions of fibres (10% and 20%). Better correlation is obtained between the results of experimental approach and ANSYS simulation. Mechanical properties of various fibres with polyester resin for different weight fractions obtained using experimental approach and ANSYS simulations are illustrated in the Table 3.1. Incorporation of fibres (10% and 20%) in polyester resin leads to enhancement in tensile strength, modulus, toughness and impact strength of the polyester composites.
The FEA results in Figure3.7 to Fig 3.12 show deflection and equivalent SFRP composites. The result shows that the deflection in 20% SFRP is higher compared to 10% SFRP results having deflection around 2.3042. Similarly Equivalent stress in 20% SFRP is higher compared to 10% SFRP results having Equivalent stress around 45.61 MPa [6,7]

Table 3.1 Comparison between experimentally and analytically result

Fibre content Weight (%)	Tensile strength (MPa) experimentally	Total deformation (mm) experimentally	Tensile strength (MPa) analytically	Total deformation (mm) analytically	% error in tensile strength	% error in total deformation
Polyester resin	29.8	5.45	29.079	3.7255	2.41 %	3.164%
10% composite	33.9	2.42	35.084	1.1521	3.49 %	7.157%
20% composite	47.2	3.49	45.61	2.3042	3.37%	3.397%

Conclusion

The study presents experimental investigation and analysis of Mechanical properties of Sisal fibre reinforced Polyester composites. Based on the experimental and analysis results the following conclusions were drawn.

- Increase in weight fraction of fibre in composites tends to increase the tensile strength and Flexural strength.
- Maximum load required to fracture, increase in weight fraction of fibre.
- FEA shows maximum deflection and equivalent stress are 3.7255 mm and 45.61 MPa for SFRP composites respectively.
- % Error between experimental and analytical result in tensile strength and % error between experimental and analytical result in total deformation are much less.

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