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Effect of Silica on Thermal and Mechanical Properties of Sisal Fiber Reinforced Polyester Composites

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Abstract
The main objective of this paper is to investigate effect of silica on thermal and mechanical properties of sisal natural fiber reinforced polyester composites. The composites with and with out silica have been made by incorporating 100% biodegradable sisal fibers as reinforcement in the polyester matrix. The results show that the tensile strength and tensile modulus of composite with silica are 1.5, and 1.08 times greater than that of composite without silica, respectively. The impact strength of composite with sand is 1.36, and 1.8 times greater than that of composite with out silica and plain polyester, respectively. The effect of silica on specific heat capacity of composite is also considered and discussed.

Key words: Sisal fiber, silica, Mechanical properties, Specific heat, matrix

1. Introduction
Nowadays, people are thinking about biodegradable materials, since after end use disposed off easily without affecting environment. Natural fibers are completely biodegradable and can be used as reinforcement in the development of green composites. The advantageous of natural fibers: low cost, low density, acceptable Specific strength, less tool wears biodegradability, eco-friendly and renewability. Therefore, research in the field of using natural fibers has attracted much attention in the composite materials [1].

Several investigators worked on mechanical and thermal properties of natural fibers such as sisal, hemp, coir, kenaf and jute reinforced polymer composites. The tensile properties of sisal, hemp, coir, kenaf and jute reinforced composites have been studied, and reported [3]. Work is also done on the investigation of mechanical properties of bamboo fiber reinforced polymer composite. The experimental results of ultimate tensile strength and tensile modulus are 126.2Mpa and 2.48Gpa, while the ultimate flexural strength and flexural strength are 128.5Mpa and 3.7Gpa respectively [4].

In many applications, particularly in automotive industry components were subjected to mechanical as well as thermal loads. Hence, the thermal behavior of composites is of great importance. A considerable amount of literature is available on thermal behavior of synthetic fiber reinforced polymer composites [5-7]. However, little information is available on thermo physical properties of natural fiber reinforced composites over and above room temperature. Thermal conductivity and specific heat of composite increased with increase in the percentage of date pits flour and with the temperature of the blends; while MFI decreased as the percentage of the date pit increased [8]. Thermo physical properties such as thermal conductivity, thermal diffusivity and specific heat of waste grass broom fiber/ polyester composites were studied [9]. The thermal conductivity of composite decreased with increase in fiber content and the quite opposite trend was observed with respect to temperature. The specific heat capacity of the composite as measured by differential scanning calorimeter showed similar trend as that of the thermal conductivity. The variation in thermal diffusivity with respect to volume fraction of fiber and temperature was not so significant. Xue Li et al [10], studied the effect of volume fraction of flax fiber on thermal properties of the composite. It was found that thermal conductivity and thermal diffusivity of the flax fiber reinforced composite were decreased as fiber content increased. The effect of fibre volume fraction and fibre surface modification on thermo physical properties of sisal-banana hybrid fibre reinforced composites was studied [11]. It was found that as the fiber content increased the thermal conductivity of composite was decreased.

According to Lyons and Ahmed [12] , one of the main difficulties dealing with natural fiber composites is the adhesion between the fibers and the matrices. The chemical affinity between the cellulose and the polymeric matrix can be improved by the modification of the fiber surface or the polymer, using chemical additives, for instance, the maleic anhydride [13]. Tae-Hwan Park et.al studied synthesis of silicon monoxide–pyrolytic carbon–carbon nanofiber composites and their hybridization with natural graphite as a means of improving the anodic performance of lithium-ion batteries [14].

Previous researchers investigated the effect of silica on mechanical properties of natural fiber reinforced polymer composites [15,16]. Jia-Lin and Yi-Lieh [15], examined the response of mechanical behavior of composite with the addition of nanosilica particles. They found that as silica content increases, the compressive strength of composite increased. The effect of silica particles on the glass fibers surface is evaluated by Cao and Cameron [16], and concluded that the particles minimizing the onset and rate of crack propagation, due to increase in interfacial area.

There is no information available in the literature on effect of silica on thermal properties for polyester resin matrix of composite with sisal fiber .Therefore the focus of the work is to investigate the effect of macro particle silica on thermal and mechanical properties of sisal natural fiber reinforced polyester composite.

2. Materials and methods

2.1 Materials

Unsaturated polyester resin of grade ECMALON 4411, methyl ethyl ketone peroxide and cobalt naphthanate were purchased from Ecmass resin (Pvt) Ltd., Hyderabad, India. Sisal natural fibers were extracted from Sisal plant. Silica fine particles (size of 10 microns) were collected from local construction industry.

2.2 Extraction of sisal fiber

The sisal leafs are cut from Sisal Plant. These leafs are tied in to bundles and retted in water for about two weeks. The retted leafs were washed in running water and then fiber was cleaned and dried in sunlight for 12 hours and cut to the desired length.

Table 1. Composition of sisal fiber-polyester resin composition with and with out silica

Sample code	Polyester	Sisal fiber	Silica
A	100	0	0
B	65	35	0
C	60	35	5

Note: A=matrix, B=composite, C=composite + silica

2.3 Fabrication of composite

Hand lay-up technique was adopted in the preparation of unidirectional composites. The quantity of accelerator and catalyst added to resin at room temperature for curing was1.5% by volume of resin each. The mold was filled with an appropriate amount of polyester resin mixture and unidirectional fibers, starting and ending with layers of resin. Fiber deformation and movement should be minimized to yield good quality, unidirectional fiber composites. Therefore at the time of curing, a compressive pressure of 0.05MPa was applied on the mold and the composite specimens were cured for 24 h. The specimens were also post cured at 70 °C for 8 h after removing from the mold. In the same above process composites are also prepared by adding silica (5%) to resin and proper mixing were done before poured on fibers.

2.4 Tensile testing of the composite

The tensile properties of the composites were measured as per the standard test method ASTM D638-89. The test specimens with 160 mm long, 12.5 mm wide and 3 mm thick were prepared. Five identical specimens were tested for each type of composite. Overlapping aluminum tabs were glued to the ends of the specimen with epoxy resin filling the space at the tab overlap to prevent compression of the sample and also for effective gripping in the jaws of the chuck. The specimens were tested at a cross head speed of 2 mm/min, using an electronic tensometer (Model METM 2000 ER-1), supplied by M/s Mikrotech, Pune. India.

2.5 Impact strength testing of the composite

Izod impact test notched specimens were prepared in accordance with ASTM D256-88 to measure impact strength. The specimens were 63.5 mm long, 12.7 mm deep and 10 mm wide. A sharp file with included angle of 45° was drawn across the center of the saw cut at 90°to the sample axis to obtain a consistent starter crack. The samples were fractured in a plastic impact testing machine (capacity-21.68 J), supplied by M/s International equipment, Mumbai, India.

2.6 Measurement of specific heat capacity

Specific heat capacity is one of the most important thermodynamic properties of the engineering materials. The specific heat capacity of samples was measured using a differential Scanning calorimeter (Netzsch, Model No 200F3) at a heating rate of 10 °C/min.

3. Results and discussion

3.1 Mechanical properties

It is necessary to examine effect of silica on sisal fiber reinforced polyester composite. The mechanical properties such as tensile strength, tensile modulus and impact strength of sisal fiber reinforced polyester composites with and with out silica are presented in table 2(a)&2(b) .and also displayed in figures.

3.1.1 Tensile strength and tensile modulus

Tensile strength and tensile modulus are important mechanical properties in engineering materials .Effect of silica on tensile strength and tensile modulus of composite shows better results by comparing composite without silica and pure resin

Table 2(a): Tensile strength &Tensile modulus values for matrix, composite and composite with Silica

Samples	Tensile strength(MPa)	Tensile modulus(MPa)
A	36.28	803
B	61.1272	1667.245
C	92.6	1809.23

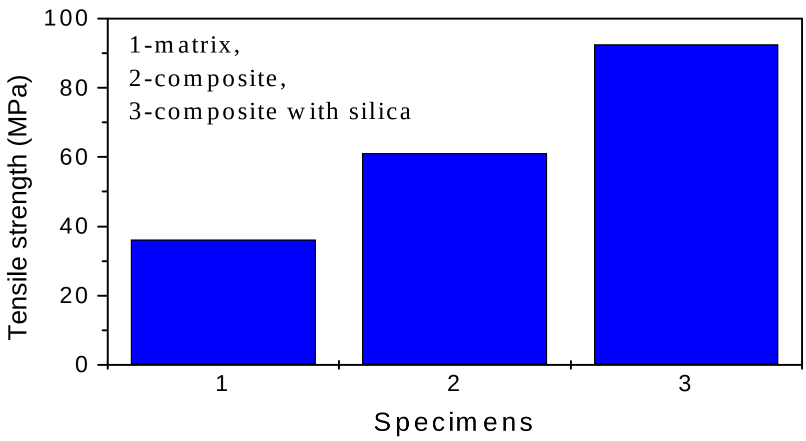

Figure.1: variation of tensile strength values of matrix, composite, and composite with silica.

It is seen that the tensile strength of the composite with silica is 1.5 times greater than that of composite with out silica and 2.5 times greater than that of pure resin. Tensile modulus of composite with silica (1809.23Mpa) is also higher than composite (1667.245Mpa) and virgin resin (803 Mpa) as shown in figure 2.

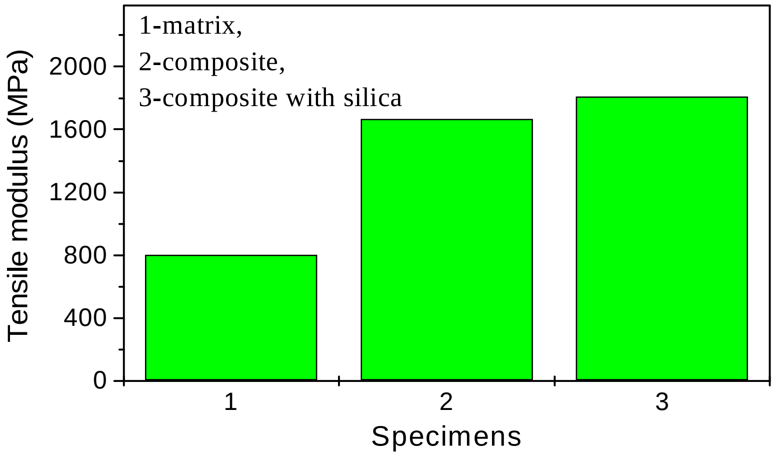

Figure 2: Tensile modulus of matrix, composite and composite with silica

3.1.2 Impact strength:

The variation of impact strength of sisal fiber reinforced composite by adding silica is shown in figure 3.By adding the silica, the value of impact strength of composite increases. The impact strength of composite with silica is 1.36 times more than composites and 1.8 times more than matrix. Hence, sisal fiber composites by adding silica have potential applications where light weight and resistance to impact are primary requirements.

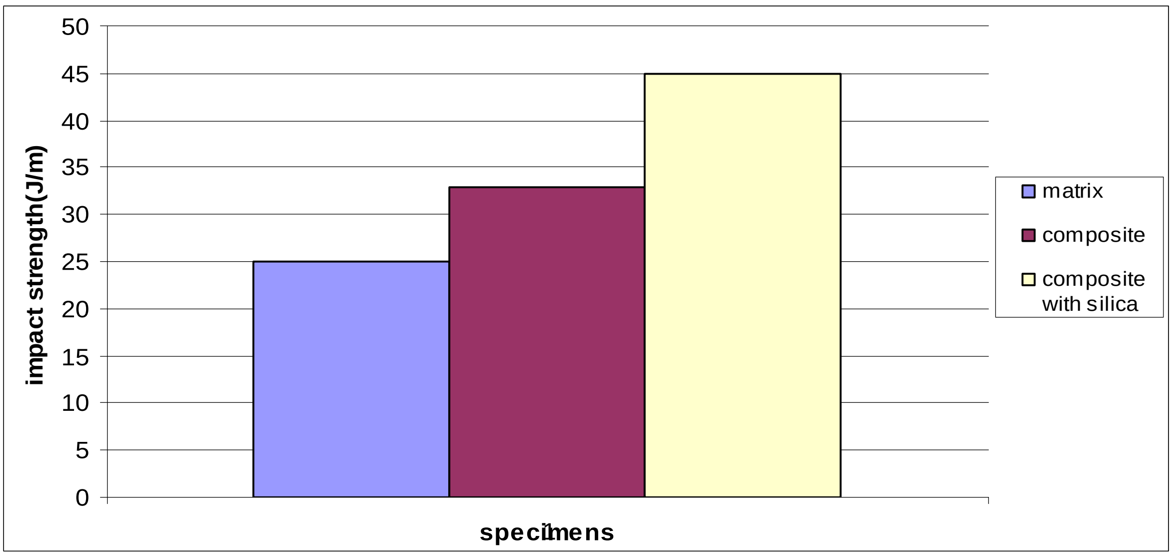

Figure 3: Impact strength of matrix, composite and composite with silica

3.2. Specific heat capacity

Specific heat capacity is one of the most important thermodynamic properties of the engineering materials. The specific heat capacity was independent of the mass and shape of the material. Figure 4 shows the variation in specific heat values of samples with respect to temperature. It is observed that specific heat values of all the measured samples increased gradually in the temperature range of 30°C to 85 °C i.e. better storage of heat is possible.

In the temperature range (30°C - 85 °C), the specific heat of composite is increased by 13.6 % over the virgin polyester. The increase in specific heat of composite with silica over composite and matrix is 19.16% and 35.37%, respectively. This may be due to higher values of specific heat of silica and fiber than virgin polyester. Further increase in temperature (85°C-120°C) for three samples, the decrease in specific heat is observed (Fig 4). This is attributed to decrease of photons mean free path. In application, if there is more than 85 °C, it leads to thermal instability of composite.

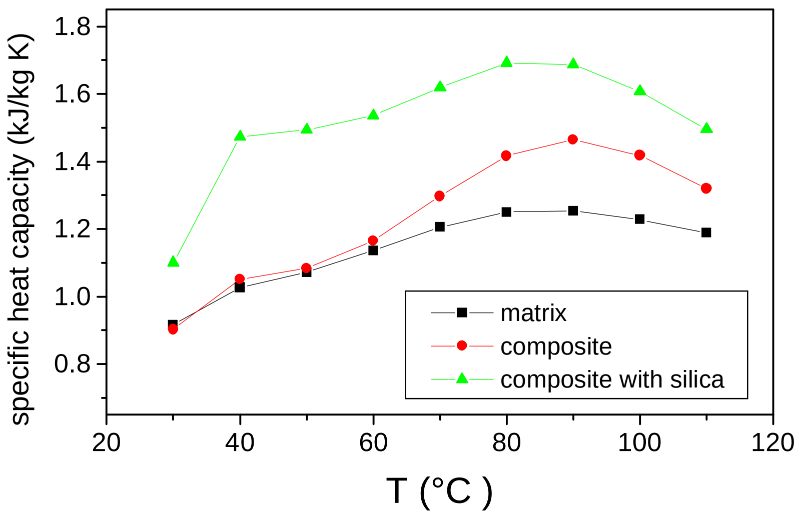

Figure 4: Variation of specific heat capacity of matrix, composite and composite with silica

4. Conclusion

From the experimental results obtained, the following conclusions are drawn:

- The tensile strength of composite with silica is 1.5 times greater than that of composite with out silica and 2.5 times greater than that of pure resin.
- Tensile modulus of composite with silica is1.809 GPa, whereas for composite without silica is about 1.67 GPa.
- The impact strength of composite with silica is 80% greater than that of matrix.
- The specific heat capacity of all samples increased with increase of temperature (30°C - 85 °C), and then decrease beyond 85 °C.

Hence, the addition of silica exhibit favorable both in mechanical and thermal properties. Further, the authors investigating the effect of silica on fire behavior of composite which is under process.

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