Study on Treatment for Long Sisal Fibers for the Direct Extrusion Compression Moulding Process

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***Abstract*— In recent years, natural fiber reinforced composites have received much attention because of their many advantages such as light weight, non-abrasive, non-toxic, low cost and biodegradable properties. Natural fiber reinforced composites have many applications as a class of structural materials because of the case of fabrication, relatively low cost of production. Although the synthetic fibers such as glass, carbon possess high specific strength, their fields of application are limited because of their inherent higher cost of production. Natural fibers reinforced composites material can be processed by direct extrusion compression moulding. In this process the effect of heat on the matrix is very high, therefore thermal degradation is major concern. The adjective of the project were is to study of chemical treatment on sisal fibers and their co-relation with the final mechanical properties of moulded part.**

INTRODUCTION

In recent times polymer matrix composites reinforced with fibers such as glass, carbon, aramid, etc. are getting in more uses because of their favorable mechanical properties. However, they are quite expensive materials. Composites made from glass fiber as reinforcement cause acute irritation of the skin, eyes, and upper respiratory tract. When released, glass fiber does not degrade and results in environmental pollutions and threatens animal life and nature. The new environmental regulations and uncertainty about petroleum and timber resources have triggered much interest in developing composite materials from natural fibers. This interest in the natural fibers has resulted in a large number of modifications to bring it at par and even superior to synthetic fibers. Because of such tremendous changes in the quality of natural fibers, they are fast emerging as a reinforcing material in composites. Different matrices before and after treatment by different methods; along with this they present a summary of recent developments of sisal fiber and its composites. The properties of sisal fiber interface between sisal fiber and matrix, properties of sisal fiber-reinforced composites and their hybrid composites.

Sisal fibre is obtained from the leaves of the plant *Agave sisalana*, which was originated from Mexico and is now mainly cultivated in East Africa, Brazil, Haiti, India and Indonesia (Nilsson, 1975; Mattoso et al., 1997). It is grouped under the broad heading of the "hard fibres" among which sisal is placed second to manila in durability and strength (Weindling,1947). The name "sisal" comes from a harbor town in Yucatan, Maya, Mexico (Nilsson, 1975). It means cold water. Agave plants were grown by the Maya Indians before the arrival of the Europeans. They prepared the fibres by hand and used it for ropes, carpets and clothing. It is one of the most extensively cultivated hard fibre in the world and it accounts for half the total production of textile fibres (Lock, 1962; Wilson, 1971). The reason for this is due to the ease of cultivation of sisal plants, which have short renewing times, and is fairly easy to grow in all kinds of environments. A good sisal plant yields about 200 leaves with each leaf having a mass composition of 4% fibre, 0.75% cuticle, 8% other dry matter and 87.25% moisture. Thus a normal leaf weighing about 600g yields about 3% by weight of fibre with each leaf containing about 1000 fibres (Kallapur, 1962). The fibre is extracted from the leaf either by retting, by scraping or by retting followed by scraping or by mechanical means using decorticators (KVIC, 1980). The diameter of the fibre varied from 100 m to 300 m (Mukherjee & Satyanarayana, 1984).

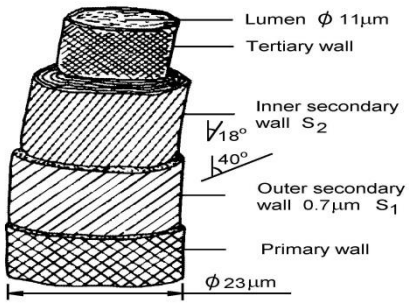

Fig 1. Schematic sketch of a sisal fiber cell with approximate dimensions

CONTINUOUS FIBRE COMPOSITES:

Long fibre reinforcements produce a significant improvement in the strength of thermoplastic based composite parts (Bartus et al.). The main limitation for the production of long biofibre composites is the ability to feed them into the compounding system. Short fibres of about 3 mm or less can be pre-compounded and pelletized using batch or continuous systems which can be later feed into the hopper of a twin screw extruder. The fibres can also be pelletized using the method described earlier on this paper, but this is a labour intensive process with applicability at a laboratory scale. The goal is to devise a Direct Long Fibre Thermoplastic (D-LFT)

process using continuous sisal rovings. The sisal rovings are characterized by their tex number, defined as the number of grams of material per kilometer of roving, and the tpi, defined as the number of twists per inch. The tex number is crucial in the determination of the percentages of fibre added to the composite material whereas the tpi is a parameter that affects the pulling strength, generally increasing as the number increases, but also affects the ability to de-bundle and disperse the fibres into the polymer melt. The selection of the right combination of tex and tpi numbers for the sisal rovings has a significant impact on the effectiveness of the manufacturing technique. In order to attain the typical properties required for automotive components, natural fibres are used in conjunction with glass fibres.

LITERATURE SURVEY

Barkakaty (1976) has reported the structural aspects of sisal fibre. He has studied the molecular structure of the paracrystalline cellulose, which forms the major constituent of the fibre by x-ray diffraction technique. He also studied the multicellular structure, surface topology, and fracture morphology and the effect of chemical treatment on sisal fibre.

Mattoso et al. (1997) have reported the extraction methods, morphology and chemical modifications of sisal fibre and its application as reinforcement agents in polymer composites.

Mukherjee & Satyanarayana (1984) have studied the mechanical properties of sisal fibre such as initial modulus (the extent to which the fibre resists the deformation in the low strain region is called the initial modulus of the fibre), ultimate tensile strength, average modulus and percent elongation as a function of fibre diameter, test length and the speed of testing. It was reported that tensile properties of fibre vary with test length of the fibre.

Padmavathi & Naidu (1998) have studied the chemical resistance and tensile strength of sisal fibres (*Agave veracruz*). It was noted that sisal fibres were more resistant to concentrated HCl compared to other acids. The fibres treated with 18% solution of NaOH showed more tensile load than the other chemically modified fibres

Edwards et al. (1997) have studied the application of FT-Raman microscopy to the non-destructive analysis of sisal fibres.

Chand & Joshi (1995) have investigated the effect of gamma irradiation on structure and dc conductivity of this sisal fibre. It was found that exposure of sisal fibre to gamma-irradiation increased the dc conductivity, which has been explained on the basis of microstructure.

Singh et al. (1998) have studied the adsorptive interaction between sisal fibre and coupling agents using contact angle measurements and Fourier transform infrared spectroscopy. It was found that high contact angle and reduced hydroxyl groups on titanate-treated fibres favor its better hydrophobicity over the other treatments

Joseph et al. (1992,1993ab, 1994) have investigated the mechanical, rheological, electrical and viscoelastic properties of short sisal fibre reinforced LDPE composites as a function of processing method, fibre content, fibre length and fibre orientation. They have reported that the fibre damage normally occurs during blending of fibre and the polymer by the melt mixing method can be avoided by adopting a solution mixing procedure. They have also reported that unidirectional alignment of the short fibres achieved by an extrusion process enhanced the tensile strength and modulus of the composites along the axis of the fibre alignment by more than two fold compared to randomly oriented fibre composites.

MATERIALS AND METHODS

MATRIX PREPARATION

Thermoplastic is a thermosetting polymer that cures (polymerizes and cross links) when mixed with a hardener. Thermoplastic resin of the grade LM-556 with a density of 1.1–1.5 g/cm3 was prepared with a mixture of thermoplastic and hardener (HY-951) at a ratio of 10:1.

Fiber preparation

The natural fibers such as Sisal, banana empty fruit bunch fibers and bamboo were extracted by the process of retting and decorticating. The cured fibers were then thoroughly washed and combed to free the flesh thoroughly and dried. The dried fibers were thinned by ramming to remove the unwanted short and broken fibers.

SURFACE TREATMENT

As the natural fibers bear hydroxyl groups from cellulose and lignin, therefore, they are amenable to modification. The hydroxyl groups may be involved in the hydrogen bonding within the cellulose molecules thereby reducing the activity towards the matrix. Chemical modifications may activate these groups or can introduce new moieties that can effectively interlock with the matrix. Pretreatments of the fiber can clean the fiber surface, chemically modify the surface, stop the moisture absorption process and increase the surface roughness.Initially, all the fibers were washed with water for five times, dried at room temperature for 48 hours, then, were immersed in 10% sodium hydroxide (NaOH) solution for 24 hours and finally washed with very dilute hydrochloric acid (HCl) to remove the residual alkali. Then, the fibers were rinsed with distilled water twice or thrice. The rinsed fibers were dried at room temperature for 2–3 days.

PREPARATION OF THE MOULD

A mould made up of GI (gauge 25) sheet of dimension 170X15X3 mm is prepared. Casting of the composite materials is done in this mould by hand lay up process. Later specimens are cut from the prepared casting according to the ASTM (D 638 M) Standard.

CHEMICAL TREATMENT ON INTERFACIAL ADHESION:

ALKALI TREATMENT

Alkali treatment of cellulosic fibers, also called mercerization, is the usual method to produce high quality fibers. Alkali treatment improves the fiber-matrix adhesion due to the removal of natural and artificial impurities. Moreover, alkali treatment leads to fibrillation which causes the breaking down of the composite fiber bundle into smaller fibers. In other words, alkali treatment reduces fiber diameter and thereby increases the aspect ratio. Therefore, the development of a rough surface topography and enhancement in aspect ratio offer better fiber-matrix interface adhesion and an increase in mechanical properties. Alkali treatment increases surface roughness resulting in better mechanical interlocking and the amount of cellulose exposed on the fiber surface. This increases the number of possible reaction sites and allows better fiber wetting. The possible reaction of the fiber and NaOH is as below.

Fiber-OH + NaOH ------- Fiber-O^-Na^+ + H_2O

Alkali treated natural fibers favored the reinforcement in the thermoplastic matrix in the composite showing perfect chemical bond and better interface adhesion and thus increased the tensile strength of Hybrid composite samples. The failure of Natural fiber–thermoplastic Hybrid samples, characterized by brittle failure, showed long tails after the predominant damage. It is thus estimated that an interfacial interaction in the present composite would result in a higher elongation to break due to alkali treatment. we can clearly absorb the fiber wetting of the treated fiber and also good fiber matrix interaction.

Fig.2. Fiber is immersed in NaOH solution

SILANE TREATMENT

Silane is used as coupling agents to modify fibre surface. It undergoes several stages of hydrolysis, condensation and bond formation during the treatment process with the fibre. Silanols forms in the presence of moisture and hydrolysable alkoxy groups. It reacts with cellulose hydroxyl group of the fibre and improves fibre matrix adhesion to stabilize composite properties. The chemical composition of silane coupling agents (bifunctional siloxane molecules) allows forming a chemical link between the surface of the cellulose fibre and the resin through a siloxane bridge. This co-reactivity provides molecular continuity across the interface region of the composite. It also provides the hydrocarbon chains that restrains fibre swelling into the matrix. Natural fibres exhibit micropores on their surfaces and silane coupling agent act as a surface coating which penetrates into the pores and develop mechanically interlocked coating on their surface. Silane treated fibre reinforced composite provides better tensile strength properties than the alkaline treated fibre composites

Fig.3. NaCl solution is prepared

AFTER TREATMENT:

After treatment the weight fraction of the fiber calculated as follows:

The weight loss was calculated from the following equation:

Weight loss = (Wo- W_1/ Wo)×100--------->(1)

Weight loss= (500-424/500) ×100
=0.152 or 15.2%

where w_o denotes the weight of sisal fibers before NaOH treatment, and w_1 the weight of fibers after having been treated with NaOH.

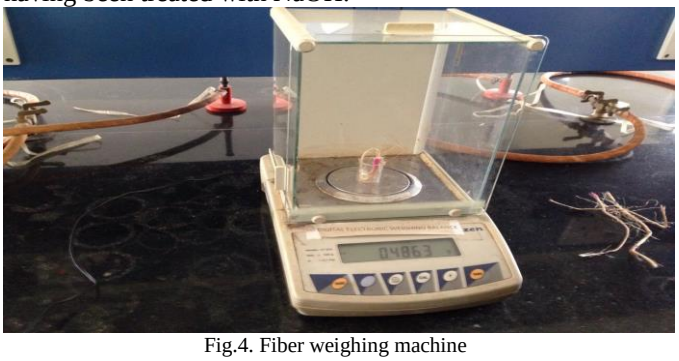

Fig.4. Fiber weighing machine

THE STRENGTH AND STIFFNESS OF CONTINUOUS FIBER COMPOSITES

When a load is applied parallel to the fibres, effectively little load is carried by the matrix. The principal purpose of the matrix is to bind the fibres together. For long fibres, stress is constant over the whole length of the fibres. This idealised composite is the starting point for all theories of reinforcement. When a load is applied parallel to the fibres, the load is distributed in proportion to the relative volume fractions of the fibre and matrix, the composite's mechanical properties in this direction can be described by The Rule of Mixtures. If we assume the fibres and matrix behave elastically and are perfectly bonded to each other and consider what happens when a strain c is applied uniformly in the fibre direction (Figure 1), the total force will be the sum of the forces in the fibre and matrix.

Formula used to calculate:

The Young's modulus of the composite $\mathbf{E_c}$ in the fibre direction is: -

$$\mathbf{E_c=V_fE_f+(1-Vf)E_m}\text{---------(1)}$$

where
$\mathbf{V_f}$ = volume fraction of fibres
$\mathbf{E_f}$ = Young's Modulus of fibres
$\mathbf{E_m}$ = Young's Modulus of matrix

The tensile strength of the composite $\boldsymbol{\sigma_{uc}}$ is given by: -

$$\boldsymbol{\sigma_{uc}= \sigma_{uf}V_f+ \sigma'_m(1-V_f)}\text{------(2)}$$

where
$\boldsymbol{\sigma_{uf}}$= ultimate strength of fibre
$\boldsymbol{\sigma`_m}$ = stress in matrix at the ultimate strain of the fibres
$\mathbf{V_f}$ = volume fraction of fibres

PROCESSING STEPS

Continuous natural fibers are pulled from roving through overhead lines to the extruder station.The fibers are spread and preheated before introduction to the combining extruder, where they will be mixed with the molten resin at 1/3 distance from the extruder die.The molten mixture is pushed through a forming die and sheared to the length required for molding.The extrudate will transfer to the compression molding.The final product will transfer to trimming and finishing station.

Implementing method

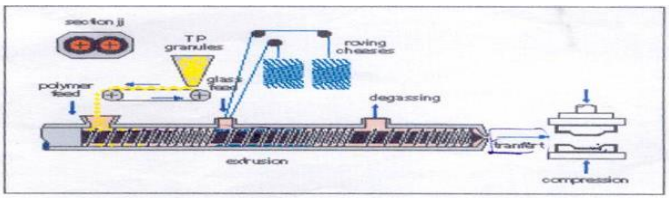

Fig.5. Schematic diagram of single step process of Natural fiber reinforced thermoplastic product

CONCLUSIONS

- The effect of various parameters like alkali treatment, fiber loading of Natural fiber reinforced thermoplastic composites has been studied.
- The natural fibers used such as Sisal Fiber (SF) have shown good compatibility with the matrix.
- The composite with alkali treated fibers exhibited a slightly higher tensile strength than the one with untreated fibers.
- The alkali treatment of natural fibers improved the quality of the fiber/matrix interface.
- Tensile test results showed that NaOH treatment used have a significant effect on the mechanical properties of Natural fiber reinforced composites.
- Out of the composites tested maximum tensile strength was obtained for the fiber loading (weight fraction) of 25-30%. This can be considered as the optimum fiber loading.
- It can be concluded that alkali treatment of the natural fibers is necessary to get composites with moderate mechanical properties as well as better adhesion between fibers and matrix.

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