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Failure analysis of discarded *Agave tequilana* fiber polymer composites

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ABSTRACT

Natural fiber polymer composites are mostly preferred due to its specific properties, whereas at present deployment of leftovers from agro-industries plays a key role in polymer composite industries. Utilization of such waste from the industries diminishes deforestation and helps in the preservation of the environment. In this line, the present study imparts the discarded blue agave fiber (BAF) as a reinforcement in composite by examining its thermo-mechanical properties. Composite specimens were prepared for the uniform fiber length with variation in fiber and matrix content. Meanwhile, the investigated composites displayed better mechanical properties at high fiber content, whereas abrupt bend was occurred at 50 wt.% fiber content due to poor compatibility between the fiber and the matrix. Therefore the 40 wt.% fiber content was recognized as optimum weight percent and the high specific strength endorsed their potentiality in composite fabrication for locomotive and basic applications. Moreover, the reason for the failures of the fractured tensile and flexural tested specimen was examined using the scanning electron microscopy (SEM).

1. Introduction

Globally, materials play a very major role in our daily needs and also it can be expressed in other words that it drives our society. However, during the recent decades more attention has been drawn over composite materials due to its high specific strength, better dimensional stability, better durability, low thermal conductivity and highly corrosion resistant properties. Moreover, the development of new materials by reinforcing natural fiber with polymer matrix composites was gaining momentum in a drastic mode during the modern years. Development of composite materials by the addition of natural or synthetic fibers to polymer matrices enhances the mechanical and thermal properties [1]. Generally, synthetic fiber reinforced polymer composites possess good mechanical properties on one side whereas, on the other side they also displays their negative impacts like high density, toxic, high cost, less corrosion resistance, non-renewable and low machinability [2].

In contrast, nowadays the natural fibers have been used as a raw material for different applications and is being used as a reinforcing material for polymer composite fabrication. K. Ramanaiah et al., stated that unsaturated polyester has extremely versatile properties and applications and is a popular matrix for making composites. This matrix has been used for many years in broad technology fields such as naval construction, offshore applications, waterlines, and building construction. The reinforcement of polyester with various cellulosic fiber has been widely reported. The growing interest in using natural vegetable fiber as a reinforcement of polymeric-based composites is in an increasing rate and various research is under progress on natural fibers such as

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bamboo, coir, jute, flax, sun hemp, ramie, kenaf, roselle, straw, rice husk, sugar cane, grass, raphia, papyrus, pineapple leaf, etc. [3]. In addition, the better biodegradable property of the natural fiber contributes an eco-friendly environment and also its low cost favors a good benefit for many industrial sectors [4]. However, the main drawback of these natural fiber/polymer composites appears to be the poor compatibility between the hydrophilic fibers and the hydrophobic matrix which makes essential to use compatibilizers to improve the surface adhesion between fiber and matrix [5]. Apart from the hydrophilic nature of the fiber, possessions of the natural fiber reinforced composites can also be influenced by fiber content [3].

Human remains dating back at least 10,000 years shows the early usage of agave for food and fiber. Agave is derived from a greek word "Agavos" with a meaning named illustrious and belongs to the family Asparagaceae and subfamily Agavoideae composing of about 203 polymorphic species [6]. Agave is a short term perennial crop available in many areas of southern and western America including India. Agave initially starts as seedling and when it is displaced under the soil it grows to further heights. Later it get matures and becomes ready for harvesting only after a minimum growth of 8 to 10 years [7]. Once it is extracted, pina known as the heart of the agave and pencas the leaves of it are used for making a syrup, which is widely used by the people for medicinal purposes [6]. The implication of this study is to explore the new natural resource i.e. agave fiber which is renewable with low production cost while focusing on it's readily availability, particularly from agricultural crops in India.

Agave tequilana, commonly called as blue agave (*Agave azul*) or tequila agave, is one type of agave plant which is an important economic product of Jalisco, Mexico, due to its role as the base ingredient of tequila, a popular distilled beverage [8]. Agave plant grows to a height of more than 1500 m and also generally grows in rich and sandy soils. Blue agave plant grows in huge quantity with spiky fleshy leaves and a stalk during the age of about 5 years old along with a yellowish colour flower. Among these variety, Blue agave was selectively bred for its flavor, relatively short maturation cycle, baking qualities and compatibility with the industrial processes. Moreover, during the dry season, it responds energetically and will gather up to reduce the amount of surface for evaporation, whereas during excess heat, they familiarize the angle of their leaves to either get more sun or decrease its properties. Specifically, the agave bagasse is a waste of the tequila industry and represents a serious environmental issue in the state of Jalisco [1]. Large amounts of bagasse developed by the tequila industry has given rise to illegal dumping or improper uses in agricultural fields, with the consequent risks of negative changes in soil fertility and environmental pollution by leachate [8].

Blue agaves are also measured to be one of the major substituents for sugar in India and the production of blue agave fiber (BAF) is found to be approximately 13 million tones in India and 65 million tones in the world every year [6,7]. Many studies have been reported on agave fiber (*A. tequilana*) composites having good mechanical properties. Nevertheless, the combination of agave fibers with biopolymers as matrices to produce green-composites has not been fully investigated. Development of green-composites with combination of natural fibers and biopolymers, have rushed to an environmental-friendly and attractive alternative to conventional glass fiber composites which are difficult in recycling and requires high cost for waste disposal [1]. Therefore, an effort has been made in the present work to express its potentiality and the appraisal endorses that BAF composite as a probable reinforcement in polymer composite for automotive, light weight and structural applications.

2. Materials and methods

2.1. Fiber preparation and characterization

Blue agave plant leaves thrown out as waste after using its commercial parts were collected from the local town Marthandam, Tamilnadu, India and drenched in water for about 1 week. This process was done for the removal of waste particles and softening the leaves for easy removal of fiber commonly called as microbial degradation technique. Later the washed fibers were dried in sunlight to remove the moisture content and finally the raw BAF extraction were done using metal brush by mechanical combing methods [5]. Fig. 1 shows the processing chart from raw material to fabrication stage.

The density of BAF is determined on mass volume basis by filling the powdered sample in a container of known volume [4]. The major bio-chemical ingredients of BAF like cellulose, hemicelluloses, lignin and wax content are determined using standard test procedures [9]. The ash content is quantified as per ASTM E 1755-61 standard, whereas the moisture content is determined by drying the sample in an oven at 104 °C for 4 h. The mechanical properties of BAF are estimated from the tensile test carried out in INSTRON (5500R) universal testing machine as per ASTM D3822-07. 20 samples are tested at five different gauge lengths (10 mm, 20 mm, 30 mm, 40 mm and 50 mm) by keeping the cross head speed constant at 5 mm/min under ambient atmospheric conditions.

2.2. Matrix preparation

The matrix, curing catalyst and accelerator were supplied by Leo Enterprises, Nagercoil, Tamil Nadu, India and the liquid resin was tested at Saint-Gobain Vetrotex India Ltd., Thimmapur, Andhra Pradesh, India. However, the cured resin was tested at Composites Technology Centre, Indian Institute of Technology-Madras, Chennai, TamilNadu, India. The properties of selected matrix material is shown in Table 1. The selected matrix was unsaturated polyester with methyl ethyl ketone peroxide (MEKP) as curing catalyst and cobalt napthanate as an accelerator [5,10]. The matrix, curing catalyst and the accelerator of correct proportions were taken in a glass beaker and mixed thoroughly using continuous stirring process. All these process were done at ambient temperature (~21 °C) with relative humidity of about 65%.