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A Study on the Mechanical Behaviors of Jute-Polyester Composites

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Abstract

In the present exposition, coupon specimens extracted from jute-polyester laminates fabricated by the hand layup method combined with compression molding are subjected to tensile, compression and flexural tests in a UTM. Next a novel hybrid jute-steel composite is studied under similar conditions. It is shown that the gap in tensile strengths in warp and weft directions found in plain jute laminates is perceptibly reduced in their hybrid jute counterparts. Also, hybrid jute laminates have substantive residual tensile strengths on reaching peak strengths as compared to plain jute-polyester composites which fail abruptly, i.e. in a brittle manner, on reaching peak strength. Additionally, hybrid jute composites displayed higher tensile modulus and flexural stiffness, and consistent compressive strength as compared to plain jute-polyester composite laminates. It is shown that improvement in moisture resistance is an additional advantage of hybrid jute laminates.

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Keywords: Jute-PolyesterComposite; Hybrid Laminate;Tensile Strength/Modulus;Compressive Strength, Flexural Stiffness; Mositure Absorption.

1. Introduction

Fiber-reinforced composites which can often be tailored for a specific structural need are rapidly replacing conventional materials such as metals in a number of industry sectors including aerospace, automotive, rail, petrochemical, civil construction, marine vessels, and sports goods. In demanding applications such as an aircraft body, high performance or advanced fiber-reinforced composites with exceptionally high elastic modulus and failure strengths are preferred. Man-made fibers such as glass and carbon fibers have been dominant as reinforcements in polymer matrix composite materials. However, within the past few decades, utilization of natural plant-based fibers in the form of jute, hemp, coir, flax, etc. in a polymeric matrix has attracted the attention of the scientific community. Due to growing environmental concern over using synthetic fibers in composites, researchers have felt the need for exploring renewable resources in the form of natural plant fibers as reinforcement in composites.

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As an additional benefit, such a consideration would ensure good economic returns for cultivation of the above-mentioned natural fibers. When compared with man-made fibers, natural fibers are generally of lower cost and density, and are biodegradable with acceptable specific mechanical properties. Also, unlike glass fibers, these are generally not hazardous to health. Hence, it makes a lot of sense to study and characterize natural fiber-reinforced composites for common applications in which these are still relatively rare.

Bledzki and Gassan [1] have reviewed the most readily-used natural fibers in polymer composites up until 1999 in their review paper. Faruk et al. [2] in their paper reviewed more recently-used natural fibers as reinforcement in polymer composites (from 2000 to 2010). Summerscales et al. [3] in Part 1 of their review paper discussed in detail growth, harvesting, fiber separation and then characterization of bast fibers. Bast fibers included were jute, hemp, nettle, kenaf and flax. In Part 2 [4] of their review the same authors focused on micromechanics-based prediction of the properties of natural bast fiber reinforced composites, manufacturing techniques, and characterization using microscopy, mechanical, chemical and thermal techniques. The review concluded with a brief overview of potential applications and environmental considerations which might expedite or constrain the adoption of these composites. Ku et al. [5] reported a detailed review of the tensile properties of natural fiber reinforced polymer composites. In this review, various aspects such as effect of fiber volume fraction and surface treatment of fibers on tensile strength of composites were discussed.

It may be pointed out that relatively few studies are available on mechanical characterization of jute fiber based composite laminates [6-12]. Shah and Lakad [6] presented the mechanical properties of unidirectional jute-polyester and jute-epoxy composites as well their hybrid versions by adding glass fibers. Acha, Marcivich and Reboredo [7] carried out physical and mechanical characterization of jute fabric; the authors further investigated the effects of jute fiber treatments on the performance of resulting composites. Gowda, Naidu and Chhaya [8] evaluated various basic mechanical properties of jute-polyester composites such as tensile strength, compressive strength, flexural strength, impact strength, in-plane shear strength, inter-laminar shear strength and hardness. In their studies, the authors demonstrated the potential of this renewable source of natural fiber for use in a number of consumable goods. Ahmed and Vijayarangan [9] investigated mechanical behavior of isothalic polyester based untreated woven jute-fabric composites under tensile, compressive, in-plane shear, inter-laminar shear and impact loading conditions.

One of the main concerns in the use of natural fiber reinforced composite materials is their susceptibility to moisture absorption and the effect of the latter on their physical, mechanical and thermal properties. A few authors have studied the moisture diffusion phenomenon in natural fiber based composites and the effect of moisture uptake on their properties [13 -16].

In the current work, a systematic comparative study has been carried on the mechanical behaviors of jute-polyester composite laminates of varying ply counts, and the efficacy of hybridization with steel mesh is shown.

2. Materials and Methods

Commercially available bidirectional untreated woven jute mat with a thread count of 17 × 15 (i.e. 17 and 15 yarns in warp and weft directions respectively per inch) was used as a reinforcement for the fabrication of jute-polyester composites in the current study. The area density of the commercially-available jute mat used was approximately 220 g/m^2 (gsm). The density of the jute fibers was likely to be in the range of 1.3-1.4 g/cc [3]. The thickness of jute mat was found to be around 0.5 mm. In Fig. 1 is shown a piece of jute mat used in the manufacturing of composite laminates. The matrix material was prepared from commercially available general purpose polyester (GPP) resin to which were added cobalt naphthenate accelerator and MEKP catalyst in a weight ratio of 1:0.015:0.015 respectively.

Jute-polyester (JP) composite laminates were manufactured for different volume fractions of jute fiber by the hand-layup technique. Jute fabrics were pre-impregnated with the matrix material. The impregnated layers were placed one over the other and pressed for two hours in a compression molding machine. Uniform thickness was achieved by using spacers of desired thickness between the mold plates. After two hours, the laminate was removed from the mold and cured at room temperature for forty-eight hours. One such JP composite laminate is shown in Fig. 2.