

ORIGINAL ARTICLE

Structural mass irregularities and fiber volume influence on morphology and mechanical properties of unsaturated polyester resin in matrix composites



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ABSTRACT

This paper presents the comparative results of a current study on unsaturated polyester resin (UPR) matrix composites processed by filament winding method, with cotton spun yarn of different mass irregularities and two different volume fractions. Physical and mechanical properties were measured, namely ultimate stress, stiffness, elongation%. The mechanical properties of the composites increased significantly with the increase in the fiber volume fraction in agreement with the Counto model. Mass irregularities in the yarn structure were quantitatively measured and visualized by scanning electron microscopy (SEM). Mass irregularities cause marked decrease in relative strength about 25% and 33% which increases with fiber volume fraction. Ultimate stress and stiffness increases with fiber volume fraction and is always higher for yarn with less mass irregularities.

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Introduction

Plant fiber as reinforcing agent in the preparation of composite material, is getting more attention of the researcher due to its eco-environmental advantages over petroleum based fibers [1]. Natural fibers such as coir [2], bamboo [3], flax [4], kenaf [5], sisal [6] and jute [7] have extensively been used as reinforcing agents with comparable mechanical properties. These fibers were used in different forms such as continuous, random,

and oriented fibers. Literature shows that the main focus of the researchers' world over is to improve and relate the mechanical properties of the composite to surface modification [8], orientation [9] and content of fibers [10]. Textile yarn/fabric of different natural fibers has also been used as reinforcing agent in composites [11,12]. More recently a study was carried out to propose a model to describe the effect of yarn twist on the tensile strength of unidirectional plant fiber yarn composites [13].

Various studies are available on properties of aligned plant fiber composites focusing mechanical properties with fiber direction and volume fraction [14–21]. Presented in this paper are preliminary results of a larger study set out to investigate the mass irregularities and unevenness of spun yarn/chemically treated spun yarn and their effect on compatibility, physical properties and mechanical behavior of yarn composites. This research shows the combined effect fiber volume and mass irregularities, the variation in mass per unit length of yarn, on the mechanical properties of UPR matrix composites reinforced with spun yarn processed by filament winding method.

The main and unavoidable type of mass irregularities in yarns is due to random, short and immature natural fibers [22]. This type of mass irregularities in the yarn can be minimized by removing short and immature fibers during combing process in textile industry.

The mass irregularities in yarn structure were measured by uster evenness testing system, and its effect on physical structure of fibers in fiber bundle of yarn was analyzed by scanning electron microscopy. The results showed that mass irregularities in the structure of yarn affect the alignment of fibers at microlevel in the fiber bundle as a result average diameter varies. The average diameter of the yarn and composite was measured through SEM images to investigate and compare the mechanical properties such as ultimate stress and stiffness.

Experimental

Materials

This work is concerned with the comparative study of unsaturated polyester resin matrix composite materials reinforced with aligned yarn having different mass irregularities. The unsaturated polyester resin (UPR) used in this study was a commercial product of Al-Khair Industries, Karachi-Pakistan. Resin comprises 40% by weight styrene, with an average of 5.88 vinylene groups per unsaturated polyester molecules. The average molecular weight of the unsaturated polyester resin is 2750 g/mol and the equivalent molecular weight/(mol C=C) is 468 g/mol. The molar ratio of styrene/unsaturated polyester resin is 2.7. The unsaturated polyester resin was employed as received without removing the inhibitor.

Samples of yarn with same count (i.e., 20NE/1, 100% cotton) and different mass irregularities were taken from Fazal Textile Mills, Karachi, Pakistan.

Methods

Conditioning

Prior any testing spun yarns were conditioned under standard conditions of $20\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ and $65 \pm 3\%$ relative humidity (RH) for 24 h.

Yarn mass irregularity

Yarn mass irregularity was quantitatively measured as unevenness%, CV%, thin, thick, neps and hairiness present in yarn. Uster Technologies 4-SX evenness tester (Switzerland) was used to measure its evenness according to ASTM D1425.

Composite formation

The yarn was aligned by filament-winding machine on to a metal frame producing yarn assemblies with a high degree of alignment and controlled thickness shown in Fig. 1. Composite laminates were prepared with onefold of yarn with varying amount of resin to get the desired volume fraction of yarn. The mechanical properties of composites were determined in axial direction of yarn. The metal plate was fitted in the middle of a special type of die cast. Specific amount of resin, initiator and our recently developed promoter system [23] were transferred using RTM method. The laminate composites were then left for 2 h at room temperature for complete dryness.

The fabricated composite laminates were $300 \times 500\text{ mm}^2$ with a variable thickness of 2.0–2.9 mm. Samples of composites were produced with volume fractions (V_f) of 0.305 and 0.408 of yarn with varying quantity of mass irregularities.

SEM analysis

Mass irregularity and micro-alignment of fibers in yarn and its composite were analyzed by scanning electron microscope (SEM) model # 6380A JEOL (Japan). The samples were first coated with autocoater Model No. JFC-1500 JEOL (Japan).

Tensile properties of yarn

Tensile properties of spun yarn were measured according to ASTM D2256. Standard Test Method for Tensile Properties of Yarns by the single-strand method was used to measure single yarn breaking strength by Uster Technologies Tensorapid III. The testing speed was adjusted 500 mm/min, and the gauge length was 500 mm. The sample size was 5 and each sample was tested ten times. The yarns were picked automatically with programmed software and results were collected as print file.

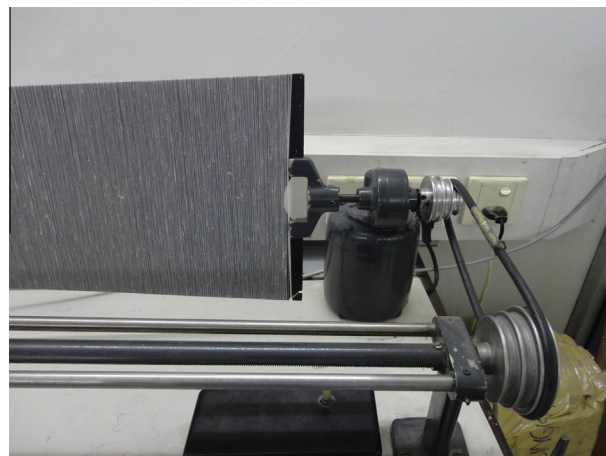


Fig. 1 Filament winding machine.

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