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Original Article

# Charpy impact tenacity of epoxy matrix composites reinforced with aligned jute fibers☆

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ABSTRACT

Natural fiber reinforced polymer matrix composites are gaining attention as engineering materials for advanced applications, including components of high performance ballistic armors. This requires superior mechanical properties, such as tenacity. Composites reinforced with jute fiber are currently being investigated as possible advanced engineering materials. Therefore, the objective of the present work was to evaluate the impact resistance of epoxy matrix composites reinforced with up to 30 vol% of continuous and aligned jute fibers. This evaluation was performed by measuring the Charpy absorbed impact energy of standard ASTM notched specimens. The results indicated a significant increase in the absorbed impact energy with the volume fraction of jute fibers. The microstructural mechanism related to this performance was revealed by scanning electron microscopy analysis.



## 1. Introduction

Polymer composites reinforced with glass and carbon fibers have replaced several conventional materials since mid-last century [1]. In the present century, however, these synthetic fiber composites are being questioned due to problem related to environmental and energy issues [2,3]. Indeed, the substitution of natural fibers for the traditional synthetic ones is gaining a growing attention since the past decade, as indicated by review articles [4–12]. The automotive industry, in particular, is already applying natural fiber composites mainly in interior parts [13,14]. In addition to lower cost and environmental benefits, technical advantages also favor natural lignocellulosic fibers extracted from plants. The impact resistance of the flexible fibers is an important advantage over the brittle glass fiber in an automobile crash event. This is the case of composites parts such as the head-rest and front panel.

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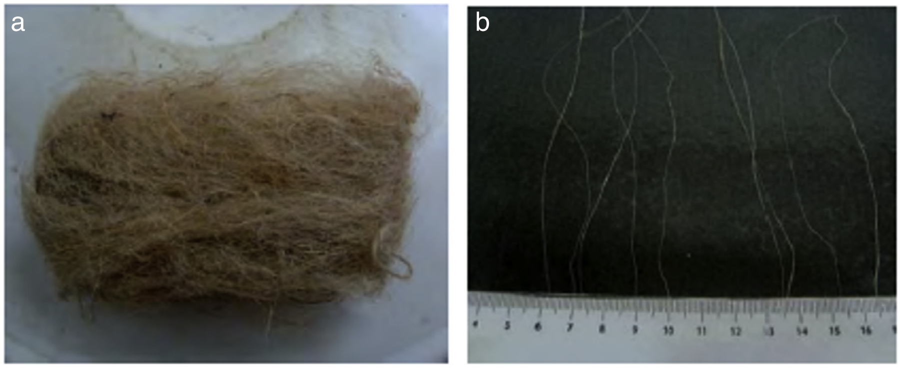


**Fig. 1 – A bundle of as-received (a) and individually separated jute fibers (b).**

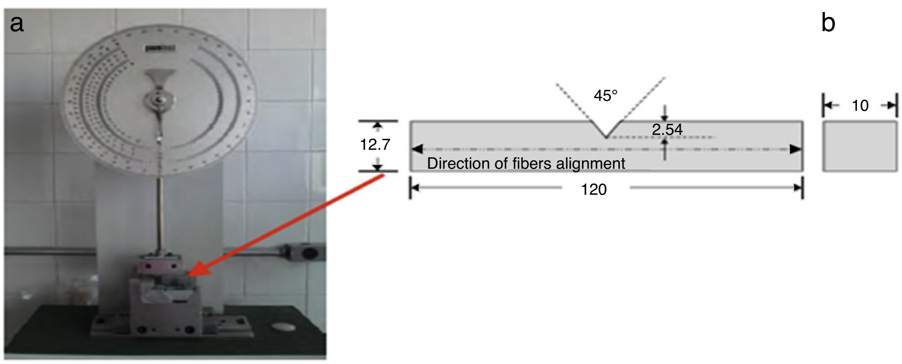


**Fig. 2 – Charpy equipment and standard specimen schematic.**

They should be soft and able to absorb the impact energy, associated with sharp pieces to avoid injuring the passengers [13].

Among the several natural fibers being used as polymer composite reinforcement, that of the jute extracted from the *Corchorus capsularis* plant is one of the most investigated, which is composed of 60% of cellulose, 22% of hemi-cellulose and 16% of lignin [15]. The jute fiber displays relevant properties for composite reinforcement, such as 393–773 MPa of tensile strength, 10–30 GPa of elastic modulus and density of 1.44 g/cm$^3$ [16]. However, some properties of specific composites reinforced with jute fibers still need evaluation. In particular, the tenacity is a relevant property for applications that might be associated with impact conditions such as the aforementioned automobile crash [13]. Additionally, impact resistance is a basic requirement for the ballistic performance of armor using natural fiber composites [17–24].

In view of these considerations, the present work evaluates the Charpy notch impact tenacity of epoxy matrix composites reinforced with up to 30 vol% of continuous and aligned jute fibers. The impact tenacity of plain epoxy used as matrix was also evaluated as control specimen.

## 2. Materials and methods

The jute fibers used in this work were supplied as a 5 kg lot by the Brazilian firm Sisalsul. Fig. 1 illustrates a bundle of the as-received lot of jute fibers as well as isolated fibers extracted from the bundle.

As composite matrix, a type diglycidyl ether of the bisphenol A (DGEBA) epoxy resin hardened with 13 parts per hundred of triethylene tetramine (TETA) in stoichiometric proportions was used. The as-received fibers were water cleaned and dried in a stove at 60 °C for 24 h.

Composites with 10, 20 and 30 vol% of jute fibers as well as neat epoxy (0% fiber) were manufactured by accommodation of continuous and aligned fibers in a rectangular 152 × 122 × 10 mm mold and embedded with the epoxy matrix until the desired fraction of weight was obtained.

Plates of each composite were then cut, according to the direction of alignment of the fibers, into bars measuring 120 × 12 × 10 mm, which were the basis for making Charpy specimens for impact test as per ASTM D256 standard, according to the scheme shown in Fig. 2.

The notch was prepared with a depth of 2.54 mm and angle of 45° required by the standard (Fig. 2b). For this purpose, a manual carver style brand CEAST Notchvas was used. The specimens were tested in an instrumented Pantec pendulum (Fig. 2a) in Charpy configuration.

The impact fracture surface of the specimens was analyzed by scanning electron microscopy, SEM, in a model SSX-500 Shimadzu microscope. Gold sputtered SEM samples were observed with secondary electrons imaging at an accelerating voltage of 15 kV.