IMPACT DAMAGE CHARACTERISATION ON JUTE REINFORCED COMPOSITES

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In recent years, as a result of environmental and economical concerns, there is a growing interest in the use of natural fibre reinforced composites [1]. Natural fibres include straw, flax, hemp and jute, etc., and are already harvested in many countries of the world. Natural fibres have been used for the reinforcement of polymeric matrices, to produce composites for low-cost applications. Polyester and some phenolic resins are particularly suitable for coupling with natural fibres, because these resins are compatible with the cellulose [2]. Sufficient mechanical properties and resistance to moisture absorption of natural fibres have been achieved by an adequate surface treatment [3]. Jute is among the best natural fibres in terms of tensile strength and flexural properties, though it can present some toughness problems [4]. A significant advantage which can compensate for the low toughness of jute, is the possibility to combine this fibre with different polymeric resins: hence its versatility. Polyester resins are in most cases preferred, because they exhibit a lower shrinkage and form an intimate bond with jute fibres up to a volume fraction of 60 % [5]. Differences in the impact failure modes between traditional composite laminates (e.g., carbon fibre and E-glass fibre reinforced laminates) and natural fibre reinforced composites, such as jute fibre reinforced laminates, have also been discussed [6]. Jute/polyester woven laminates have been impacted to energies up to 20 Joules with an impact velocity of 2 m/s using a Rosand drop-weight impact tower. The diameter of the hemispherical impactor was 12.7 mm. Some of the laminates underwent to post-impact tensile tests to failure on an Instron 9501 testing machine. The aim of these tests was to measure the degradation of their mechanical performances with increasing impact energy. Tensile failure occurred by macroscopic matrix cracking under the point of impact. Here, the interlaminar fracture

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toughness of this material was sufficiently high that failure did not involve delamination. In Table 1 the average tensile properties for laminates impacted at different energies are shown.

Impact energy (J)	Ultimate stress σ_u (MPa)	Young's modulus (GPa)	Strain at σ_u (%)
0	61.13	5.61	0.89
5	36.47	5.69	0.85
7.5	38.63	5.79	0.79
10	38.17	5.52	0.92
15	37.61	5.31	0.87

Table 1 Average tensile properties for impacted laminates

In addition, some laminates underwent to fatigue loading. The maximum applied stress was 13 MPa i.e., around 25% of the ultimate tensile stress of the laminate. The fatigue ratio was 0.5 and the loading frequency used was 10 Hz. The damage produced by impact and the subsequent fatigue loading was observed using an optical microscope. In micrographs of the impacted face of the laminates, the fibres in the impact zone appeared to be damaged (Fig.1a). In this case, a stress-whitened region was apparent on the reverse side of the laminate, where the fibres appeared detached and close to failure (Fig.1b).

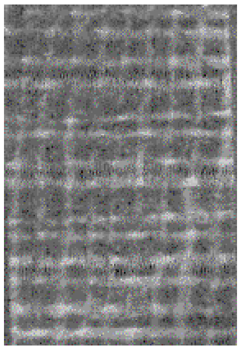

Fig. 1a Micrograph (6x) of the impacted surface of a laminate (impact energy = 10 Joules)

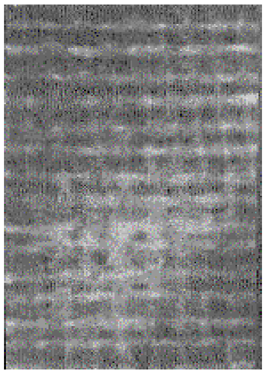

Fig.1b Micrograph (6x) of the non-impacted surface of a laminate (impact energy = 10 Joules)

The observation under an optical microscopy of the surface of the jute/polyester laminates did not yield substantial information about the size of the impact-damaged region in these laminates. As a consequence, an alternative procedure of observation was also used, removing polished sections for the impact region. One of the micrographs so obtained is shown in Fig.2. In particular, through-thethickness damage observation yielded a conical pattern, which is commonly referred to as *reversed pine tree pattern* [7].

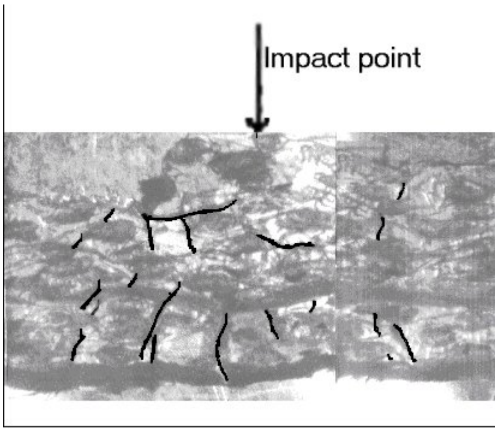

Fig.2 Micrograph (23x) of a polished section from the impact region of a laminate (impact energy= 15 Joules).

After fatigue cycling, the microscopy observation highlighted the presence of cracks both in the matrix and through the fibre bundles of the laminates (Fig.3a). A better observation of the matrix cracks is provided in Fig.3b, whilst in Fig.3c a crack passing through the fibre bundle is shown.

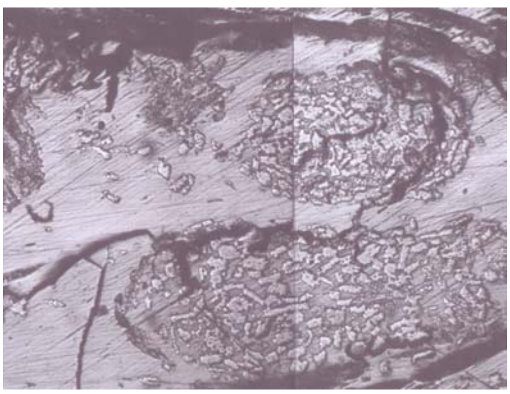

Fig.3a Micrograph (75x) of a laminate subjected to $7x10^4$ fatigue cycles after impact at 5 Joules

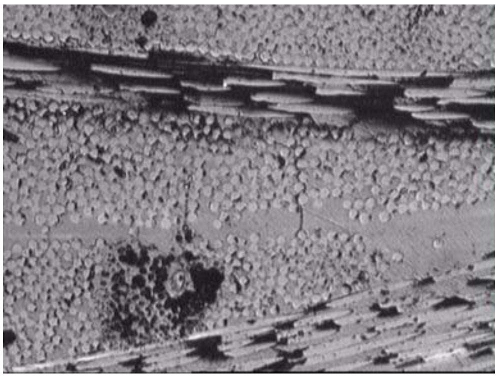

Fig.3b Matrix cracking (100x) in a laminate impacted at 5 Joules and subjected to $7x10^4$ fatigue cycles

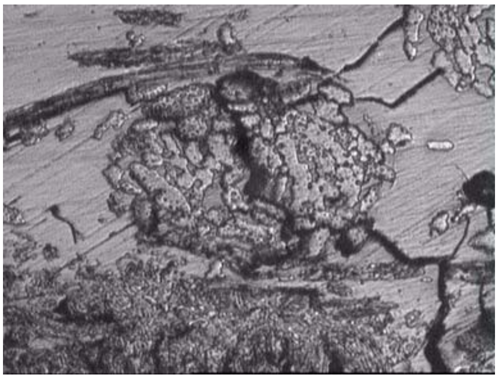

Fig.3c Fibre bundle cracking (x125) in a laminate impacted at 5 Joules and subjected to $7x10^4$ fatigue cycles

These observations highlighted the characteristic patterns of impact damage and post-impact fatigue damage in jute reinforced laminates. On a set of specimens removed from the same plate, the impact-damaged area was also measured from low magnification micrographs. The results of this measurement are shown in Fig.4.

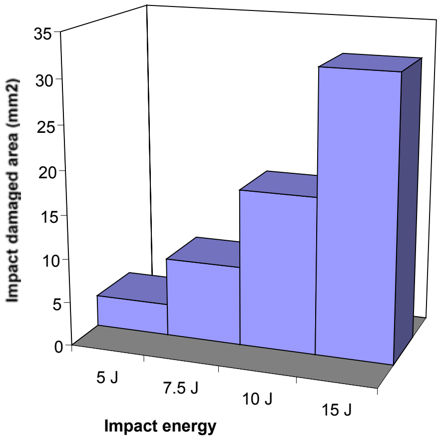

Fig.4 Damaged areas on laminates impacted at different energies

The principal difficulty of this investigation is due to the rather low mechanical stresses that are tolerable by these laminates. Further studies should concern the possible correlation of the dimension of impact-damaged area with the degradation of mechanical properties in jute reinforced composites.

References

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