Mechanical Properties Study of Jute Fiber Reinforced Polyester

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الخلاصة

تم في هذا البحث فحص الخواص الميكانيكية لراتنج البولي أستر المقوى بألياف الجوت وألياف الزجاج الثنائية الاتجاه (0^o -90^o) كلا على حدة تارة ومدمجة تارة أخرى كمادة مركبة هجينة. أظهرت النتائج إن المادة المركبة المقواة بألياف الجوت تمتلك خصائص أفضل بكثير من راتنج البولي استر غير المقوى , ولكن هذه الخواص غير مكافئة لما هو عليه الحال للمواد المركبة المقواة بألياف الزجاج. وعلى هذا الأساس فان الدور الأكثر ملائمة لألياف الجوت هو استخدامها كألياف حشو مدمجة مع ألياف الزجاج عندما تكون متطلبات الخصائص الميكانيكية ليست الطلب الوحيد.

الكلمات الرئيسة : ألياف الجوت ، التهجين، ألياف الزجاج ، المواد المركبة، الخواص الميكانيكية.

Abstract:

This work presents the mechanical properties of un saturated polyester resin reinforced bi- directionally (0^o -90^o) by jute and glass fibers singly and in combination as a hybrid laminates. The results show that the jute reinforced laminates have much better properties than the resin alone, but the properties are inferior to those of glass – reinforced plastics. The most appropriate role for the jute fibers is, perhaps, to use them as "filler" fibers in combination with glass fibers where the strength and modulus requirements are not very demanding.

Keywords: Jute fibers, Hybridization, Glass fibers, Composite, Mechanical properties

1.0 Introduction

Composite materials were known to mankind in the Paleolithic age (also known as Old Stone age). The 300 ft high ziggurat or temple tower built in the city center of Babylon was made with clay mixed with finely chopped straw [Shakir and Omidvar, 2006]. In recent years, polymeric based composite materials are being used in many applications, such as automotive, sporting goods, marine, electrical, industrial, construction, household appliances, etc. Polymeric composites have high strength and stiffness, light weight, and high corrosion resistance (Hassan and Jwn, 2005).

Natural fibers are available in abundance in nature and can be used to reinforce polymers to obtain light and strong materials. Natural fibres such as jute, sisal, banana and coir are grown in many parts of the world. Some of them have aspect ratios (ratio of length to diameter) > 1000 and can be easily woven. These fibres are extensively used for cordage, sacks, fishnets, matting and rope, and as filling for mattresses and cushions (e.g. rubberised coir). Recent reports indicate that plant-based natural fibres can very well be used as reinforcement in polymer composites, replacing to some extent more expensive and non-renewable synthetic fibres such as glass. Cellulosic fibres are obtained from different parts of plants, e.g. jute and ramie are obtained from the stem; sisal, banana and pineapple from the leaf; cotton from the seed; coir from the fruit, and so on (Smith and Sanjay, 2006)

The maximum tensile, impact and flexural strengths for natural fiber reinforced plastic (NFRP) composites reported so far are 104.0 MN/m^2 (jute-epoxy), 22.0 kJ/m^2 (jute-polyester) and 64.0 MN/m^2 (banana-polyester), respectively. There are many examples of the use of cellulosic fibres in their native condition like sisal, coir jute, banana, palm, flax, cotton, and paper for reinforcement of different thermoplastic and thermosetting materials like phenol-formaldehyde, unsaturated polyester, epoxy, polyethylene, cement, natural rubber, etc. (Martin and Jan van Dam, 2003).

Different geometries of these fibres, both singly and in combination with glass, have been employed for fabrication of uni-axial, bi-axial and randomly oriented composites. Amongst these various ligno-cellulosic fibres, jute contains a fairly high proportion of stiff natural cllulose. Rated fibres of jute have three principal chemical constituents, namely, a -cellulose, hemicellulose and lignin. In addition, they contain minor constituents such as fats and waxes, inorganic (mineral) matter, nitrogenous matter and traces of pigments like b - carotene and xanthophyll (Martin et al., 2000).

A number of investigations have been conducted on several types of natural fibers such as kenaf, hemp, flax, bamboo, and jute to study the effect of these fibers on the mechanical properties of composite materials (Tajvidi et. al., 2003) (Wu. et. al., 2000). Mansur and Aziz (Mansur and Aziz 1983) studied bamboo-mesh reinforced cement composites, and found that this reinforcing material could enhance the ductility and toughness of the cement matrix, and increase significantly its tensile, flexural, and impact strengths.

On the other hand, jute fabric-reinforced polyester composites were tested for the evaluation of mechanical properties and compared with wood composite (Lu et. al., 2000), and it was found that the jute fiber composite has better strengths than wood composites. A pulp fiber reinforced thermoplastic composite was investigated and found to have a combination of stiffness increased by a factor of 5.2 and strength increased by a factor of 2.3 relative to the virgin polymer (Lundquist et. al., 2003).

Considerable work has also been done at the National Aeronautical laboratory and the Vikram Sarabhai Space center on jute- reinforced epoxy and polyester resins (Nagabhushan et. al., 1987); however, their work is more oriented towards product development than evaluation of the mechanical properties. Similarly, work done by Winfield (Winfield, 1989) in connection with the application of jute- reinforced plastics to low cost housing also places more stress on application than on the evaluation of properties. Moreover, properties of jute / glass hybrid unidirectional laminates, which form an important component of the present study.

The objective of this paper is to study the tensile, compression, flexural, and impact properties of jute reinforced plastic (JRP), glass reinforced plastic (GRP), jute glass- reinforced plastic (J/GRP) hybrid laminates.

2.0 Jute and Glass Fibres

Although the tensile strength and Young's modulus of jute are lower than those of glass fibres, the specific modulus of jute fiber is superior to that of glass and on a modulus per cost basis, jute is far superior. The specific strength per unit cost of jute, too, approaches that of glass. Therefore, where high strength is not a priority, jute may be used to fully or partially replace glass fiber without entailing the introduction of new techniques of composite fabrication.

The need for using jute fibres in place of the traditional glass fiber partly or fully as reinforcing agents in composites stems from its lower specific gravity (1.29) and higher specific modulus (40 GPa) of jute compared with those of glass (2.5 & 30 GPa respectively). Apart from much lower cost and renewable nature of jute, much lower energy requirement for the production of jute (only 2 per cent of that for glass) makes it attractive as a reinforcing fiber in composites (Zoin Al- Abedin, 2007)

Jute composites may be used in everyday applications such as lampshades, suitcases, paperweights, helmets, shower and bath units. They are also used for covers of electrical appliances, pipes, post-boxes, roof tiles, grain storage silos, panels for partition & false ceilings, bio-gas containers, and in the construction of low cost, mobile or pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc (Saha et. al.; 1999).

3.0 Experimental Work

Two types of fibers reinforcements are used in the preparation of composites:

1. E- glass, plain fabric, areal density 300 g/m^2 , Fiber glass, Ltd., UK.
2. Jute plain fabric, areal density 316 g/m^2, State Enterprise for Fabrics, India.

The resin used in this work is Viapal H 265 unsaturated polyester resin based on tetrahydrophthalic acid and appropriate blends of ethylene glycol, propylene glycol, and di (propylene glycol) dissolved in styrene. The resin, promoter and catalyst were supplied by Vianova Kunstharz, Austria. Bulk resin sheets were prepared by mixing resin with 0.5% (w/w) cobalt octoate in xylene containing 6% active cobalt as promoter, and 2% (w/w) methyl ethyl ketone peroxide as a catalyst. These materials were thoroughly mixed and stirred at low speed until it become uniform. The matrix material was poured into the mould slowly in order to avoid air trapping. The mixture was left for two hours so that it becomes a little tacky. After that, the reinforcement fiber woven fabric was laid on the matrix layer, which was covered by another layer of matrix by pouring the mixture slowly onto the surface of the fiber woven fabric. The multiple layered composite was cured at room temperature until it was dry. The same steps were used to make an un reinforced unsaturated material.

The amounts of reinforcement fibers were calculated according to the following Equation (Lukkassen and Meidell, 2003):

$$\Theta = 1/\ 1+ [(1- \psi)/\ \psi].\ \rho_f / \rho_m \ \ldots\ldots\ (1)$$

Where Θ: Volume fraction of fibers %.

Ψ : Weight fraction of fibers %.

ρ_f: Fiber density in kg / m^3.

ρ_m: Matrix density in kg / m^3.

Volume fraction for each reinforcement fibers (glass or jute) was 30% but for hybrid composite was (15% glass fibers and 15% jute fibers).

4.0 Mechanical Tests

4.1 Tensile Test

After the un reinforced unsaturated polyester resin and fibers reinforced composite was dried, it was cut using a saw cutter to get the dimension for mechanical testing. The tensile test specimen was prepared according to ASTM- D- 638. The pieces were tightened evenly and firmly, positioned vertically with the aid of grips of the Instron 1195 testing machine, to prevent any slipping during tension. Force value and cross head speed rate (0.5 mm/ min.) were recorded until a rupture of the specimen was obtained.

4.2 Compression Test

The compression test specimens are prepared according to (ASTM- D 618) using hydraulic press type (Leybold Harris No. 36110).

4.3 Flexural Test

The Flexural test specimen dimension was made according to ASTM standard D-790 using the following equation (Gowda, 1999):

$F.S= 3\,P.S/\,2bt^2$ ……………… (2)

Where: P: Maximum load
S: Span length
b: Width of sample
t: Thickness of the sample

4.4 Impact Test

This test is important to calculate the energy density adsorption due to impact energy acting by kinetic energy of hammer. Hammer with 2 joules energy was used to test un reinforced polyester specimen, 10 joules energy hammer was used for fiber reinforced specimens. Standard dimensions were used to prepare pieces according to (ISO.179).

5.0 Results and Discussion

5.1 Tensile Properties

Fig. 1 indicate that the addition of glass or jute fibers as a reinforcement by about 30% volume fraction increases the ultimate tensile strength of polyester resin by 1126% and 143% respectively. On the other hand, the combination of jute and glass fiber in (15% glass fibers and 15% jute fibers as volume fraction) increases the ultimate tensile strength of polyester by 628%.

Fig.2 shows the results of Young modulus of the un reinforced polyester resin and reinforced polyester composite. It can be seen that the Young modulus of the fiber reinforced composites were greater than the un reinforced polyester resin. The values of Young modulus of un reinforced polyester resin, GRP, JRP, J/GRP hybrid laminates are: 4084.52 MPa, 39012.42 MPa, 12342.56 MPa, and 18097.24 MPa respectively, which indicates that the Young modulus increased by 855%, 202%, and 343% for GRP, JRP, and J/ GRP respectively.

The increase in the strength and modulus is naturally dominated by the content of glass fibers in the composites due to their higher strength.. The polyester matrix transmitted and distributes the applied stress to the fibers resulting in higher strength. Therefore, the composite can sustain higher load before failure compared to un reinforced polyester. In addition, higher ultimate tensile strength and higher elongation leads to higher toughness of the material (Bos et. al., 2002).

5.2 Compression Properties

Fig.3 shows the ultimate compression strength (UCS) of un reinforced polyester and fiber reinforced composite. The compression test results depict that UCS of unsaturated polyester, GRP, JRP, and J/GRP hybrid laminates are 78.35 MPa, 320.75 MPa, 116.47MPa and 204.38 MPa respectively. The UCS of GRP, JRP and

J/GRP hybrid laminates increased by 309%, 48%, and 160% as compared to the un reinforced polyester resin. Values of the (UCS) emphasize the common observation, regarding fiber –reinforced composite materials, that un like homogenous materials, the UCS is lower than the UTS. During testing, the failure modes in compression for JRP and J/GRP have been observed to be different. The failure in JRP specimens in compression occurs roughly at 45^o to the loading direction indicating shear failure, where as, in the J/GRP hybrid laminates specimens and GRP specimens the compressive failure appears to be due to delaminating.

5.3 Flexural Properties

Fig .4 shows the flexural strength of the un reinforced polyester and fiber woven fabric reinforced polyester composite. From this figure, it can be seen that the flexural strength increased by 1120%, 77%, and 227% for GRP, JRP, and J/GRP hybrid laminates respectively in comparison with polyester resin alone.

The flexural modulus which is used as an indication of a material's stiffness in static bending condition shows an increase by 588%, 71%, and 294% for GRP, JRP, and J/GRP hybrid laminates respectively in comparison with un reinforced polyester resin as shown in Fig. 5

5.4 Impact Properties

The impact response in fiber reinforced polyester composites reflects a failure process involving crack initiation and growth in the resin matrix, fiber breakage and pullout, delaminating and disbanding (Van den Oever et. al., 1999). Fig 6 shows the impact energy values for un reinforced polyester and for composite material. It can be seen that impact energy increased by 651%, 128%.and 329% for GRP, JRP, and J/GRP hybrid laminates respectively in comparison with un reinforced polyester resin. Higher impact strength values leads to the higher toughness properties of the material.

6.0 Conclusions

The results of the tests on mechanical properties clearly show that the jute fibers, when introduced into the resin matrix as reinforcement, considerably improve the mechanical properties, but the improvement is much lower than that obtained by introduction of glass fibers. Hence, the jute fibers can be used as reinforcement where modest strength and modulus are required.

Another potential use for the jute fibers is to use them as a partial replacement of the glass fibers where strength and modulus requirements of the components are not very high. Thus it can be used as a filler fiber, replacing the glass as well as the resin in hand lay up component.

The main problem of the present work is the difficulty to introduce a large quantity of jute fibers in the JRP laminates because the jute fibers, unlike glass fibers, soak up large amount of resin. This problem is partially overcome when hybridization with glass fibers is carried out.

7.0 References

- Bos, H.L., Van den Oever, M.J.A. and Peters, O.C.J.J., 2002, Tensile and Compressive Properties of Flax Fibers for Natural Fiber Reinforced Composites, J. Material Science, 37 1683.
- Gowda, T. M., Naidu, A. C. B., and R. Chhaya, 1999, Some Mechanical Properties of Untreated Jute Fabric-Reinforced Polyester Composites, J. Composites Part A: Applied Science and Manufacturing, Vol.30, No. 3, pp. 277–284.
- Hassan and Jwn, 2005, Mechanical Properties of High Impact ABS/PC Blends Effect of Blend Ratio, Symposium Polymer Kebangsam, Ke-v.
- Lu, J., Wn, Q., and McNabb, H., 2000, Chemical Coupling in Wood Fiber and Polymer Composites, Wood Fiber Science, pp.88-104.
- Lukkassen, D., and Meidell, A.; 2003; "Advanced Materials and Structure and Their Fabrication Process", Third Edition, Narvik University, HIN.
- Lundquist, L., Marque P. -O. Hagstrand, Y. Leterrier and J. -A. E. Månson, 2003, "Novel Pulp Fiber Reinforced Thermoplastic Composites" Composites Science and Technology, Vol.63,No. 1, pp. 137–152.
- Mansur, M. A., and Aziz M. A., 1983, Study of Bamboo – Mesh Reinforced Cement Composites, Int. Cement Composites and Light Weight Concrete, Vol.5, No.3, pp.165-171.
- Martin H.B Snijder and Jan van Dam, E.G., 2003,Emerging areas of applications in jute composites: jute reinforced polyolefins for industrial applications; materials optimizations and process up-scaling for commercialization, International symposium on jute, 22-24, Kolkata, India
- Martin H.B. Snijder, 2000 ,Reinforcement of Commodity Plastics by Hemp, Flax and Jute Fibres – Extending the Market Opportunity, online-proceedings 3rd International Symposium BIORESOURCE HEMP® & Other Fiber Crops, , Wolfsburg, Germany, (www.bioresource-hemp.de)
- Nagabhushan, T., Radhakrishnan, G., and Joseph, K. P., and Santappa, M., 1987, Proceedings 2 nd Symposium on New Fibers and Composites, Sponsored jointly by Dept. of Science and Technology, India and UNIDO, Vol. 10-11, p.31.
- Saha, A. K.; Das, S. D.; Bhatta, and Mitra, B. C.; 1999; Study of Jute Fiber Reinforced Polyester Composites by Dynamic Mechanical Analysis", Journal of Applied Polymer Science, Vol. 71, Issue 9, pp.1505-1513.
- Shakir, A, and Omidvar, 2006, Investigation on Manufacturing Composite Wheat Straw and Recycled Polyethylene, 2nd IMS Conference Sharjah.
- Smith, M. and Sanjay, K. N., 2006, Mechanical and Rheological Characterization of Treated Jute- HDPE Composite With A Different Morphology, Journal of Reinforced Plastic and Composite , Vol. 25, No. 13.
- Tajvidi, M., Falk, R. H., John, C., and Felton, C., 2003, The Seventh International Conference on Wood Fiber Plastic Composites, Monona Terrace Community and Convention Center Madison, Wisconsin, USA.
- Van den Oever M.J.A., Bos, H.L. and Molenveld, K., (1999), Flax Physical Fiber Structure and its Effect on Composite Properties: Impact Strength and Thermo-mechanical Properties, Die Angewandte Makromolekulare Chemie, 272, 71.
- Winfield, A. G., 1989, Plastics and Rubber International, Vol. 4, p.23.

- Wu, J., D., Yn, C. Chan, J. Kim, and Mai,2000, Effect of Fiber Pretreatment Condition on the Interfacial Strength and Mechanical Properties of Wood Fiber of Composites, J. of Applied Polymer Sci. Vol. 76,1000-101.
- Zoin Al- Abedin, M.; 2007, Study of Jute Fiber- Reinforced Polyester Composite"; Chem. Listry 101, s1-s72, pp.19-32.

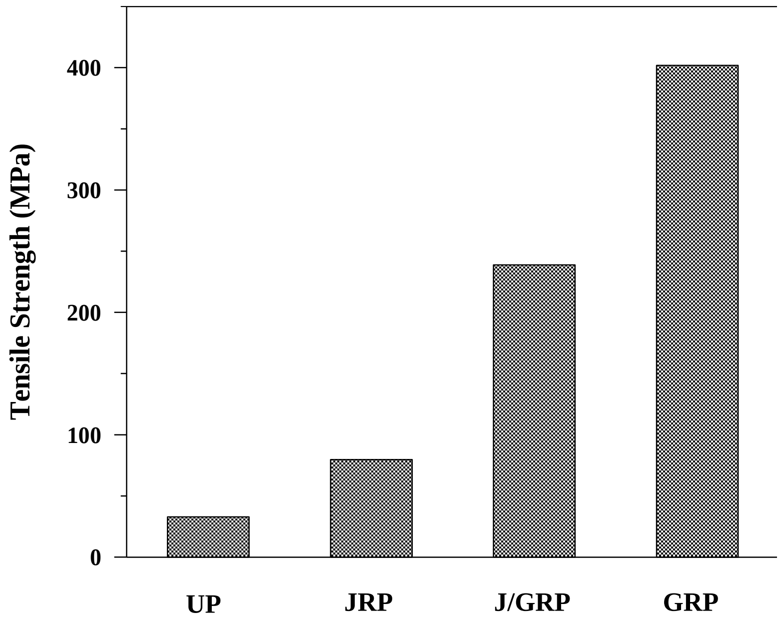

Fig.1: Ultimate tensile strength of un reinforced polyester, JRP, GRP, and J/ GRP hybrid laminates.

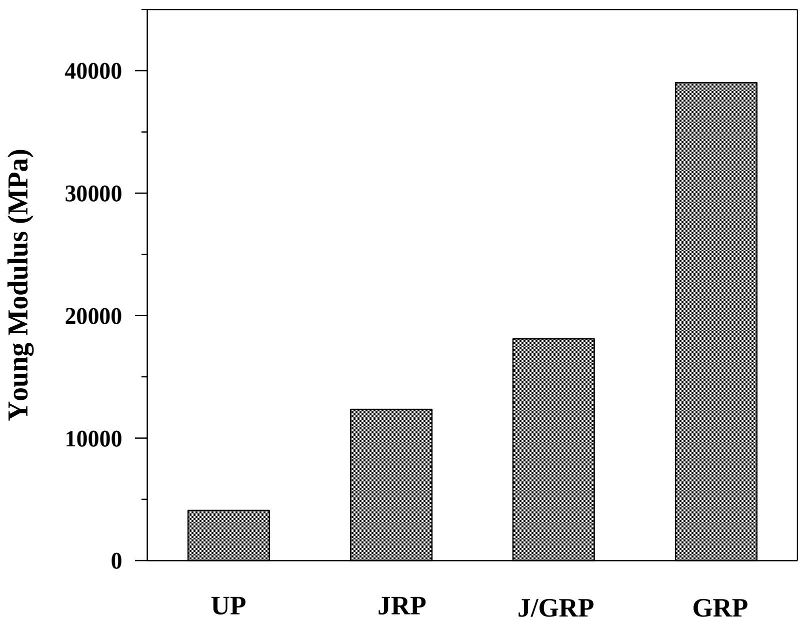

Fig. 2: Tensile young modulus of un reinforced polyester, JRP, GRP, and J/ GRP hybrid laminates.

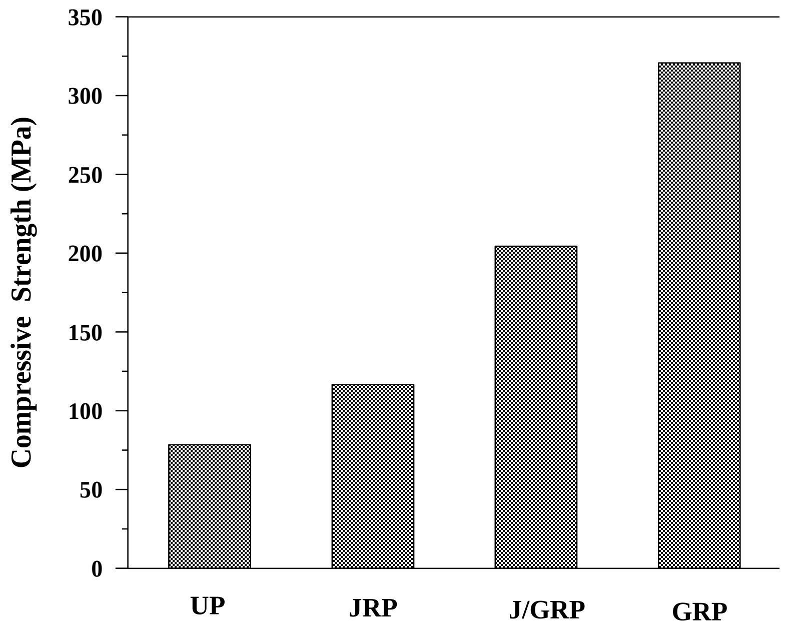

Fig. 3: Ultimate compression strength of un reinforced polyester, JRP, GRP, and J/ GRP hybrid laminates.

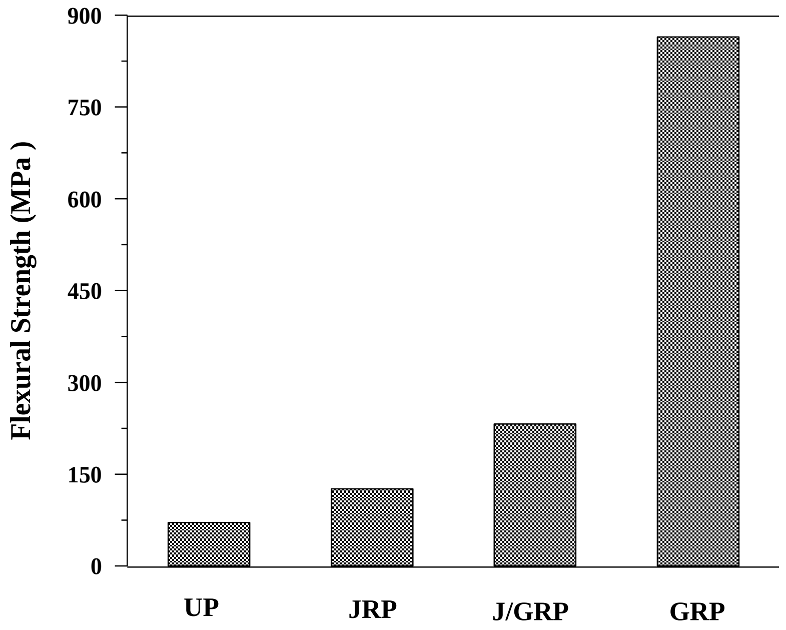

Fig. 4: Flexural strength of un reinforced polyester, JRP, GRP, and J/ GRP hybrid laminates.

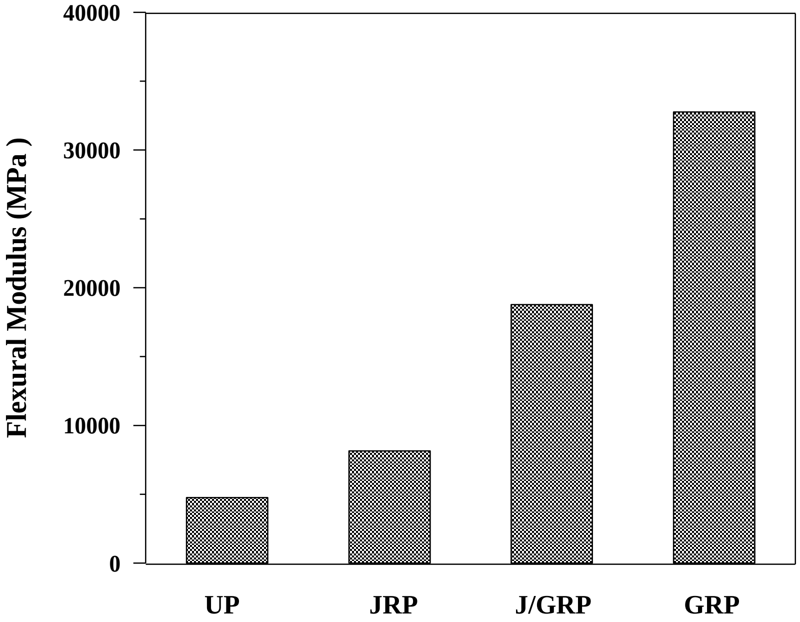

Fig. 5: Flexural modulus of un reinforced polyester, JRP, GRP, and J/ GRP hybrid laminates.

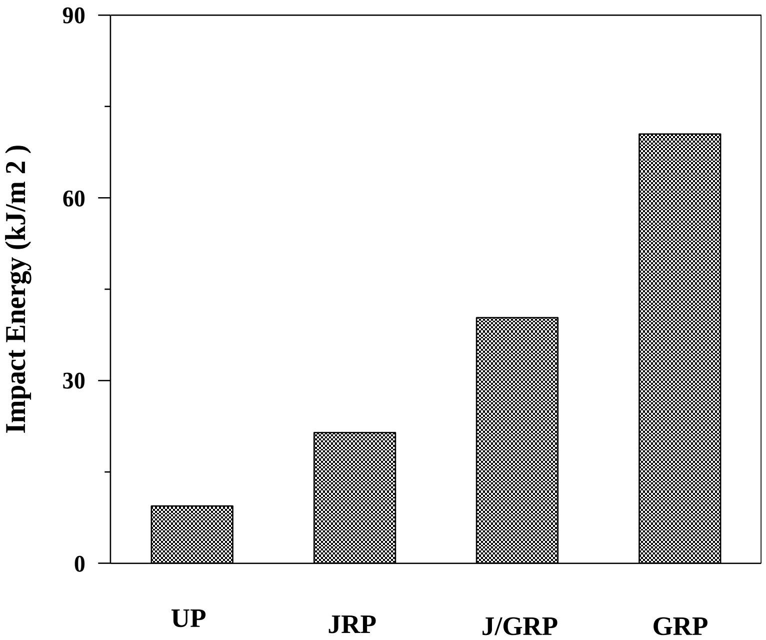

Fig. 6: Impact energy of un reinforced polyester, JRP, GRP, and J/ GRP hybrid laminates.