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Mechanical Properties of Polypropylene (PP) Reinforced Hemp Fiber Composite

الخصائص الميكانيكية لمؤلفات البولي بروبلين ونبات الكتان كألياف طبيعية

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ملخص

تعتبرآلياف التيل من أقوى الآلياف الطبيعية الموجودة وأكثرها استخداما. فى هذا البحث تم دراسة تأثيرتقوية البولي بروبلين بآلياف التيل لذا تم إضافة آلياف التيل بنسب ٣٠٪، ٣٣٪، ٣٥٪، ٣٧٪، ٤٠٪ ، وقد تم دراسة تأتير وزن الآلياف المضافه على إجهاد الشد وانفعال المؤلف وقد اظهرت النتائج أن أقصى إجهاد الشد كان عند إضافة الآلياف بنسبة 33٪ من الوزن الكلى للمؤلف حيث تحسن إجهاد الشد لمؤلف البولي بروبلين وآلياف التيل بنسبة ٣٤،٣٩٪، ٥٤،٨٪ على الترتيب. تم وضع آلياف التيل عند نسبة 33٪ من الوزن الكلى للمؤلف طوليا، بزاويه ٤٥ درجة، أفقيا، عشوائيا وتم دراسة تأثير تغيير إتجاه آلياف التيل فى المؤلف على الإجهاد والإنفعال وقد بينت النتائج أن إجهاد الشد عند الوضع الطولى أكبر من إجهاد الشد عند أى وضع آخر. كذلك تحسن إجهاد الشد كثيرآ عندما كانت الآلياف متسوجه وقد تحسن إجهاد الشد بنسبة ٢٥،٩٨٪، وقد تم دراسة تأتير آلياف التيل على صلادة البولي بروبلين حيث تحسنت صلادة المؤلف بنسبة ٥،٧٧٪ أكبر من صلادة البولي بروبلين النقى.

ABSTRACT

Hemp fibers are one of the strongest and stiffest available natural fibers and therefore have great potential for use in composite materials. This paper investigated the impact response of reinforcing PP by hemp fibers. Hemp fibers were added at (30%, 33%, 35%, 37%, and 40% wt). Influence of fiber's content on composite tensile strength and strain were revealed and the results show that at 33% wt the tensile strength of PP and hemp fiber composites was improved by 12.75%. At 33% wt, the fibers were longitudinally, at 45°, horizontally, and randomly oriented. The influence of fiber's orientation on both stress and strain of the composites was studied and the results showed that, when the fibers were longitudinally oriented, the tensile strength of the composites was higher than that of the other fiber's orientation. Also, the tensile strength of the composites at 33% wt was highly improved when the fibers were weaved and the tensile strength of the composite was improved by 25.98%. The effect of hemp fiber on the hardness of PP was deliberated where the hardness of the composite was increased by 5.77% better than that of pure PP.

Key wards: PP, Hemp fibers, NFRPCs, Tensile strength (Ts), and Hardness number.

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1. INTRODUCTION

Polymers have replaced many conventional materials in various applications which are obviously due to the advantages of polymers over conventional materials [1]. Polymeric materials have been successfully used in different industries including semiconductor, biomedical, automotive, and aerospace, because of their unique properties, such as resistant to abrasion, low heat conduction, low moisture absorption, and sufficient hardness and strength [2]. The stress transfer in a composite depends largely on fiber orientation, stress concentration at the fiber ends, fiber length, interfacial shear strength and compatibility between fiber and matrix [3]. The moisture absorption by composites containing natural fibers has several adverse effects on their properties and thus affects their long-term performance. For example, increased moisture decreases their mechanical properties, it was found that, the moisture absorption increased almost linearly with the fiber loading [4]. The manufacturing methods of natural fiber thermoplastic composites have been modified lay-up/press moulding, pultrusion, extrusion and injection moulding [5]. Currently, plenty of research material is being generated on the potential of cellulose based fibers as reinforcement for plastics and also many attempts have been made to use natural fiber composites in place of glass mostly in non-structural applications [6]. The physical and mechanical properties of lingocellulosic composites largely depend on the type of matrix, content and properties of the reinforcement fillers and filler–matrix interaction, also better dispersion of the filler can be achieved by effective mixing of the components and a proper compounding process [7]. The objective of this work is to investigate the compatibility between PP and hemp fibers to develop a new composite material. Large amounts of hemp fibers are being produced in Egypt as a result of the annual pruning or harvesting process of the trees. In this work, we reported studies on the effects of filler loading, and fiber orientation on the mechanical properties of hemp fiber reinforced PP composites.

2. EXPERIMENTAL WORK

PP sheet was supplied from the market of 295x220x0.3mm. The sheet was cut into layers of 50x50x0.3 mm then they weighted together using a sensitive balance of 0.001 gm accuracy.

The composite was prepared by initially placing a foil of aluminum inside the die, to prevent the direct contact between the specimen and the lower part of the die. A layer of PP was placed above the aluminum foil, then, the fibers were added and uniformly distributed above the first layer of PP. A second layer of PP was placed above the fibers, then, the aluminum foil was placed above the composite to insulate the specimen from the punch and the composite was compacted at 1.2 MPa under steady heating of 170 C° for 5 minutes.

Hemp fibers which submerged in a water for 4 to 8 days were chopped into 50mm length using a guillotine and using the usual treatments for the production of the hemp fibers. Then, the fibers are added to PP at 30%, 33%, 35%, 37%, and 40% wt with different orientation. The tensile test was conducted on Computerized Universal Testing Machine (model WDW-300, serial no: 5126 EXW Date 2010 Y05M, China) with a 5 KN load cell. The specimen of dimensions 50x15x7mm was clamped by the jaws of the testing machine where the force and extension were initially zero and the test was performed under constant strain rate of 2.5mm/min. Three specimens at each fraction were tested to failure. Hardness test was done using shore. Scanning electronic microscope (SEM) was used to examine the fracture samples.

3. RESULTS and DESCUSSION

Figure 1 shows the stress-strain curve of bench mark values of pure PP.

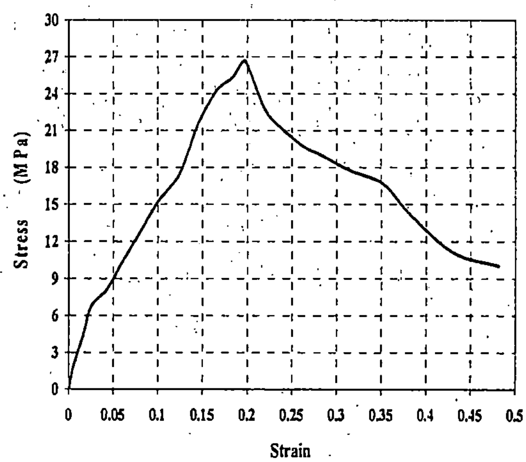

Fig.1 Stress and strain curve of pure PP

At 40% wt, weighted percentage there was no any connection between PP and fibers because of very week bonds between PP and fibers due to higher weight fraction of hemp fibers.

In general, at the proper fabrication conditions addition of hemp fibers to PP improved the stress of the composites greater than that of pure PP as in Figure 2. At 30%, 33%, 35%, and 37% wt of fibers, the average tensile strength of the composites was improved by 3.91%, 12.75%, 6.19%, and 2.59% respectively. This attributed to good interfacial bonding at the filler–matrix interface, better adhesion between PP and hemp fibers, good coherent, and strong interactions between them.

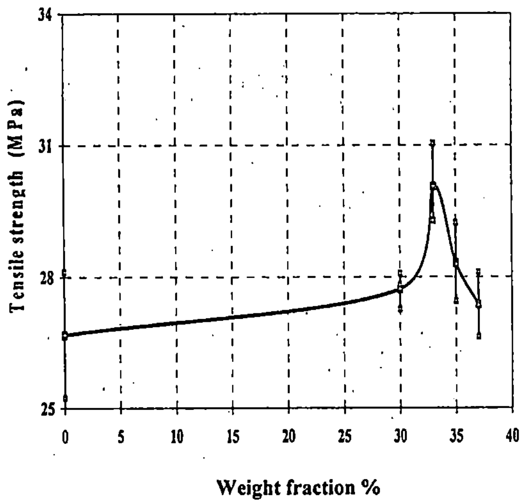

Fig.2 Ts of PP/hemp fiber composite at different fractions of fiber

The average tensile strength of the composite at fiber loading of 33% wt was higher than that of other fiber's content, due to very good connection between the fibers and PP, uniform load distribution, better adhesion, and improved interfacial bonding, which made the composite more stronger. The average tensile strength of the composites was decreased as the fiber loading decreased below 33% wt, because of lower fiber fraction, which decreased the ability of the composite to carry the loads. Also, when the fiber fraction increased greater than 33% wt, the average tensile strength of the composite was less than that at 33% wt, due to higher fiber fraction, lower adhesion between the fibers and PP, and week coherent between them.

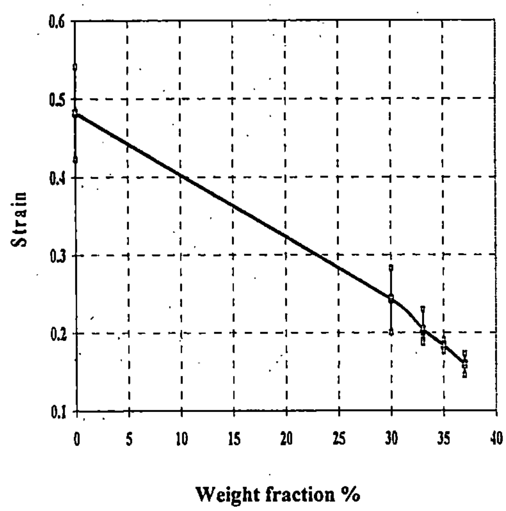

Fig.3 Strain of PP/hemp fiber composite at different fractions of fiber

The strain of the composite at any fiber fraction was lower than that of the pure PP shown in Figure 3. As the fiber content increased, the strain decreased because hemp fibers increased the stiffness and rigidity of the composites so, its tendency to elongate was reduced. The strain of the composites at 30% wt, was greater than that at 37%wt, 35%wt, and 33%wt. The ductility of the composites at 30%wt, 33%wt, 35%wt, and 37%wt was reduced by 49.6%, 57.7%, 62.03%, and 66.8% respectively.

At 33% wt of hemp fibers, the fibers direction was varied. The fibers were placed longitudinally, randomly (where the fibers were chopped into 3mm length), at 45°, and horizontally. Also, at 33% wt, the fibers were weaved before the composite was formed. Three specimens were manufactured at each orientation. By changing the orientation of fiber at the same fiber's content changed the stress and strain of the composites as shown in Figures 4 and 5.

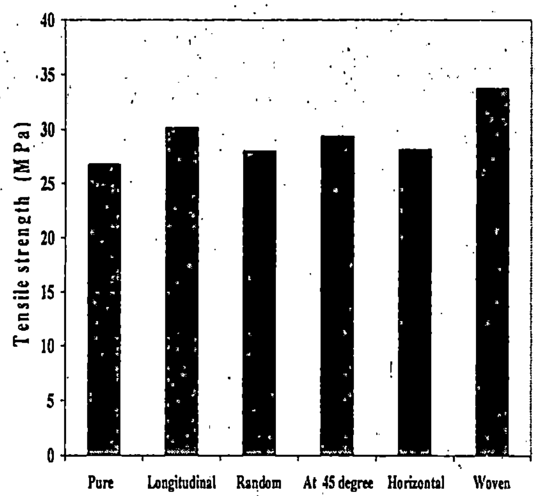

Fig.4 Ts of PP/hemp fiber composite at different orientations of fiber

The stress of the composite when the fibers were oriented longitudinally was higher than that of the other orientations. The average tensile strength of the composite was increased by 12.75% greater than that of pure PP. When the fibers were randomly and horizontally oriented, the improvement of the composites tensile strength was nearly equal and less than that of the other orientations due to lower interfacial bonding action, separation of fibers from PP layers when the composites was undergone the test. But, when the fibers were placed at 45°, the tensile strength was increased and improved by 9.75%. This attributed to better adhesion, improved interfacial bonds, and good coherent. Also, when the fibers were weaved like spin, the tensile strength of the composites was greatly increased and improved by 25.98% due to higher adhesion, better interfacial bonds due to penetration of molten PP through the fiber spin.

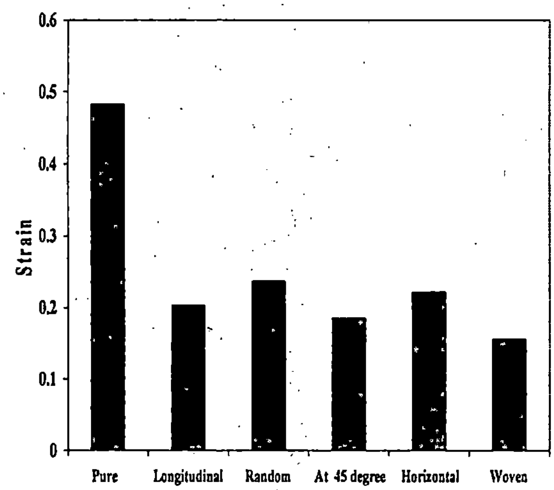

Fig.5 Strain of PP and hemp fiber composite at different orientations of fiber

When fibers were randomly oriented, the strain of the composites was greater than that of the other orientations. When the fibers were oriented at 45°, the strain was less than that of the other orientations, because of a good connection between the fibers and PP due to rough surface of PP layers, and penetration of fibers into slots made in PP surface at 45°.

The hardness of the composites was measured using a hardness tester "shore A" of accuracy "0.2 HA". The hardness number was the average of five measures taken at the surface of the composites. The average bench value of PP hardness number was 88.4 HA. But that of PP and hemp fibers composite was increased by 5.77% better than that of pure PP as shown in Figure 6.

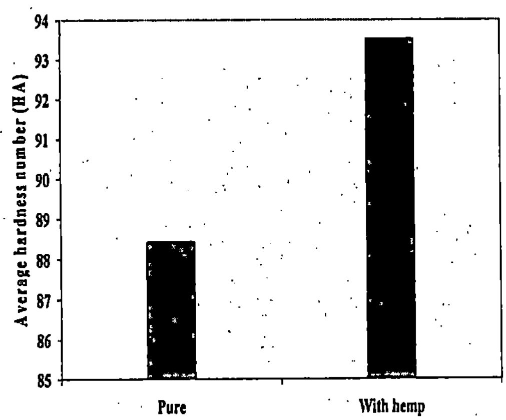

Fig.6 The average hardness number of PP/hemp fiber composites

The failure of the composites and interfacial bonding between the fibers and matrix were examined using a scanning electron microscope (JSM-5500LV) supplied by JEOL Company Limited, Japan. The samples were viewed perpendicular to the electron beam, and different portion of the fractured surface were examined. Figure 7 showed the surface morphology of hemp fibers.

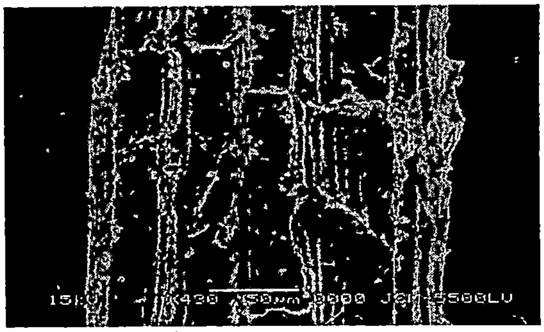

Fig.7 SEM observation of the surface morphology of hemp fibers

SEM micrographs showed that, the fibers were well connected to PP as represents by arrows in Figure 8. The interfacial adhesion between hemp fibers and PP induced higher interfacial bonding, increased the effective contact area between the fiber and PP. The fibers were also very well dispersed resulted in improved mechanical properties.

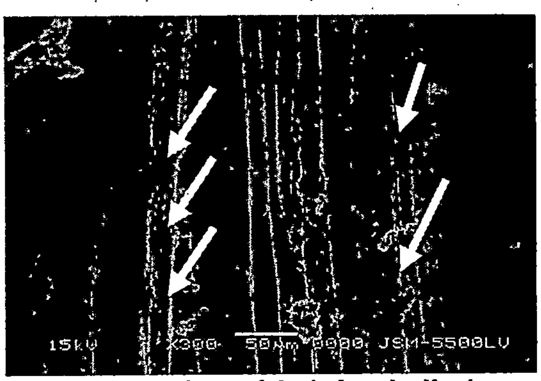

Fig. 8 SEM photo of the induced adhesion between the fibers matrix

The fibers were tear when the samples were undergone the test and also kinks were produced as illustrated by arrows in Figures 9 and 10. It is obvious that, separation occurred at the fiber-matrix interface as shown by arrows in Figure 10. Under the loading conditions, fibers were pulled out from the matrix, due to the presence of hemicelluloses lignin and cellulosic matters present on the fiber surface. Thus, it resists the stress transfered from the matrix to the fiber [8]. These constituents covered the reactive hydroxyl groups of the fiber and lowered the effective interaction with the matrix [8].

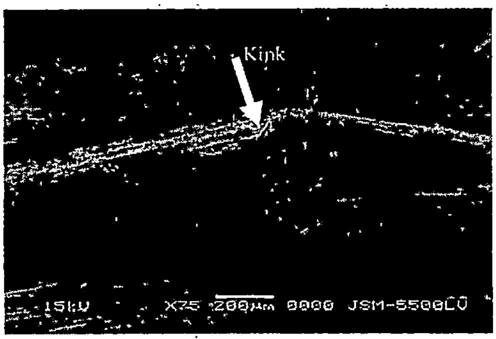

Fig.9 SEM photo shows the fracture of fibers due to kinks

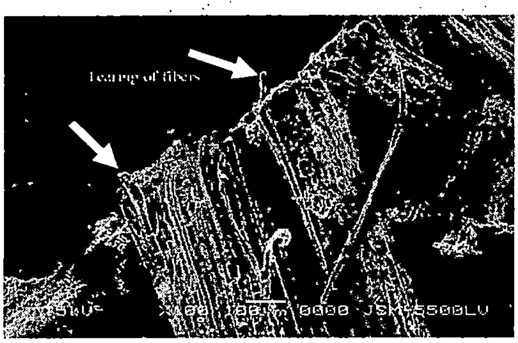
Fig.10 SEM photo showing tearing of fibers

Fig.11 SEM photo shows the separation of fibers in the samples

4. CONLUSION

In general, reinforcing PP with hemp fibers improved the stress of the composites where at 30%, 33%, 35%, and 37% wt of fibers the average tensile strength of the composites was improved by 3.91%, 12.75%, 6.19%, and 2.59% respectively. On the other hand, the strain was decreased due to the increasing of stiffness of the composite. Also, by varying the fiber's orientation, both the stress and strain of the composites were affected. Also, the tensile strength of the composites was greatly increased and improved by 25.98% when 33%wt of fibers were weaved like spin. Also, the average hardness number the composites was increased by 5.77% better than that of pure PP.

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