

**RE-EVALUATION OF COTTON AND E-GLASS FIBRE FABRIC WASTES
IN THE MANUFACTURE OF HYBRID COMPOSITES**

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Abstract

Turkey is a land of cotton fibres furthermore cotton fabric production. In recent years, glass fibre fabric manufacture is rapidly developing in the country, as well. The production wastes of these two industries are re-used in various applications however the key aim of this preliminary work is to re-evaluate and combine these two very different waste fibers, namely cotton and glass, in a hybrid composite in order to design a more value added product. For this purpose, waste E-glass and cotton fibres were used as reinforcement in the polyester matrix in order to produce a hybrid composite by using compression moulding technique. Mechanical analyses including impact resistance, tensile strength and hardness tests were investigated. For micro-structural analysis, scanning electron microscopy (SEM) was also carried out as an instrument. Consequently, cotton and E-glass fiber fabric wastes can be recycled for making more value added products in the future.

Key words: hybrid composite, cotton waste, e-glass fibre, natural fibre composite.

1. INTRODUCTION

In recent years, there has been a growing interest for using natural fibres in polymer matrices because they are environmentally friendly, low cost, biodegradable, and renewable resources. Although there are some drawbacks in using natural reinforcement materials in synthetic polymer matrices, such as their inherent variability, poor wettability and poor interfacial adhesion with many polymer matrices; getting hybrid composites by combining proper reinforcement materials or using physical and chemical treatments of the fibres can be the solutions [1,2].

Mostly, interior panels for automobiles and trucks are an example of today's use of natural fibres in polymer matrix composites [2,3]. The main advantages of using natural fibres are related with their environmental aspects and their low weight which let these composites be able to compete with glass mat thermoplastics in wide spread use for automotive industry. Compression molding and resin transfer molding techniques are mostly preferred methods for producing thermoset composites[3]. In the literature, there are several studies on natural fibre reinforced polymers and hybridization of composites [1-6].

Since Turkey is a land of cotton fibers for years, there is a vast production of cotton fabric in the country. Waste of this fabric production is reused in many fields in Turkey on the other hand these wastes can be evaluated in more value added novel products, like benefiting them in hybrid composites. Nowadays, glass fiber fabrics are being manufactured increasingly in Turkey, mostly used in sailing sector. There has been also some waste in this sector however they are not evaluated in a professional manner. The key aim of this study is to re-evaluate and combine the two very different waste fibers, namely cotton and glass, in a hybrid composite in order to design a more value added product. For this purpose, waste E-glass fibres and cotton fibres opened from waste cotton fabrics

were reinforced to the polyester matrix in order to produce a hybrid composite by using compression molding technique. Mechanical performances of these composites were investigated with Shore D hardness, tensile strength and Charpy impact resistance tests. Scanning electron microscopy (SEM) was carried out to investigate the fibre-matrix adhesion.

2. MATERIALS AND METHOD

2.1. Reinforcement and matrix material selection

In this study, for manufacturing the hybrid composite; polyester (PET) was used as the matrix material where both waste e-glass and cotton fibers were used as reinforcement materials. Cotton fibers were recycled from woven cotton fabric by using rag pulling machine which can be seen in Fig. 1a. Waste E-glass fibers were provided from a fiber glass fabric manufacturer (Fig. 1b) [7]. Moreover, E type glass was selected owing to its conformity of usage with PET resin and manufacturing by compression molding technique [8]. Key characteristics of cotton and E-glass fibers were listed in Table 1 and 2.

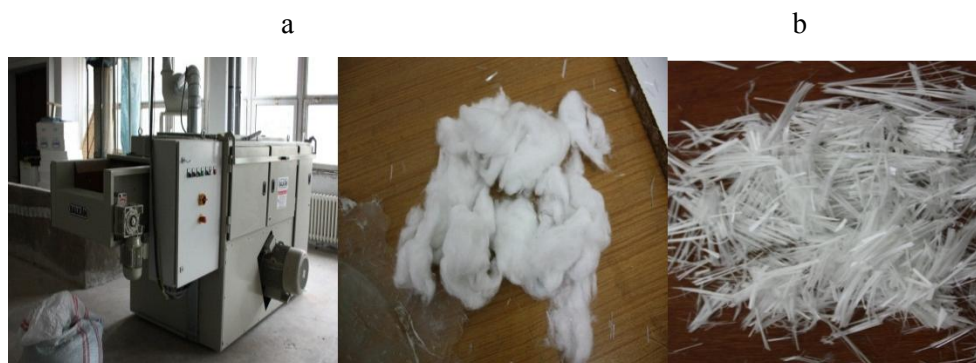


Fig. 1. Rag pulling machine and recycled cotton fibers (a), trimmed waste e-glass fibers (b).

Table 1. Key characteristics of Cotton fiber [12]

Young Modulus (MPa)	5300-8000
Tensile Strength (MPa)	400-850
Elongation (%)	3-8

Table 2. Key characteristics of E-glass fiber [8, 12]

Type of fiber	E
Availability with resin	Polyester
Fiber diameter(μ)	Nom. 12
Weight/ unit area(g/m^2)	$225 \pm 7\%$
Split Tex (g/1000m)	30
Wettability	Quick

Crosslinking type	Silane
Trimmed length(mm)	50
Young Modulus (MPa)	73000
Tensile Strength (MPa)	1900-2600
Elongation (%)	0-3.2

2.2. Manufacturing methodology

Composite panels were manufactured manually by the compression molding technique. Both female and male moulds were designed for this study. Before placing the materials into these moulds, moulds were smoothed over with wax to let them re-usable. Moreover polyester resin, trimmed e-glass fibers and recycled cotton fibers were mixed with using separator paper in the moulds due to the predetermined amounts. In this application, the most crucial parameter was to provide homogeneity in the composite and in order to accomplish this, preparation of the samples were done in extreme care. Moulds were then placed into hydraulic press (Fig. 2a) under 90 bar pressure through 24 hours. Characteristics of the manufactured hybrid composites are listed in Table 3.

All test specimens were cut from these composite panels by CNC milling cutter (Fig. 2b) in relation to the according standards [9-11].

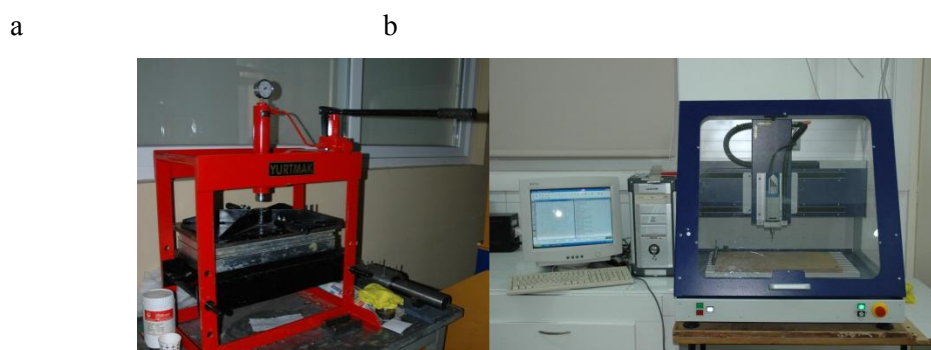


Fig. 2. Hydraulic press (a), CNC milling cutter (b).

Table 3. Characteristics of hybrid composite specimens

Specimen Code	Polyester (g)	Hardener (g)	Cobalt (g)	E-glass fiber (g)	Cotton fiber(g)	Total fiber ratio (%)
1	300	5	1	-	-	0
2	300	5	1	40	15	15.5
3	300	5	1	60	15	20
4	300	5	1	60	25	22

2.3. Performance tests and analysis

Shore D Hardness test (ASTM D 2240-05) [9], Charpy impact resistance test (EN-ISO 179:1997) [10] and tensile strength (ASTM D368-08) [11] test were performed to the composites (Fig. 3). Also, SEM analysis was made to investigate the hybrid microstructure.

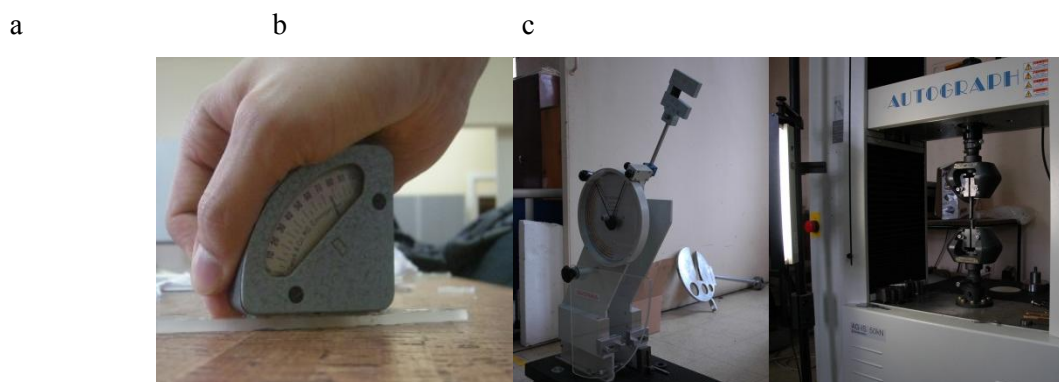


Fig. 3. Equipments of Shore D hardness test (a), Charpy impact resistance test (b), Tensile strength test (c).

3. RESULTS AND DISCUSSION

3.1. Tensile strength tests

Test results indicate that the hybrid composites including 60 g e-glass fiber and 15 g cotton (coded as 3) wastes demonstrate higher maximum stress and maximum force values when it is compared to the composites including 40 g e-glass fiber and 15 g cotton (coded as 2). This result can be clearly justified by glass fibers' superior tensile strength and modulus characteristics when compared with that of cotton and polyester resin. Glass fibers have confirmed their superior reinforcement characteristics to the hybrid composite therefore the increase of the glass fiber weight ratio improves the strength of the composite as expected. On the other hand, the same specimens (coded as 3) have also higher maximum stress values compared to the composites including 60 g e-glass fiber and 25 g cotton wastes (coded as 4). This can be explained with the accumulation of cotton wastes in higher weight ratios through the cross section of the test specimens which leads to weak points (Table 4, Fig. 4a) and moreover cotton fibers inherent low tenacity and low modulus characteristics to that of glass fibers explain the reduction of the stress values, but on the other hand enhancing the strain characteristics. Either they are e-glass or cotton, the increase in total fiber ratio results in higher breaking elongation values as well (Table 4, Fig. 4b).

Table 4. Tensile strength test results.

Specimen Code	Maximum Force (N)	Breaking Elongation (%)	Maximum Stress (N/mm ²)
1	1051.56	0.519	21.91
2	1410.94	0.525	29.39
3	1606.25	0.662	33.46
4	1532.81	0.743	31.93

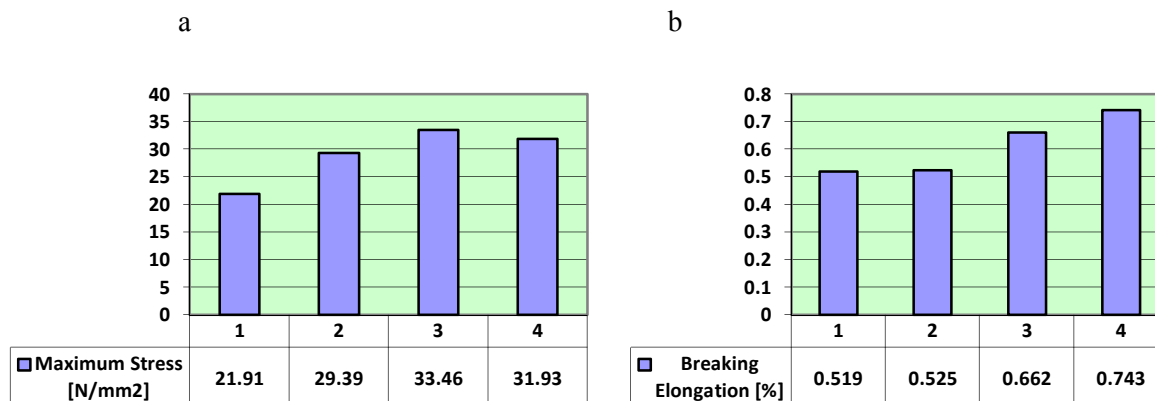


Fig. 4. Tensile strength test results: maximum stress (a), breaking elongation (b).

3.2. Shore D hardness test and Charpy impact resistance

According to test results, composites with increasing e-glass fiber ratio have higher hardness and Charpy impact resistance values (Fig. 5). These results can be explained by the glass fibers high modulus characteristics. The hardness of the materials can be lowered down by addition of cotton fibers, as seen in the specimen coded as 4. For reducing the hardness of the hybrid composite, the cotton fiber weight ratio can be increased but on the other hand, the preparation of the samples with higher cotton fiber is becoming more difficult. High wetting characteristics and interfacial adhesion of cotton fibers make them easily accumulate in the resin at higher weight ratios therefore non-uniformity occurs in the hybrid composite. This is a challenging problem and it can be overcome by improving mixture application and determining an optimum ratio for cotton fiber.

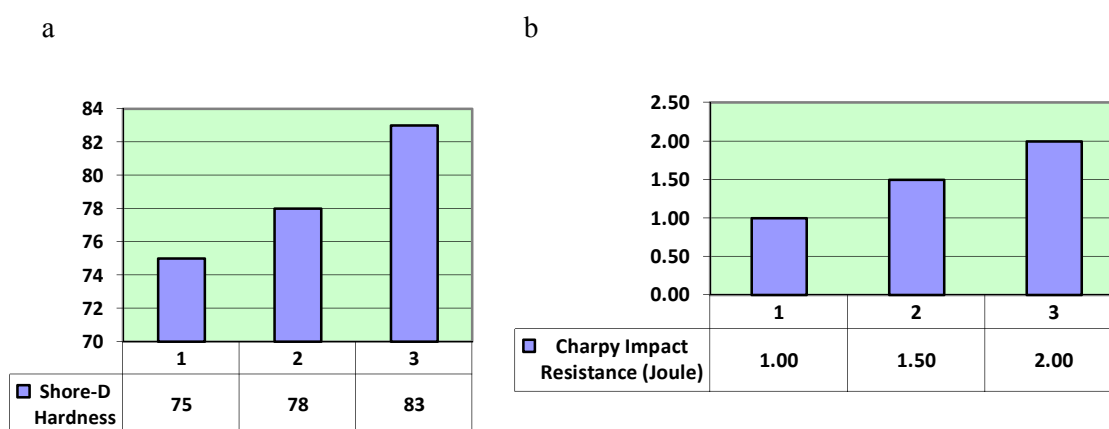


Fig. 5. (a) Shore D hardness test results, (b) Charpy impact resistance test results.

3.3. SEM analysis

Recycled cotton fibers and trimmed waste e-glass fiber bundles in the brittle polyester matrix can be seen in Fig. 6a. Moreover, average diameter of the e-glass fibers used in this study was given as 12μ in

Table 1. This can also be confirmed by the measurement of the diameters of e-glass fibers from the SEM images shown in Fig. 6b.

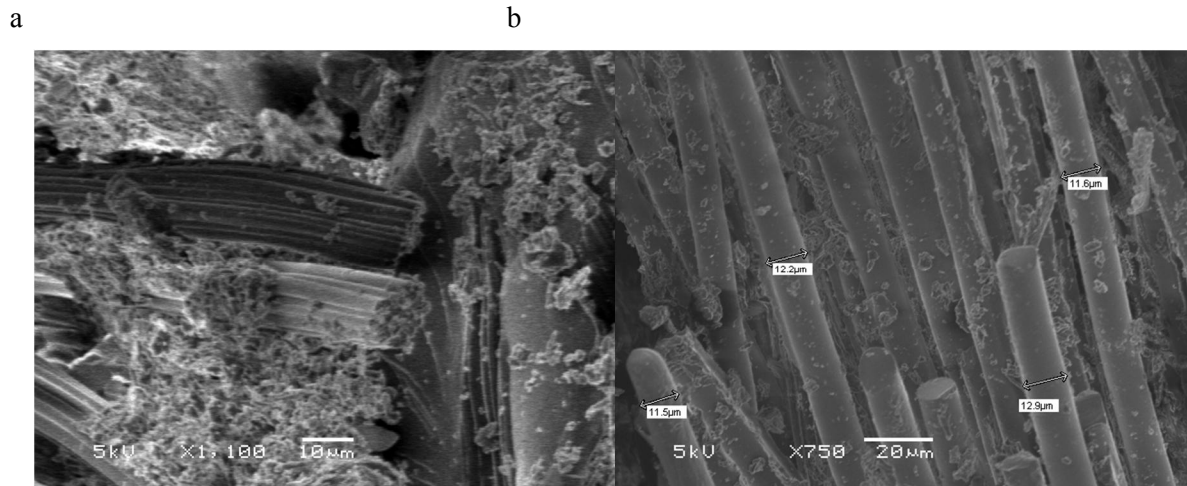


Fig. 7. SEM analysis: Hybrid composite structure (a) diameters of e-glass fibers (b).

4. CONCLUSION

In this preliminary work, test results indicate that increase in e-glass fiber ratio improves the tensile strength of hybrid composites while it is contrary for cotton fibers. Utilization of waste cotton fibers as a reinforcement material in 15g shows better tensile strength in comparison with its 25g in 300g PET matrix. Although addition of cotton allows low density and low cost production by recycling the wastes; it causes accumulation through the cross section of the specimens that leads to weak points and so, loss of strength. Higher hardness and impact resistance were achieved by increasing the e-glass fiber amounts from 40g to 60g in 300g PET matrix because of both thermoset PET matrix and e glass fibers. Although high modulus and brittle structure of E-glass fibers causes hardness in the composite this can be reduced by hybridization of the composite by utilizing cotton fibers that causes an increase at the breaking elongation of the composites. Hybrid structure can be separately seen from SEM images which also approves the fiber matrix adhesion.

These hybrid composites can be preferred in automotive industry as a buffer material. Their cost analysis, mechanical performance including hardness and tensile strength seems to be adequate. However, toughness of these hybrid structures is not in sufficient limits. Therefore, for future work, to eliminate ductility, composites can be subjected to thermal treatments. Moreover, homogeneity of the panels must be improved.

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