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Mechanical Properties of Continuous Glass Fiber/Pet Composites

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The interest and demand towards the use of thermoplastic composites have been gradually increasing each day due to their high damage tolerance, recycling, and energy absorption capability compared to thermoset composites. Despite such positive properties, thermoplastic materials have a negative side, which is their high melt viscosity. The solution to this problem can be achieved by using hybrid yarns in which reinforcement and matrix fibers are homogeneously mixed together. In this work, it was aimed to investigate the mechanical properties of thermoplastic composites to be prepared using continuous glass fiber/poly(ethylene terephthalate) (CGF/PET) hybrid yarns in different proportions by volume. CGF/PET hybrid yarns containing glass fiber in different volumes (35, 45, 55 and 65%) were produced, woven and then transformed into thermoplastic composite test plates using hot press. Microstructural properties of the composites were investigated using optical microscopy analyses. Tensile, three point bending and impact tests were used to investigate the mechanical properties.

Keywords: Glass fiber, PET, Hybrid yarn, Thermoplastic composite, Mechanical properties

Introduction

Polymer-based composites are divided into two classes as thermoset composites and thermoplastic composites. Thermoset-based composites such as unsaturated polyester, epoxy and vinyl ester have begun to be replaced by thermoplastic composites due to reasons such as limited shelf life, long production times and lack of recycling. Thermoplastic composites, unlike thermoset composites, can be recycled, reshaped by heating without significant changes in their properties, and do not undergo chemical changes during molding[1]. While thermoplastic composites have many advantages, their high resin viscosity is a major concern during the production of composites. One of the best methods to produce thermoplastic composites where the resin wraps the reinforcing fiber in the best way is to use homogeneously mixed hybrid yarns. Homogeneous mixing of matrix and reinforcing fibers provides short cycle times and reduces mass transfer distances. In thermoplastic composites produced using hybrid yarn, the production occurs by melting the matrix part of hybrid yarns under the required temperature and pressure. In the process, the matrix fibers reach their melting temperature, begin to melt, and after melting, it fills the spaces between the fibers and layers[2].

For the production of thermoplastic composites, it is common to use thermoplastic polymers as matrix materials and glass fibers as reinforcement elements[3-5]. In some of the previous studies, it has been observed that thermoplastic matrix composites have higher compression values than epoxy matrix composites[6,7]. Vieille et al. stated that there are less delamination areas under impact load in thermoplastic matrix composites compared to epoxy matrix composites[8]. The analysis of the manufacture of glass/polypropylene hybrid yarns and the low speed effect (15J, 25J and 35J) and the impact (CAI) performance of thermoplastic and thermoset composites produced from hybrid yarns were examined. The results showed that the hybrid yarn strength and blend quality were highly affected by the change of air pressures. Impact tests have shown that thermoplastic composites absorb approximately 73-80% of the impact energy, while thermoset composites absorb 39-41%[2].

The aim of this study is the production of lightweight and high performance thermoplastic composite materials from woven fabrics using continuous glass fiber/PET hybrid yarns containing different proportions of glass fiber, determination of process parameters and characterization of the mechanical and microstructural properties of the produced thermoplastic composite materials.

Experimental

Materials

In this study, to be used in the production of hybrid yarn, continuous E-glass fiber that is compatible with polyethylene terephthalate (PET) from Nippon Electric Glass and red PET yarn from Korteks Mensucat Sanayi ve Ticaret A.Ş.company were supplied, and the properties of these materials are shown in Table 1.

Table 1. Properties of Glass Fiber and PET Yarn

Characteristic	Glass Fiber	PET Yarn
Type	E-Glass	FDY
Yarn Count (tex)	300	35
Density (g/cm^3)	2.66	1.38

Production of CGF/PET Hybrid Yarn

A modified air-jet texturing machine was used for the production of continuous glass fiber/PET hybrid yarns containing different amounts of glass fiber by volume (Korteks Mensucat Sanayi ve Ticaret A.Ş., Turkey). Using this machine, as shown in Figure 1, the continuous glass fiber and PET yarn was passed through delivery/drawing godets to the mixing unit, where the components were opened and mixed with the help of cold air. After mixing, continuous glass fiber/PET (CGF35/PET) containing 35% glass fiber by volume, continuous glass fiber/PET (CGF45/PET) containing 45% glass fiber by volume, continuous glass fiber/PET (CGF55/PET) containing 55% glass fiber by volume and continuous glass fiber/PET (CGF65/PET) hybrid yarns containing 65% glass fiber by volume were obtained.

Preparation of CGF/PET Fabrics

CGF35/PET, CGF45/PET, CGF55/PET and CGF65/PET fabrics were produced using weaving machine (Zorluteks, Turkey). Each fabric is woven with a twill 2/2 weave pattern.

Preparation of Test Samples

CGF35/PET, CGF45/PET, CGF55/PET and CGF65/PET fabrics were turned into thermoplastic composite test plates of 150x300 mm with the help of hot press using different temperature, pressure, time and fabric layers, as shown in Table 2.

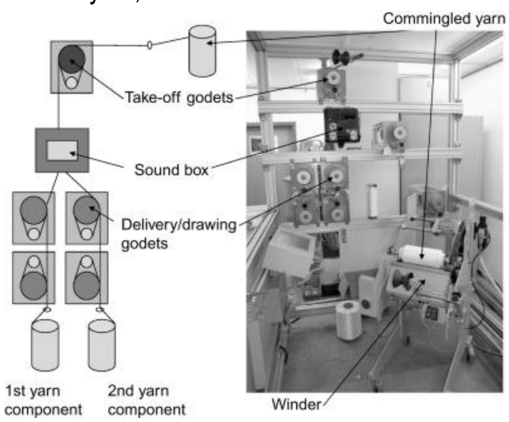

Fig.1. Production of CGF/PET Hybrid Yarn

Results and Discussion

CGF35/PET*, CGF45/PET*, CGF55/PET* and CGF65/PET * were produced using 28 bar pressure from thermoplastic composite test plates prepared using different temperature, pressure, time and fabric layers given in Table 2. However the pressure was insufficient, so the samples were not suitable. Later trials (CGF35/PET, CGF45/PET, CGF55/PET and CGF65/PET) were done with 40 bar and were successful.

Table 2. Preparation of Test Samples

Sample	Pressure (bar)	Number of Fabric Layer	Heating Temp. (°C)	Heating Time (min)
CGF35/PET*	28	6	285	15
CGF35/PET	40	7	290	10
CGF45/PET*	28	6	285	15
CGF45/PET	40	7	290	10
CGF55/PET*	28	6	290	15
CGF55/PET	40	6	290	10
CGF65/PET*	28	6	290	15
CGF65/PET	40	6	290	20

Optical microscopy analysis was performed to see the microstructural properties of CGF35/PET, CGF45/PET, CGF55/PET and CGF65/PET thermoplastic composite samples. As seen in Figure 2, CGF35/PET, CGF45/PET, CGF55/PET shows good impregnation but CGF65/PET shows poor impregnation because matrix level too low to impregnate glass fibres. Fiber breakage was observed in all composite samples. The reason for this may be that the air in the hybrid yarn production breaks the glass fibers, albeit a little.

ISO 527-4 Tensile, ISO 14125 3-point bending and ISO 6603-2 impact tests were performed to investigate the mechanical properties of CGF35/PET, CGF45/PET, CGF55/PET and CGF65/PET thermoplastic composite samples. As seen in Table 3, according to ISO 527-4 tensile test results, the most durable sample was the CGF45/PET thermoplastic composite sample. As the glass ratio increased, the tensile strength initially increased, but decreased after the glass volume ratio in the material exceeded 45.

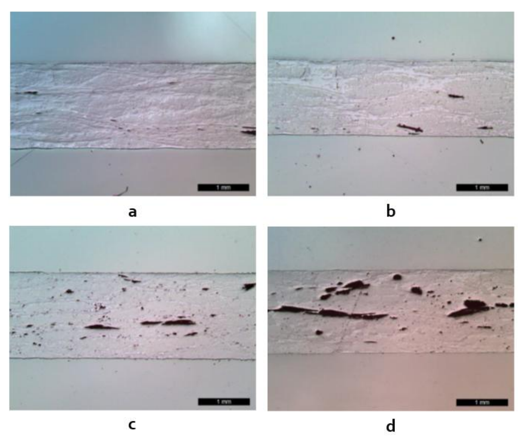

Fig.2. a) Optical microscope image of CGF35/PET thermoplastic composite sample, b) Optical microscope image of CGF45/PET thermoplastic composite sample, c) Optical microscope image of CGF55/PET thermoplastic composite sample, d) Optical microscope image of CGF65/PET thermoplastic composite sample

Table 3. Tensile Test Results			
Sample	Fmax (N)	Tensile strength (MPa)	Elongation at break (%)
CGF35/PET	10947	242.5	1.5
CGF45/PET	11687	268.7	1.5
CGF55/PET	9742	223.8	3.29
CGF65/PET	5374	131.8	2.0

As seen in Table 4, according to ISO14125 3-point bending test results, the most durable sample was the CGF45/PET thermoplastic composite sample. As the glass volume ratio increased, the bending tension initially increased, but decreased after the glass volume ratio in the material exceeded 55.

Table 4. 3-Point Bending Test Results			
Sample	Fmax (N)	Bending Tension (MPa)	Modul (MPa)
CGF35/PET	307	278	14275
CGF45/PET	240	279	16031
CGF55/PET	248	309	19900
CGF65/PET	119	188	18413

Table 5. Impact Test Results			
Sample	Fmax (N)	Energy at hole (J)	Total energy (J) [a]
CGF35/PET	5020	13.3	-
CGF45/PET	4863	18.1	-
CGF55/PET	5127	19.5	-
CGF65/PET	6051	-	42.2

[a] After the test, the total energy result is given since the CGF65/PET thermoplastic composite sample did not puncture.

As seen in Table 5, according to ISO 6603-2 impact test results, CGF65/PET sample showed the best resistance. As the glass volume ratio increased, the impact resistance of the material increased.

Conclusions

CGF35/PET, CGF45/PET, CGF55/PET and CGF65/PET hybrid yarns were prepared successfully with the help of compressed air and their fabrics produced. Different 4 composite samples (CGF35/PET, CGF45/PET, CGF55/PET and CGF65/PET) were prepared using hot press molding. While the impregnation process was successful for CGF35/PET, CGF45/PET and CGF55/PET samples, good impregnation could not be performed for CGF65/PET sample. According to tensile test CGF45/PET sample showed the best mechanical strength property. According to 3-point bending test CGF55/PET sample showed the best mechanical strength property. According to impact test, CGF65/PET sample showed the best resistance.

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