Proceedings of the Estonian Academy of Sciences,
2018, **67**, 2, 165–168
https://doi.org/10.3176/proc.2018.2.06
Available online at www.eap.ee/proceedings

MATERIALS SCIENCE

Development of air-jet textured and twisted carbon fibre–polyamide 6,6 hybrid yarn for the production of thermoplastic composite materials

Müslüm Kaplan

Department of Textile Engineering, Faculty of Engineering, Bartin University, 74100 Bartin, Turkey; mkaplan@bartin.edu.tr

Received 19 October 2017, accepted 28 December 2017, available online 24 April 2018

Abstract. Recently, fibre-reinforced thermoplastic composite materials have been used widely in the automotive and aerospace industries because of their fracture toughness and recycling. Despite such superior properties, these materials have a weak side: high melt viscosity and low thermal resistance. The high melt viscosity of such materials makes the homogeneous wetting process difficult. This property leads to problems with the machinery and equipment at the mass production lines, and thus costs increase. Reinforcing the fibre and matrix mixed in the solid state and consolidating them helps to solve this problem. This creates a new type of semi-finished material for thermoplastic composites – hybrid yarn. The main aim of the current study was to solve the problem with high melt viscosity of thermoplastic composite materials by mixing the reinforcing fibre and matrix in the intermingling and twisting process and consolidating them. Fabricated hybrid yarns can be processed by using different textile surface forming techniques (weaving, knitting, etc.).

Key words: hybrid yarns; thermoplastic composite; carbon fibre; polyamide 6,6; air-jet texturing; twisting.

1. INTRODUCTION

Carbon fibre-reinforced composites (CFRCs) composed of endless carbon fibre yarn (CFY) reinforcement combined with a binding matrix have been widely used for load bearing structural components because of their excellent strength, rigidity, and damping properties as well as their low weight and high resistance to impacting and corrosion. Considering the type of polymer matrix used for volume application, CFRCs are divided into thermoset and thermoplastic composites. Although CFRCs are preferentially manufactured based on a thermoset matrix (more than 75% of all the composites), thermoplastic composites have now been developed due to some distinctive advantages over thermoset composites [1].

Thermoplastic CFRC materials have been widely used in the automotive and aerospace sectors due to their fracture toughness and recyclability. However, besides their superior properties, these materials have some weaknesses such as high melt viscosity and low thermal resistance. High melt viscosity complicates the work and increases the production costs. To solve this problem, reinforcing fibre and matrix mixed in the solid state and consolidating them could be applied. In this way a new type of semi-finished material for thermoplastic composites – hybrid yarn – is produced.

The idea of mixing the solid form of the reinforcing fibres and the matrix to solve the problems such as high melt viscosity, which increases production costs and complicates the operating conditions of thermoplastic materials, has been developed. Consequently, many hybrid yarns are used as semi-finished in the production of thermoplastic composites.

The aim of this work is to develop a new method for obtaining CFRCs that could be used for example in aerospace, automotive, machine, construction, energy, and marine industries.

2. EXPERIMENTAL

2.1. Raw materials

To produce the hybrid yarns CFY (A38 3K, Dowaksa, Turkey) and polyamide (PA) 6,6 (Kordsa, Turkey) were used. The characteristics of the components are detailed in Table 1.

2.2. Hybrid yarn manufacturing

A modified air-jet texturing machine with an added twisting part was used for the production of commingled hybrid yarns consisting of CFY and PA 6,6 filament yarns. The CFY and PA 6,6 filament yarns were fed by means of separate godet pairs. The mixing of the CFY and PA 6,6 filament yarns was realized aerodynamically using an intermingling nozzle. In the second stage the produced hybrid yarns became semi-finished by weaving in the sample weaving machines. In the next stage, the woven fabric preform obtained from the hybrid yarn was formed into thermoplastic composite by consolidation (see Fig. 1). The consolidation process was carried out in the heat press at a temperature higher than the melting temperature of the used thermoplastic polymer (Table 2).

For a homogeneous mixing of both the components, the tension in the filaments must be low to expedite the opening of the filaments at the mixing point. This was done by means of an overfeeding of the filaments, keeping the speed of the feeding rollers faster than that of the drawing roller. The overfeed used for CFY and PA 6,6 was 2% and 4%, respectively. The hybrid yarns were produced by varying the air pressure from 3 to 4 bar, keeping the delivery speed (90 m/min) constant.

2.3. Preparation of the woven thermoplastic composite test specimen

In order to investigate the influence of different process parameters on the mechanical properties of thermoplastic composites manufactured from the hybrid yarns, woven composite preforms were produced. This was done by using a sample weaving machine (Gülas Makina, Turkey).

Table 1. Characteristics of carbon fibre yarn (CFY) and polyamide (PA) 6,6 used for the manufacturing of hybrid yarns

Characteristic	CFY [2]	PA 6,6 [3]
Yarn fineness, tex	200	96
Number of filaments	3000	144
Tensile strength, MPa	3800	735
Tensile modulus, GPa	240	9.7
Elongation at break, %	1.6	24.4
Melting temperature, °C	–	260

Table 2. Process variables and specifications of the manufactured hybrid yarns

Hybrid yarn specification	Twisting	Air pressure, bar
CF/PA-01	No	3.0
CF/PA-02	Yes	3.0
CF/PA-03	Yes	3.5
CF/PA-04	Yes	4.0

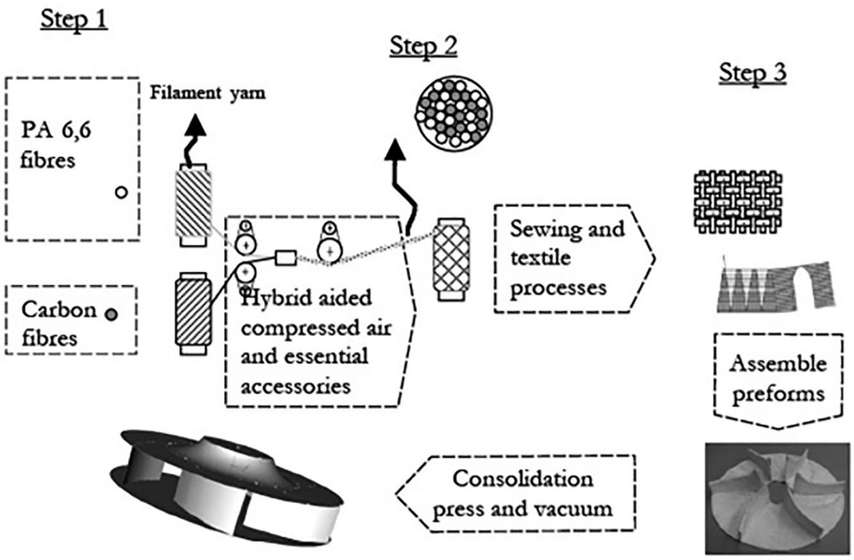

Fig. 1. Production of a thermoplastic composite with carbon fibre and polyamide (PA) 6,6 hybrid yarns [4].

2.4. Analysis of mechanical properties of composites

Testing of the tensile, flexural, and apparent interlaminar shear properties of the composite specimens was performed on the testing device Zwick. The impact tests were carried out on the Charpy impact test device with the aid of a pendulum arm type impact tester based on the principle of the Charpy impact test technique.

3. RESULTS AND DISCUSSION

The main aim of this study was to acquire a better understanding of the influence of different process parameters and twisting of commingling hybrid yarns on the adhesion between the fibre and the matrix in CFRC composites. It can be seen that, as expected, the hybrid yarn strength significantly increased with the increase of air pressure (Fig. 2).

As the PA 6,6 filaments became homogeneously distributed in the yarns section at a shorter distance to reach the composite materials, complete wetting of the reinforcing fibres was realized. Consequently, the tensile and shear strength as well as the bending resistance of the obtained CFRCs were higher than of the conventional CFRCs. Finally, the hybrid yarn was characterized with regard to parameters such as air pressure, feeding and winding speeds, nozzle shape, and twisting on the hybrid yarn structure.

The results of the apparent interlaminar shear strength test, illustrated in Fig. 3, reflect also the influence of mixing and/or better compatibility of twisted CFY and PA 6,6 on the tensile strength of the composites. Interestingly, the highest apparent interlaminar shear strength was found in the composite produced from CF/PA-04 hybrid yarn (twisted, 4 bar air pressure). With the application of additional twisting, the apparent interlaminar shear strength can be increased by 8%.

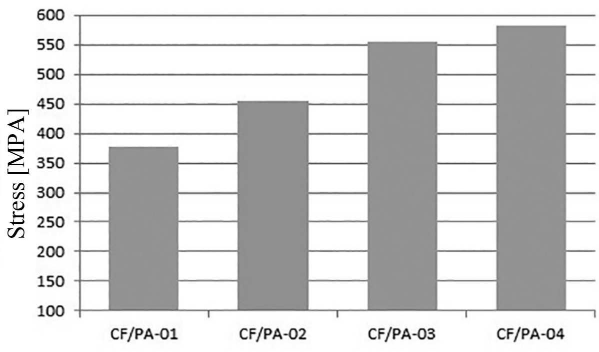

Fig. 2. Tensile modulus of the manufactured hybrid yarns. For hybrid yarn specifications, see Table 2.

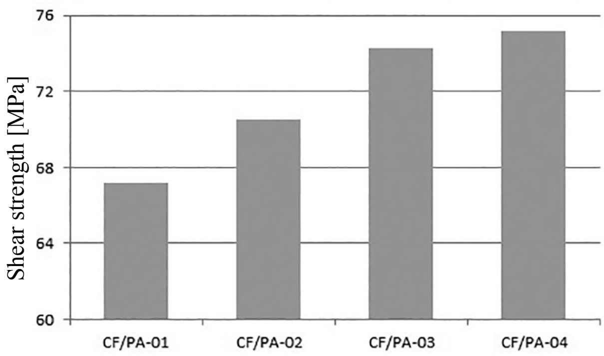

Fig. 3. Apparent interlaminar shear strength of composites produced from commingled hybrid yarns. For hybrid yarn specifications, see Table 2.

4. CONCLUSIONS

The investigations showed the potential of the application of twisting to improve the mixing and the adhesion properties between the matrix and the CFY. A lower tensile, bending, and impact strength indicated that there was some damage due to the application of twisting; this, however, can be improved by the modification of the twisting device.

As a result, it is aimed to develop high-performance FRTC materials. Additionally, preforms produced with different textile production techniques (weaving, knitting, etc.) by using hybrid yarn, have a potential for developing FRTC materials, especially for the automotive and aerospace industries.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the support provided by The Scientific and Technical Research Council of Turkey (TÜBİTAK) under research project 115M813. The publication costs of this article were partially covered by the Estonian Academy of Sciences.

REFERENCES

1. Long, A. C. *Design and Manufacture of Textile Composites*. Woodhead Publishing Limited, UK, 2005.
2. Dowaksa carbon. http://www.dowaksa.com/aksaca/ (accessed 2017-09-15).
3. Kordsa Products. http://www.kordsa.com/media/downloads/urun_pdf/TireBrosurORJ.pdf (accessed 2018-03-14).
4. Golzar, M. *Melt Spinning of the Fine PEEK Filaments*. PhD Thesis. Fakultät Maschinenwesen, Technische Universität Dresden, Germany, 2004.

Proceedings of the Estonian Academy of Sciences, 2018, ***67****, 2, 165–168*

Õhujoas tekstureeritud ja kokkukeerutatud süsinikkiud-polüamiid 6,6 hübriidse lõnga arendamine termoplastsete komposiitide tootmiseks

Müslüm Kaplan

Kiududega armeeritud termoplastseid komposiite kasutatakse tänapäeval laialdaselt auto- ja lennukitööstuses nende purunemiskindluse ning taaskasutatavuse tõttu. Vaatamata sellistele erakordsetele omadustele on nende materjalide puudusteks suur sulamassi viskoossus ja väike termiline vastupidavus. Selliste materjalide suur sulamassi viskoossus raskendab sarruse ühtlast märgamist termoplastse maatriksi poolt. Termoplastse materjaliga töötamise komplitseeritus tekitab masstootmises probleeme ja suurendab seetõttu toodangu maksumust. Seda probleemi võimaldab lahendada armeerivate kiudude ja maatriksi segamine ning tihendamine tahkes olekus. Nii saadud hübriidne lõng on uut tüüpi termoplastsel komposiidil põhinev pooltoode. Käesoleva uurimuse peamiseks teemaks on armeerivate kiudude ja maatriksi pneumoühenduse ja kokkukeerutamise protsess ning tihendamine, et lahendada termoplastsete komposiit-materjalide suur sulamassi viskoossuse probleem. Selliselt valmistatud hübriidseid lõngu võib töödelda erinevate tekstiilmaterjalide formeerimise meetoditega, nagu kudumine või silmuskudumine.