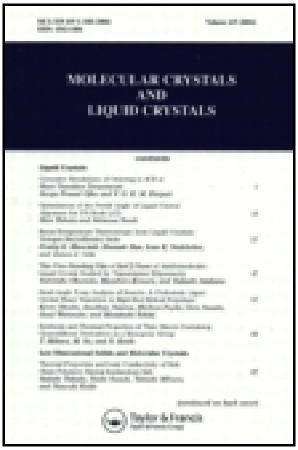

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The Influence of Structure of Hybrid Yarns Glass/PA6 on Mechanical Properties of Composites

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The fabrication process of thermoplastic composites using hybrid fabrics composed of yarns made of glass and PA6 fibres as prepregs is presented. The influence of the structure of hybrid yarns produced using commingled, texturising, twisting and friction spinning technology on the mechanical properties of composites is discussed. The results of the investigation indicate that the best tensile and bending properties of composites were achieved using fabrics made from texturing yarns produced under optimal conditions. These optimal conditions should ensure the minimum destruction of filaments during the blending process.

Keywords: thermoplastic composites; commingling yarns; texturing yarns

INTRODUCTION

The mechanical properties of thermoplastic composites are heavily influenced by the strength of an interface between a matrix and reinforcing fibres. One way of modification of the mechanical properties of interface is the chemical treatment of reinforcing fibres with the coupling agents[1,2]. The second way is to select the appropriate manufacturing process of composites, which ensures complete wetting of fibre bundles with molten thermoplastic. This can be achieved by the application of the textile hybrid structures made of reinforcing and thermoplastic fibres as prepregs in the fabrication process of composites[3-7]. The main objective of the project is to optimise the manufacturing process of hybrid fabrics made form glass and polyamide fibres to ensure good mechanical properties of composites produced from these fabrics. The first problem which has to be solved is good selection of glass fibres characterised by the appropriate chemical and physical surface properties, which promote a good adhesion between reinforcement and matrix. The second problem is an appropriate selection of the technological process of blending of reinforcing and thermoplastic fibres. The results of the investigation on both problems are the subject of this paper.

ANALYSIS OF WORK OF ADHESION

To estimate the thermodynamic work of adhesion between modified glass surfaces and polyamide 6 the procedure proposed by Good and Girifalco[8] was used. The results of calculation of theoretical work of adhesion is presented in Table I. The third column presents values of work of adhesion calculated on the basis of surface tension measurements for glassy substrates coated with complete modifying mixture. i.e., containing dispersion of polymer resin, wax or paraffin emulsion, surface-active agent and organosilane. The results presented in Table I indicate that work of adhesion between polyamide and treated glass is smaller than for interactions with untreated glass surface. Only one sample, coated with aminosilane II, has comparable work of adhesion. Elimination of paraffin emulsion and surface active component from modifying mixture results in significant increase of theoretical work of adhesion as shown in column 4 of Table I. The largest difference appears for the aminosilane I prèparation, which contains about 3-fold more sizing agent than the aminosilane II preparation.

TABLE I. Thermodynamic work of adhesion for polyamide/glass interface.

Art of coupling	Interaction parameter ϕ	Work of adhesion, W_A mN/m	Work of adhesion, W_A mN/m
Glass (untreated)	0.76	74.0	74.0
Methacrylosilane	0.73	57.4	62.7
Aminosilane I	0.82	59.9	79.6
Aminosilane II	0.61	69.7	69.7
Vinylsilane	0.63	48.7	-

Calculation of theoretical work of adhesion indicates that aminosilanes are the best component to improve adhesion to polyamide.

SELECTION OF THE TECHNOLOGICAL PROCESS OF FIBRE BLENDING

Interface bonding could be also enhanced by optimising the combination of thermoplastic polymers and reinforcing fibres. The appropriate manufacturing process of composites has to ensure complete wetting of fibre bundles with molten thermoplastic. Since most thermoplastics have average molecular weights of at least 20 000, therefore the melt viscosity of the molecules of that size is so high that it is very difficult to achieve the sufficient permeation of bundles by a molten resin. Permeation conditions could be improved by the melt impregnation introduced either by methods such as melt coating, powder coating in a fluidised bed, solution coating, film stacking, or forming hybrid textile structures. These textiles can be manufactured by the following basic methods: weaving of hybrid fabrics, spinning of hybrid staple yarns and spinning of hybrid multifilament yarns. Generally, hybrid textiles belong to postimpregnated prepregs in which both components: reinforcing and thermoplastic take a form of fibres. The intimate contact of thermoplastic fibres with individual reinforcing filaments creates very good permeation conditions. Moreover the thermoplastic component incorporated into fabrics makes them flexible and simultaneously protects the reinforcing fibres from the negative influence of surface abrasion during the manufacturing processes of fabrics.

The flexibility of hybrid fabrics allows them to drape over complex moulds without wrinkling or overlaps. Therefore, hybrid structures can be used for production of elements with the deeply drawn shapes, as for example helmets, pressure vessels e.t.c. The comparison of the features of various hybrid textiles indicates that hybrid multifilament yarns are the most interesting one due to their flexibility and their effectiveness in the utilisation of the reinforcing fibre strength. Therefore the main objective of this part of investigation is to select the appropriate process for blending the glass filament with the polyamide fibres.

MANUFACTURING OF HYBRID YARNS

In the manufacturing process of hybrid yarns and textiles the glass and polyamide multifilament were used. According to results presented in the first part of this paper the glass filaments were covered with aminosilane II. The blending process of reinforcing glass filaments and thermoplastic polyamide filaments was realised using four various spinning processes: texturing process, commingling process, twisting process and friction spinning. The selection of technological parameters of each process was based on the criterion of minimal destruction of glass filaments. The rate of destruction of glass filaments was evaluated by the loss of tensile properties of hybrid yarns in comparison to the tensile properties of the glass multifilament yarns as shown in Table II. The initial investigations indicate that the greatest loss of tenacity of glass filaments is observed in texturing yarns, then in commingling yarns. The ratio of tenacity of hybrid yarns to tenacity of glass yarns R is equal to 0.31 and 0.40 respectively. The processes of friction spinning and twisting are not so destructive and the ratio R is equal to 0.54 and 0.55 respectively. In the second part of investigations, it was found that the most important parameters influencing the destruction of glass filaments are the tension of glass and polyamide filaments during texturing process and the speed of the process. The best results were obtained for variant five.In this variant, the speed was equal to 240 m/min and the value of tension was in the range 8-10 cN for glass samples were formed as unidirectional plates with the rectangular cross-section and thickness of 2.3 mm and were subjected to mechanical tests.

RESULTS OF TESTS

The mean values of interlaminar shear strength, flexural strength and tensile strength were calculated using the load-deflection curves from Instron tester. The results are presented in Table III.

TABLE III. The results of the tests of the mechanical properties of composites.

Type of yarns	Mass content of glass [%]	Tenacity of yarns [cN/tex]	Tensile strength [MPa]	Interlaminar shear strength [MPa]	Bending strength [MPa]
Glass 68x1+PA 26x2 DREF	51,4	26,1	101,8	19,0	183,5
Glass 68x1 + PA 26x2,Commingling	55,7	I 19,7 II 15,8	137,9	22,7	213,7
Glass 68x1 + PA 26x2,Twisting	56,6	I 26,8 II 17,9	145,6	20,3	251,8
Glass 68x1 + PA 26x2,Texturising	55,8	I 14,9 II 14,9	126,4	22,1	201,0
Glass 68x1 + PA 26x2,Texturising;	55,2	I 16,3 II 16,0	147,7	22,1	207,1
Glass 68x2 + PA 26x4,Texturising	56,0	I 21,6 II 15,5	185,0	30,2	255,8

CONCLUSIONS

The analysis presented in Table II indicates that the application of blending process of glass and thermoplastic filaments results in loss of tensile properties of hybrid yarns in comparison to the glass multifilament yarns. There is a negative influence of the mechanical processes on the tenacity of glass filaments. Moreover, the analysis carried out shows that despite the fact that the maximum loss of tenacity of hybrid yarns appears in the case of the multifilaments and 6-8 cN for polyamide multifilaments. Further improvements in texturing process were achieved by blending two glass yarns together with four polyamide yarns (variant 6). For this variant, the ratio R takes the value of 0.44.

TABLE II. The results of the tests of the mechanical properties of hybrid yarns.

Type of yarns	Mass content of glass [%]	Tenacity of yarns [cN/tex]	Ratio of tenacity hybrid/glass R
V.1. Glass 68x1+PA 26x2 DREF	51,4	26,1	0.54
V.2.Glass 68x1 +PA 26x2,Commingling	55,7	I 19,7 II 15,8	0.40
V.3. Glass 68x1 + PA 26x2,Twisting	56,6	I 26,8 II 17,9	0.55
V.5.Glass 68x1 + PA 26x2,Texturising	55,8	I 14,9 II 14,9	0.31
V.6. Glass 68x1 + PA 26x2,Texturising	55,2	I 16,3 II 16,0	0.33
V.7. Glass 68x2 + PA 26x4,Texturising	56,0	I 21,6 II 15,5	0.44

The analysis of the cross-sections of fibres obtained using different methods showed that the best blending of glass and polyamide filaments is obtained using texturing and commingling method. The improvement of blending of both types of filaments was achieved by texturing two multifilaments of glass fibres with four polyamide multifilaments.

MANUFACTURING OF COMPOSITES

The knitted fabrics was placed in the specially shaped mould attached to the bottom plate of press. Subsequently, the stacks of fabrics were subjected to the automatically controlled appropriate thermal and pressure cycle. All composite application of texturing process, the composites made from this type of yarns are characterised by the best mechanical properties. Discussed results reflect the influence of the rate of blending of reinforcing filaments with thermoplastic filament on mechanical properties of composites.

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