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Dedicated to Prof.Dr.Ing. Georg Menges on the occasion of his 80th birthday

Effect of fiber type on mechanical properties of polyurethane composites

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Summary

The effects of three different types of fibers (E-glass, S-glass and Carbon fibers) on physical and mechanical properties of polyurethane resin based composites were studied. The mechanical properties (tensile strength and modulus, flexural strength and modulus, and interlaminar shear strength) of the polyurethane composites were found to depend primarily on the type of fiber, and specifically on the accessibility of hydroxy functionality on the fiber. The results showed that carbon fiber reinforced polyurethane composite had superior properties compared to E-glass and S-glass reinforced composites and the lowest void fraction.

KEY WORDS
E-glass fiber
S-glass fiber
Carbon fiber
polyurethane resin
mechanical properties

KLJUČNE RIJEČI
E-staklena vlakna
S-staklena vlakna
ugljikova vlakna
poliuretanska smola
mehanička svojstva

Utjecaj vrste vlakna na mehanička svojstva poliuretanskih kompozita

Sažetak

Proučavan je utjecaj tri različite vrste vlakana (E-staklena vlakna, S-staklena vlakna, ugljikova vlakna) na fizička i mehanička svojstva kompozita na osnovi poliuretana. Mehanička svojstva (rastezna čvrstoća i modul, savojna čvrstoća i modul i međuslojna smična čvrstoća) poliuretanskih kompozita ovise o vrsti vlakna, a posebice o kemijskoj reaktivnosti površine vlakana. Rezultati su pokazali da poliuretanski kompoziti ojačani ugljikovim vlaknima imaju bolja mehanička svojstva i manji udio šupljina u usporedbi s kompozitima ojačanim E- i S-staklenim vlaknima.

Introduction

Fiber reinforced polymeric composites are becoming increasingly accepted for use in various industries, such as aircraft, automobiles and construction where the structural components are usually designed to optimize the mechanical properties. Therefore an in-depth knowledge of the mechanical properties is of fundamental importance. The advantages that have contributed to the recent increase in the use of fiber reinforced polymeric composites include, amongst others their high specific strength and stiffness, the ease with which complex shapes may be formed, and their chemical and environmental resistance. Woven fabrics, which are the most common forms of textile composites, present various attractive aspects, such as low fabrication costs and ease of handling.[1-4] The common styles of woven reinforcement are plain weaves, twills, and satins. Compared to metals, composite parts can also be easily made at relatively low tooling costs.[5] Thermosetting and thermoplastic polymers can be used as the matrix system in fiber reinforced composites.

Polyurethanes are probably the most versatile class of polymers, owing to the great variety of row materials that can be used in their formation. Because of its versatile mechanical, chemical, and thermal properties, polyurethane has found many applications in various fields. Polyurethanes are usually used as adhesives, coatings, foams, and different kinds of plastics and elastomers, as well as matrix for polymeric composites.[6,7] The unique feature of polyurethane based composites is that they can exhibit usable ranges of deformations much larger than those of composites with stiffer matrices, such as metals, ceramics, or rigid polymers.[8]

The purpose of this study was to examine the influence of the fiber types on the mechanical properties of polyurethane composites produced by simple hand lay-up technique. Composites were produced using E-glass fiber, S-glass fiber, Carbon fiber and polyurethane resin based on commercial polyol Jeffol G30-650 and isocyanate Rubinate M.

Experimental

Materials description

Three types of fiber and one type of polyurethane resin were considered in this study. Commercial polyol Jeffol G30-650 and isocyanate Rubinate M, supplied by Huntsman and Catalyst Dabco T-12, supplied by Air Product, were used. The fibers used in this study were E-glass fiber, fabric weight: 303 g/cm^3, weave style: 8H satin, supplied by Composite Structures Technology (CST), S-glass fiber, fabric weight: 300 g/cm^3, weave style: 8H satin, supplied by CST and Carbon fibers, fabric weight: 370 g/cm^3, plain weave style, supplied by CST. The polyurethane resin was prepared by mixing 50 g polyol with the catalyst 0,03 g Dabco T-12 and subsequent mixing with 81 g isocyanate Rubinate M.

Fabrication of composites

Three types of composite panels were manufactured in the laboratory by simple hand lay-up technique, using all types of fibers. Ten layers of fabric were impregnated with polyurethane resin and placed in the mold (2 mm deep). Pressure was applied (20 min at 110 °C). The samples were left overnight in an oven (12 h, 110 °C) to complete curing. The samples were conditioned for two days at room temperature and tested. The composites were designated as E-composite, S-composite and C-composite. Five samples were prepared in three series.

Methods

The characterization (determination of physical properties) of composites includes the determination of: composite (apparent) density S_c; weight content of fiber M_m, volume content of fibers V_f; and volume content of voids V_v. Void contents of the cured E-glass fiber/polyurethane composites were measured according to ASTM D2734. The E-glass and S-glass fibers weight fraction M_f was determined by ignition of resin, in a muffle furnace, at temperature of 625 °C, in air. The removal of the matrix at the Carbon fibers composites is performed by chemical digestion in the boiled mixture of 10 % solution of potassium hydroxide in ethylene glycol. The reinforcement volume fraction V_f was calculated using fiber, resin and composite density.

The mechanical properties of composites were studied on a series of flat specimens with at least five nominally identical specimens. The mechanical properties of composites were examined by several methods. Tensile tests, interlaminar shear strength (ILSS) and flexural tests were performed according to the norms ASTM D3039, D2344 and D790M, respectively.

The focus in the present paper will be on mechanical tests. The mechanical properties of the composites were evaluated on three series of five specimens cut from the same plate. The tests were executed at the ambient conditions using Instron 4467 testing machine. The thickness of each specimen was measured in at least three sections to verify its regularity. The mean values of the mechanical properties were calculated as an average of five results from each series of tests.

Results and discussion

The results for the physical and mechanical properties of polyurethane composites are given in Table 1 and 2, where the most significant properties (flexural strength and modulus, interlaminar shear strength and tensile strength and modulus) are listed. Each data point reported in the results is an average value from five specimens measured separately.

Voids are among the most common manufacturing induced defects in polymeric composites. They are formed primarily due to the entrapment of air during the formulation of the resin system, in resin reach areas, and due to moisture absorbed during the material storing and processing. It is well known that voids have detrimental effects on the strength of fiber reinforced composites. In general, they decrease the static strength and fatigue life of composite laminates and cause greater susceptibility to water penetration and environmental conditions. The influence is more pronounced in interlaminar shear strength, compressive strength, and flexural strength, which are associated with the matrix dominated mechanical properties.[9]

The effect of void content on the strength of polyurethane composites reinforced with E-glass, S-glass and carbon fibers are illustrated in Figure 1. The decrease in tensile, flexural and interlaminar shear strength of polyurethane composites is caused by an increase in the void content. In Figure 2 the values of the flexural, tensile and interlam inar shear strength of polyurethane composites (see Table 2) are reported as a function of fiber type. In Figure 3 the values of the flexural and tensile modulus of polyurethane composites (see Table 2) are reported as a function of fiber type. Comparisons of values between the E-glass fiber reinforced composites, S-glass fiber reinforced composites and carbon fiber reinforced composites yielded the best results in carbon fiber reinforced composites. Carbon fiber reinforced composite appears to be the best material in terms of mechanical properties.

TABLE 1. Physical properties of polyurethane composites

SAMPLE	Density g/cm^3	Fiber content %	Void content %	
		Weight	Volume	Void
E-composite	1,82	69	49	4,4
S-composite	1,88	74	56	4,2
C-composite	1,54	71	63	2,4

TABLE 2. Mechanical properties of polyurethane composites

SAMPLE	Flexural strength MPa	Flexural modulus MPa	Interlaminar shear strength MPa	Tensile strength MPa	Tensile modulus MPa
E-composite	444	27 075	27	278	18 654
S-composite	665	31 809	39	444	25 747
C-composite	766	41 083	41	736	34 374

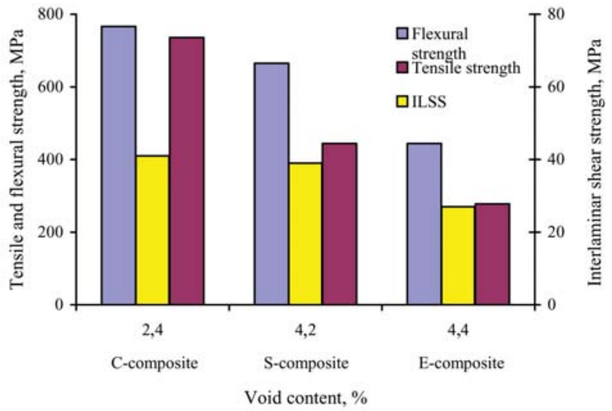

FIGURE 1. Effect of void content on the strength of polyurethane composites

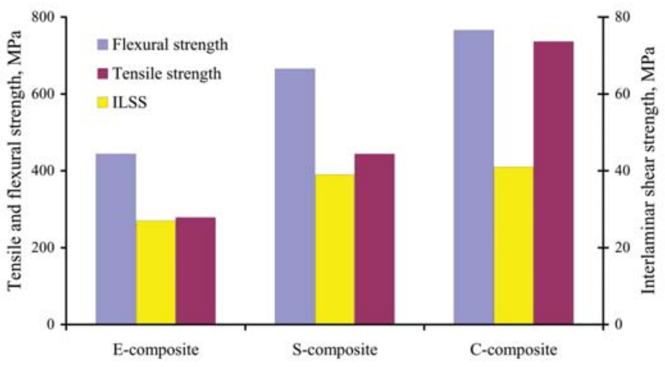

FIGURE 2. Effect of fiber type on the strength of polyurethane composites

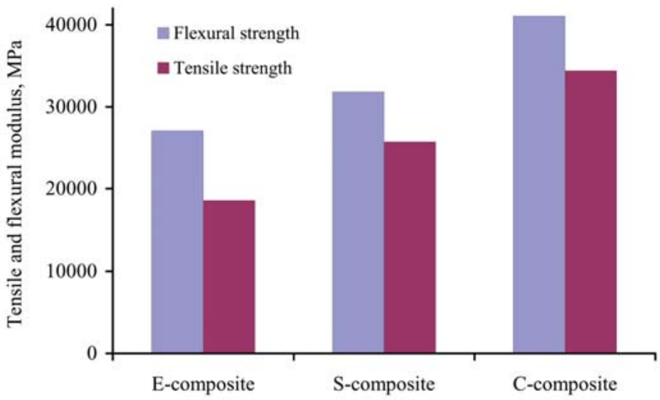

FIGURE 3. Effect of fiber type on the modulus of polyurethane composites

Conclusions

The investigation of the effects of fiber type on the mechanical properties of polyurethane composites is reported here. It was found that the composites prepared with carbon fibers and polyurethane resin have superior mechanical properties compared to E and S glass fibers. Also, carbon fiber composite demonstrated higher specific strength and modulus. For many applications, such as those in aircraft and automobile manufacturing, reduction in part weight is highly desirable.

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Polimeri u službi zaštite umjetnina

Talijanski su istraživači razvili polimerna otapala u obliku emulzija s pomoću kojih se uklanjaju akrilni i vinilni polimeri kojima su, kao zaštitnim slojem premazivane slike i freske. Iako se taj način zaštite umjetnina rabi već dosta dugo on ima i svojih loših strana. Toplinski i fotokemijski procesi na polimernoj površini mogu izazvati depolimerizaciju i umreživanje, što dovodi ne samo do žućenja površinskoga sloja, već i do mehaničkih naprezanja u sloju boje i time stvaranja mikronapuklina.

Ispitano je nekoliko četvero- i peterokomponentnih emulzija s pomoću kojih se otapa polimer s umjetnine. Mehanizam uklanjanja djeluje na način koji se može opisati kao sinergijski učinak pojedinih sastojaka mikroemulzija i nanesenih zaštitnih slojeva polimera. Slika prikazuje fresku iz 16. stoljeća u mjestu Conegliano u sjevernoj Italiji s koje je, s pomoću mikroemulzije uklonjen zaštitni vinilni sloj.

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Freska iz 16. stoljeća spašena zahvaljujući sinergijskom djelovanju polimera

Polimeri kao pomoć pri otkrivanju opasnih mikroorganizama

Mikrobi, virusi i bakterije potencijalni su uzročnici bolesti. Međutim, dok se bakterije salmonele u prehrambenim proizvodima razvijaju izuzetno brzo, laboratorijski testovi kojima se dokazuje njihova prisutnost i potencijalna opasnost izuzetno su spori. Stručnjaci Fraunhoferovoga Instituta za primijenjena istraživanja u polimerstvu zajedno sa svojim kolegama sa Sveučilišta u Bonnu razvili su novi proces brzoga otkrivanja postojanja opasnih klica.

Svaka bakterija, virus ili toksični protein povezan je s odgovarajućim antitijelima jednako kao što je to u imunološkome sustavu živih organizama. Otuda se rodila ideja potrebe razvoja prepoznavanja antitijela, a na taj način i pripadajućih opasnih mikroorganizama. Stoga su razvijeni novi testovi kod kojih se uzorci uzimaju s pomoću polipropilenskih ili polietilenskih podloga, na njih se stavljaju reagensi u boji, a boja se mjeri prijenosnim fotometrom. Kako je odnos bakterija i antitijela već poznat, na taj se način sigurno, brzo, jeftino i na licu mjesta može ocijeniti kvaliteta prehrambenih proizvoda izvan laboratorija.

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