TESTING OF RIGID POLYURETHANE FOAM REINFORCED NATURAL FIBERS PROPERTIES AND POSSIBILITY OF USING THIS MATERIALS IN AUTOMOTIVE INDUSTRY

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Abstract

The contribution provides an overview of composite materials, their distribution and use in the automotive industry. Further this contribution provides an overview of the properties of composite foam specimens. Selected natural fibers (hop, corn, sunflower and chestnut) were used as reinforcement in polyurethane (PUR) foam in order to increase the properties of foam. The polyurethane foam specimens reinforced by 4wt% and 6wt% of individual fibers were produced to investigate two mechanical tests - three point bending test and fatigue test.

Keywords: Composite material, automotive industry, polyurethane foam, natural fiber, mechanical testing

1 Introduction

With the composite materials we meet more frequently, they are applied in a wide range of industries. Use of the composite materials in the automotive industry is today more and more frequently. This materials can be used in many parts or cars, what in described in the table 1.

***Table 1** The use of composites in the automotive [3]*

The part of car	Type of composite
side door panels	PUR foam + short fiber materials, glass glass mat from glass wool
storage shelves and compartments	
beam dashboard	
cowls	
wheel arches	
bumpers, mirrors, bonnet	carbon - fiber
doors	laminate
front deformation part	plastic + steel or aluminum sheet
reinforcing inserts stifenning the car body	polyamide + sheet
bodies of commercial vehicles	fiberglass, sandwiches and more
fenders, container control unit	long fiber reinforced thermoplastic
leak- springs	long fiber composites
brake discs	Ceramic composites reinforced with carbon fiber
CNG tank	fiberglass + epoxy resin

Use of polyurethane foam is today more frequently. Reinforced composites are used in applications, where good mechanical and other properties, such as technical and construction applications are required. Use of natural fibers can provide various advantages, for example surfaces of the product have natural look, faster production cycle is possible, also savings of polymer and others. Natural fibers have a good properties and their obtaining and fabrication is easy.

2 Material preparation

Material preparation consists of fibers treatment and polyurethane foam fabrication. Fibers treatment consists from the preparation and polyurethane foam preparation described in following parts.

2.1 Fibers treatment

The natural fiber reinforced polyester composites were prepared by the hand lay-up method. Stems of corn, sunflower and hop were immersed in the container with water for two days to soften them. Chestnut fibers were obtained from the skin of chestnuts, which were also immersed in water for two days. Subsequently the stems were tenderized by rubber hammer and thus were prepared thin fibers.

These fibers were dried at air temperature, later in a dryer. After this extraction, these fibers were cut into pieces with length of about 20 mm to allow better mixing when producing the composite polyurethane foams. [1]

2.2 Polyurethane foam fabrication

In the first case, polyurethane foam was produced by mixing the polyol and isocyanate (without addition natural fibers) for preparing polyurethane foam without fibers. In the second step fibers were placed into the mold. Then were fibers sealed with polyol, mixed together and subsequently were added isocyanate. Subsequently, the mold have been closed with high compressive force, so that any components couldn´t escape from the mold. Form remained closed for one day and then foam has been removing from the mold. [1]

Fig. 1 *Placing the fibers and polyurethane components in the mold*

These operations were performed in 3 sets of the composite materials for the production. First case consisted of the production of polyurethane foam, what is the addition of 40 g of polyol and 40 g of isocyanate, without the addition of selected types of fibers. In the second case were added individual fibers to form from each type separately, of a weight 3 g of fibers with the addition of 40 g of polyol and 40 g of isocyanate. Thus we obtained polyurethane foam with a percentage of 4 % of fibers. In the third case, individual fibers were added to form every kind of a weight 6 g with an addition the same quantity of polyurethane components and we got polyurethane foam with a percentage of 6% of fibers.

2.3 Processing of samples for 3-point bending test

This testing is an important part of the characterization of any material, as test results provide relevant information on how the material will behave in real terms. This test conducted by using three point bending test. It is specifically for composite materials, which are often used in aerospace and automotive industries, also for energy applications, where it is important to understand how much you have to bend the material and maintain its strength. This 3-point bending test was performed according to EN ISO 14125. This standard is characteristic for flexural properties reinforced composite plastics. Describes procedure of determining the flexural properties of reinforced composites either 3 or 4 – point bending test. In the implementation o tests were from polyurethane foam cut specimens of size 100x20x6 mm. For testing were used 5 specimens o each type.

2.4 Processing of samples for fatigue test

In the fatigue test o elastomers, but hard plastics too, it is a cyclic dynamic stress test specimen under such conditions, which lead to destruction of the specimen. The method of deformation can be tension, compression, tension-compression, bending or torsion. As measured by value for fatigue tests is usually the number o cycles to mechanical destroction o the specimen, which is usually assessed visually.

In making the tests were polyurethane foam manually cut the specimens the dimensions of size 120x25x20 mm. . For testing were used 3 specimens o each type.

3 Test methods

In this chapter is described in more detail mechanical 3-point bending test and fatigue test. Material for the measurement were polyurethane specimens without and with addition of selected natural fibers.

3.1 3-point bending test

The aim of test was to determine the maximum shear stress polyurethane specimens from each type. To the execution of the experiment were used two scales, which were laid on the construction. Scales were necessary to it, so that the load was exactly in the middle o the specimen. Specimens were gradually placed between scales and loaded weight, as shown in Fig.2. How load testing were used steel weights, that were added gradually, until while occurred to breach o specimens.

Fig. 2 *Bending device (three point method) of the testing machine*

A loading force applied to the specimen

To calculate the maximum shear stress is required maximum force, which were achieved, when the individual specimens were loaded. A loading force (F) acting on the specimen is measured during testing o specimens such, that were gradually loaded polyurethane specimens by steel weights. The maximum force o individual specimens is the force, which is measured from the maximum mass of weights, which is specimen able to withstand. By gradually adding weights to the rope, occurs to breach o specimen.

THE MAXIMUM SHEAR STRESS

Maximum shear stress sample polyurethane foam, which is made up of 40 g and 40 g polyol isocyanate (in the first case without fibers, in other cases with the addition of 4% individual fibers) were calculated by the maximum force, moment of inertia of the axis and bending moment.

The maximum shear stress is given by equation: [1]

$$\tau = \frac{M_f}{I}.y \qquad (1)$$

where:
τ = maximum shear stress [MPa],
M_f = bending moment [N.m],
I = moment of inertia of the axis [m^4],
y = half of thickness of specimen [m],

Equations for bending moment and moment of inertia of the axis are following:

Equation for moment of inertia of the axis:

$$I = \frac{b.h^3}{12} \qquad (2)$$

where:
b = width of specimen [m],
h = thickness of specimen [m],

Equation for bending moment:

$$M_f = \frac{F.d}{2} \qquad (3)$$

where:
F = load which acts on a specimen [N],
d = distance between supports [m].

After substituting equations for the moment of inertia of the axis (2) and bending moment (3) into equation for maximum shear stress (1), we obtain the following final equation for calculating the maximum shear stress, and it:

$$\tau = \frac{M_f}{I}.y\frac{\frac{F.d}{2}}{\frac{b.h^3}{12}}.\frac{h}{2} = \frac{6F.d}{b.h^3}.\frac{h}{2} = \frac{3F.d}{b.h^2}, \qquad (4)$$

Figure 3 and 4 show the power at the load applied to the specimen, distance between supports and dimensions of the specimens.

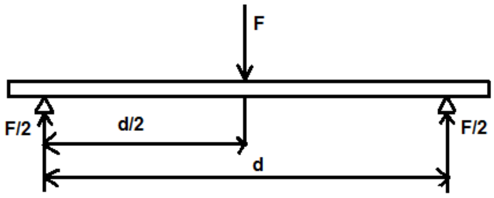

Fig. 3 *Force which is acting on the specimen and distance between supports*

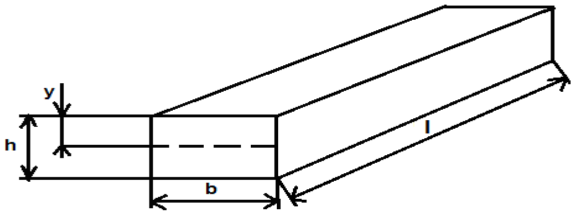

Fig.4 *Dimensions of the specimen*

<u>The dimensions of polyurethane specimen are following:</u>

- distance between supports: d = 0,08 m,
- thickness o the specimen: h = 0,006 m,
- half from thickness o the specimen: h/2 = y = 0,003 m,
- length o the sample: l = 0,1 m,
- distance between supports: b = 0,02 m

3.1.1 Results of experiment from 3-point bedning test

Maximum shear stress was obtained from results of polyurethane foam specimens with 40 g of polyol and 40 g of isocyanate, in the first case without fibers, in the other cases with addition 4wt% and 6%wt% of individual fibers. In this subchapter is overall summary of the results for comparison average values of the maximum shear stress specimens without and with addition selected natural fibers. Data from the measurement results I compare in Table 2.

Table 2 *Summary of the experimental results of bending tests - the maximum shear stress*

Kind of polyurethane specimen	**Maximum shear stress [MPa]**		**Compare of fibers**
	4 wt%	**6 wt%**	**↓↑**
polyurethane foam with addition of hop fibers	5,207	4,365	↓
polyurethane foam with addition of corn fibers	5,753	6,322	↑
polyurethane foam with addition of sunflower fibers	4,538	5,263	↑
polyurethane foam with addition of chestnut fibers	5,837	5,446	↓

The table provides information about it, which fibers improve and which aggravate properties o the foam. For better explanation I built the Fig. 5, from which we can also see, which fibers are the best for use as reinforcement polyurethane foam.

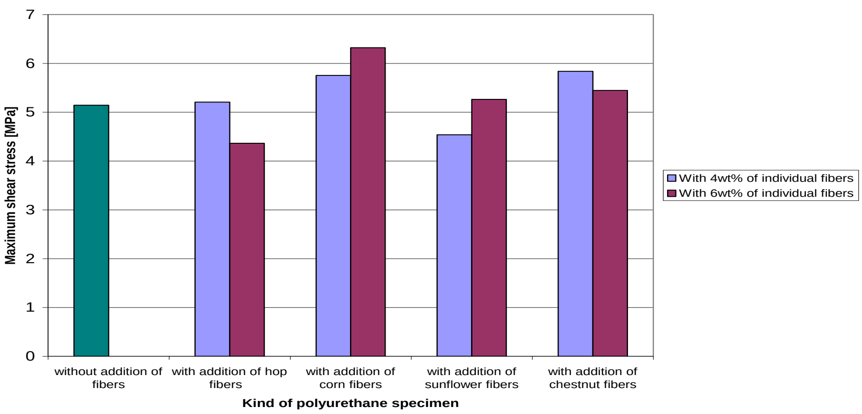

Fig. 5 *Maximum shear stress of polyurethane specimens without and with addition of 4wt% and 6wt% individual natural fibers*

At the Fig.5 are showed individual results of maximum shear stress from the three point bending test on the polyuretane foam. In the first case polyurethane foam was made without addition o natural fibers and in second and third case polyurethane foam cores consisted of 4 wt% and 6 wt% particular fibers exhibits.

3.1.2. Summary for 3-point bending test

From the mechanical testing of polyurethane foam specimens by three point bending testing was showed, that the addition of natural fibers (corn, chestnut and hop) increase the properties of the polyuretane foam (already in the case of 4% of natural fibers). Furthermore, we can say, that the best measurement results are obtained using corn fiber, what we can see in the Fig.5. Adding large amounts of corn fibers this foam to further strengthen the properties of foam, which we can not say about all cases of natural fibers.

3.2 Fatigue test

In testing, fatigue test was performed using fatigue testing machine. This was specially manufactured for testing resilience of polyurethane specimens. This fatigue test was performed to compare the properties of the specimens with and without addition selected natural fibers [2].

Fig. 6 *Fatigue test of composite specimens*

Three individual tests were performed for each type. The fatigue tests were performed at room temperature. Number of cycles were derived from time to failure which was monitored directly. In the first case, we determined 36 cycles in one minute. Then the testing machine was started and at the stopwatch was measured time to bursting of specimens. Bursting of specimens sometimes occurred immediately, other time after a short time, or crack was distributed slowly. Time at the stopwatch stopped when crack was in the middle of samples. This was observed on the edge of the samples. Piston penetrated to a depth of 2 mm to the specimen. The specimen was mounted between two metal strips, which were welded firmly welded on the bottom ot the machine (Fig.6).

3.2.1 Results of experiment from flexure test

The results of fatigue tests we obtained with way, that we like a first with stopwatchc measured the time required to breach of each specimen and then we calculated the average time for each type of specimen and multiplied by the number of cycles. The obtained average numbers burdening cycles required to breach of specimens (for specimens without addition of fibers, with the addition of 4% by weight of natural fibers and 6% by weight of natural fibers) are given in Table 3.

Table 3 *Experimental results from fatigue test*

Kind of specimens	**Number of cycles**	
polyurethane foam without addition of fibers	1044 cycles	
	with addition 4 % of fibers	**with addition 6 % of fibers**
polyurethane foam with addition of hop fibers	1872 cycles	2664 cycles
polyurethane foam with addition of corn fibers	1692 cycles	3384 cycles
polyurethane foam with addition of sunflower fibers	1512 cycles	1548 cycles
polyurethane foam with addition of chestnut fibers	2016 cycles	4572 cycles

For better explanation I built the fig. 7, from which we can also see, which fibers are the best for use as reinforcement polyurethane foam.

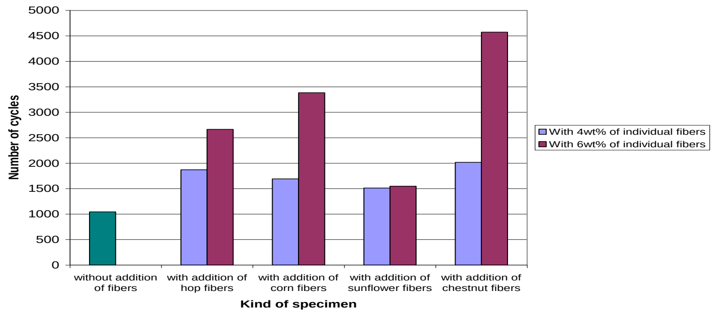

Fig. 7 *Number of cycles needed to breach o polyurethane specimens*

From the test results, we can say that the best measurement results are obtained using chestnut fiber.

3.2.2 Summary for fatigue test

From the results of the fatique testing of specimens with addition selected natural fibers we can improve properties of polyurethane foam. From the mechanical testing of polyurethane foam samples by fatigue testing, it was shown, that the best results were achieved by addition of chestnut fibers (Fig. 5). Second best results were obtained using of corn fibers like reinforce of polyurethane foam. We can conclude, that with using of corn, hop, sunflower and chestnut fibers improves properties of the polyurethane foam. In the case of 6% of natural fibers we can even more improve properties of polyurethane foam.

4 Conclusion

From the mechanical testing of polyurethane foam samples by trhee point bending testing and fatigue testing was showed, that the addition of natural fibers increase the properties of the polyuretane foam (already in the case of 4% of natural fibers). In the case of 6% of natural fibers we can even more improve properties of polyurethane foam. Use of this selected natural fibers, can provide various advantages as particular saving of polymer and improvement of overall properties of final product.

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