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TESTING OF HYBRID COMPOSITES

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Abstract: The presented article deals about mechanical testing of hybrid materials for automotive production. It describes thetest samples production and test processes methods forcomposite material´s testing. We´ve tested hybrid materials clustered from raw fibres of hemp, cotton, sisal and jute in combination with carbon fabric. The objective of the thesis is to present the testing methods for confirmation or declination of the ability of hybrid bio-composites usage in automotive industry. The results are statistically evaluated.
Keywords: Hybrid materials, natural materials, composites, testing, automotive industry

INTRODUCTION

After many tastings of pure "synthetic" composite materials as carbon, aramid or glass fibres, we´vebegan to deal with the idea of combination of the natural materials and the carbon fibres. The reason of idea was simple – the costs. The carbon fibres are too expensive for serial production so far, so we´ve decided to decrease the costs of composite car components by implementing some natural fibres into the composite´s structure. The goal has been to test material made from carbon fibre and variously natural fibres, whereby the research should concentrate on the possibility of applications of such a materials in the car production. Our ambition is to create a material, which will bestrong, resistant and ecological.[6]

Nowadays the composites are utilised in all areas of the car industry. We know number of composite materials types, whereby we´ve been concentrated us on composites from carbon fibres. These composites have big potential for car production thanks their excellent strength properties and first of all for their weight. Recently „imported" from the aerospace industry, they have already found many applications, particularly in high performance cars where they are often the primary structural material. However, a big concern relating to the wider application of carbon fibres is their fluctuating price and availability in comparison to other structural reinforcements. This adds an element of commercial risk to ongoing vehicle production [4]. On the other side, we have here natural - renewable and mainly recyclable materials as: hemp, flax, jute, Indian hemp, sisal, Abaco or coconut fibres, that can be potential usable for composite materials (Figure1).

Base types of natural fibres:

≡ bast fibres (jute, flax, hemp, kenaf,…),
≡ leaf fibres (manil, sisal, pineapple),
≡ seed fibres (coconutfibre, cotton, kapok),
≡ core fibres (kenaf, hemp a jute),
≡ core and grass fibres (wheat, corn, rise)
≡ other(wood androots). [2]

Figure 1: Used natural fibres [1]

HYBRID COMPOSITES- THE SAMPLES PRODUCTION

Our experiment was in progress through more phases, which forewent the decision of choosing the materials for hybrid components. During the first phase we´ve made samples from composite materials, and in the second phase we´ve tested them. We carried out the material tensile test and the Charpy impact test at a bending.

By the samples production we´ve used following materials and their variants:

≡ carbon fibres 160g/m2
≡ jute fibres shear 50 mm 10 g
≡ sisal fibres shear 50 mm 10 g
≡ cotton fibres shear 50 mm 10 g
≡ hemp fibres shear 50 mm 10 g
≡ 250 mm jute fibres
≡ 250 mm sisal fibres
≡ 250 mm cotton fibres
≡ 250 mm hemp fibres
≡ epoxide resin L 285

The produced samples were divided in two types.

≡ 1st type -made so that between too layer of carbon was placed one layer of natural 50mm shear. This first type of samples was made in four various modifications, when the middle layer was the shear of jute, sisal, cotton and hemp.
≡ 2nd type - made so that between too layer of carbon was placed one layer of 250mm fibres laid in one direction (Figure 2). This second type of samples was also made in four various modifications.

Figure 2: 2nd type of natural fibres sample made from straight laid 25cm fibres

According to this kind of layers laying were samples from these sheets made, blanked and prepared for testing per DIN EN ISO 527 – 4 standards(tension test) and EN ISO 179 - 1 standard (impact test).

For better results precision, there were three samples of each material for tension test made. For impact test at a bending we´ve made samples only from the first type of materials – samples with shear. There were five samples of the first type made.

The tests should prove that natural fibres in combination with carbon fibre can be characterized by same or better properties as single carbon fibre composites.

We´ve used for samples production vacuum technology. This kind of composites production is verified for us and by the help of it we are achieving good results. Simultaneously it's technologically easy production method.

Whole sample´s production process was customised for chosen samples types. We´ve created cutting plan and on his base we´ve produced sheets of composites with shear and straight fibres.

After the main sample matrix preparations, we´ve produced hard composite sheets. These sheets were trimmed into specified sample´s dimensions (Figure 3).

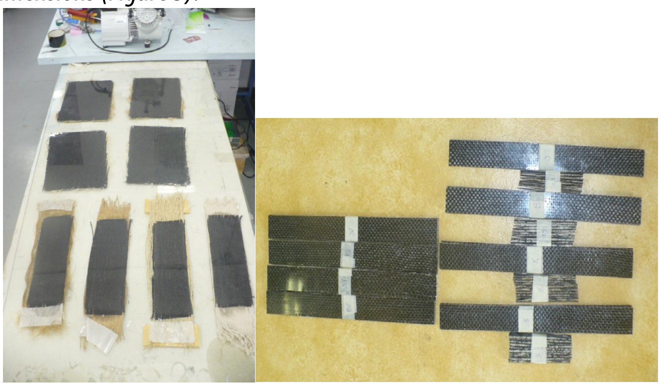

Figure 3: Finished composite sheets (left) and prepared – cut out samples for testing (right)

TESTING

Two testing methods were for testing chosen:

- material tension test
- impact test at a bending

Composite material tension test

Composite material tensile test was realised by static tensile test. We´ve used test device TIRA – Test 2300 made by VEB TIW Rauestein. Test principle is to charge the specified testing sample till its breaking. There were 24 samples with specific dimensions - 250 x 25 mm and 1,4 mm thickness (Figure 4) tested.

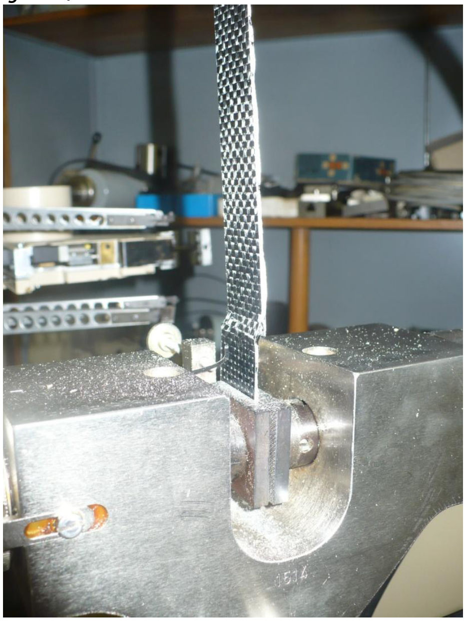

Figure 4: Test samples after braking

We´ve tested 2 types of samples in 4 modifications. There were 3 samples from each modification for more-accurately results. For better orientation, we´ve marked the samples as:

First type of samples – carbon with shear of natural fibres:

- K1, K2, K3 – samples made from carbon and hemp shear
- B1, B2, B3 – samples made from carbon and cotton shear
- S1, S2, S3 – samples made from carbon and sisal shear
- J1, J2, J3 – samples made from carbon and jute shear

Second type of samples – carbon with 25cm fibres:

- KV1, KV2, KV3 – samples made from carbon and hemp fibres
- BV1, BV2, BV3 – samples made from carbon and cotton fibres
- SV1, SV2, SV3 – samples made from carbon and sisal fibres
- JV1, JV2, JV 3 – samples made from carbon and jute fibres

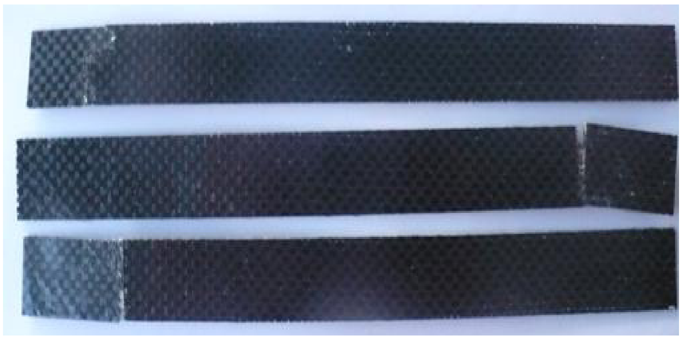

Figure 5: Beaked samples after testing (samples S1, S2, S3)

The next tables Table 1 and Table 2 showresults from each test included with arithmetical averages of results for each one sample type. Those will be our initial result for final evaluation:

Table 1. Hybrid composite material tension test results – samples with shear of natural fibres (Figure 5)

Sample	Strength [N]	Averages strength [N]	Fracture limit [MPa]	Avareges fracture limit [MPa]
K1	3964	3437,33	133	125
K2	3632		155	
K3	2716		87	
B1	3047	3162,67	110	123,67
B2	3720		138	
B3	2721		123	
S1	3010	3170	73	73
S2	3047		69	
S3	3453		77	
J1	4915	3386	204	142,67
J2	2522		106	
J3	2721		118	

Table 2. Hybrid composite material tension test results – samples with 25cm fibres (Figure 6)

Sample	Strength [N]		Fracture limit [MPa]	
KV1	5163	5444,33	115	115
KV2	6235		129	
KV3	4935		101	
BV1	7154	6738,67	114	122,33
BV2	6490		122	
BV3	6572		131	
SV1	6116	6805,67	82	89
SV2	7873		101	
SV3	6428		84	
JV1	6357	6036	131	127,67
JV2	6517		141	
JV3	5234		111	

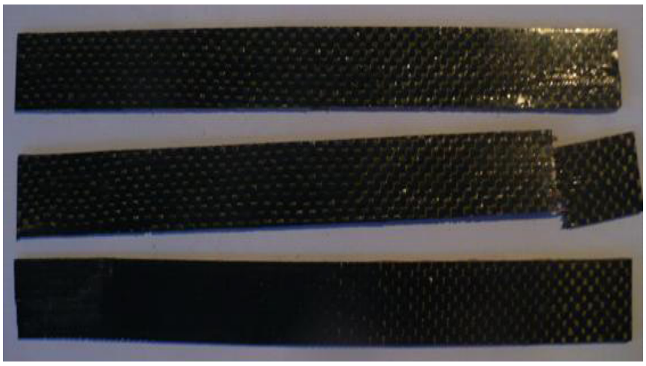

Figure 6: Beaked samples after testing (samples JV1, JV2, JV3)

Impact test at a bending

For impact test at a bending we´ve used the Charpy´s pendulum. The weight of the pendulum has been 150g. Measured value is the work and the results value is toughness of the material. The toughness has been counted as W – work to s – cross-section surface.

For impact test we´ve prepared five samples of four composite´s types:

1. samples K made from 2 layers of carbon and 1 layer of hemp shear
2. samples B made from 2 layers of carbon and 1 layer of cotton shear
3. samples S made from 2 layers of carbon and 1 layer of sisal shear
4. samples J made from 2 layers of carbon and 1 layer of jute shear

Table 3 show results of samples testing.

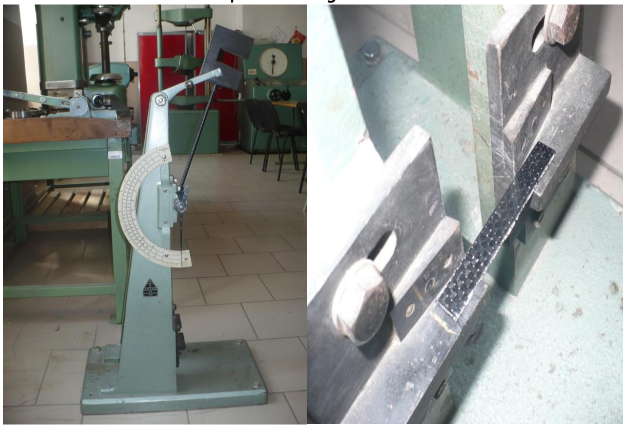

Figure 7: Charpy´s pendulum (left) and placing the sample for testing (right).

Table 3. Impact testing results

Sample	Outcome [kg.cm]	Work K [J]	S_0 [cm^2]	KC [J]
K1	10	0,981	0,094	10,44
K2	10,5	1,03005	0,119	8,66
K3	6,5	0,637	0,094	6,78
K4	10,5	1,03005	0,119	8,66
K5	8,5	0,83385	0,094	8,87
B1	6,5	0,63765	0,108	5,9
B2	5,5	0,53955	0,111	4,86
B3	6,5	0,63765	0,108	5,9
B4	9	0,8829	0,12	7,36
B5	7,5	0,73575	0,111	6,63
S1	7,5	0,73375	0,164	4,49
S2	8	0,7848	0,164	4,79
S3	7	0,6867	0,176	3,9
S4	10	0,981	0,179	5,48
S5	8	0,7848	0,164	4,79
J1	7,5	0,73575	0,096	7,66
J2	8	0,7848	0,095	8,26
J3	6,5	0,63765	0,092	6,93
J4	7,5	0,73575	0,095	7,74
J5	8	0,7848	0,096	8,18

Figure 8: Charpy´s hammer test samples after testing (test samples J).

RESULTS

For results interpretation we´ve calculated arithmetical average of results for every sample´s types.

Composite material tension test

For this kind of test we´ve evaluated two parameters – failure force needed to breaking the sample and the fracture limit of sample.

As you can see, the second type samples - made from 2 layers of carbon and 1 layer of 250mm natural fibres, needed higher tensile strength to break as the samples of first type.

As in the graph shown is, the strength needed for breaking the samples with the 250 sisal fibres is 53,4% higher than the strength for breaking the shear samples. Finally there is a makeable difference between the sample´s type, and it´s clear that the samples with 250 fibres account better results.

Maximum and minimum strength needed for breaking the sample is shown in next table.

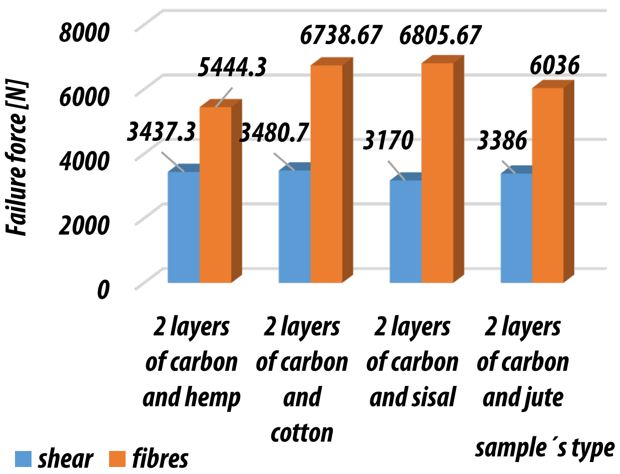

***Figure 9**. Graph of the dependencies between strength and sample type by static tensile test*

***Table 4** .Strength needed for breaking the samples*

First type samples (natural shear)	
Maximum strength	*3480,7N – cotton shear*
Minimum strength	*3170N – sisal shear*
Second type samples (250mm natural fibres)	
Maximum strength	*6805,67N – sisal fibres*
Minimum strength	*6036N – jute fibres*

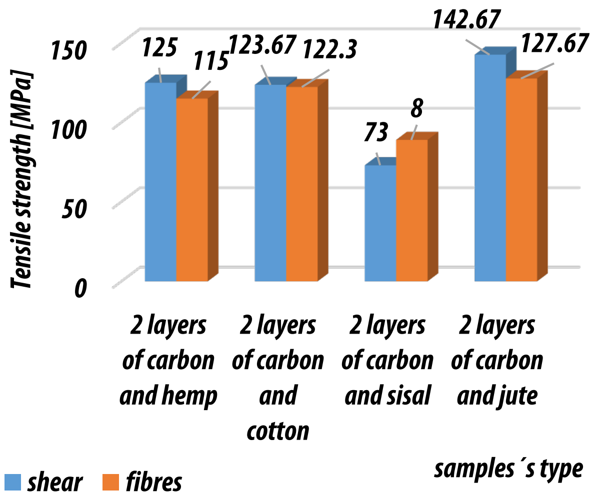

***Figure 10**. Graph of the dependencies between tensile strength and sample type by static tensile test*

Results of tensile strength testing doesn't matched with the result of "strength needed for breaking the samples" measuring. As the results show, higher fracture limit have mostly the first type samples made from natural shear.

***Table 5**. Fracture limit results*

First type samples (natural shear)	
Maximum fracture limit	*142,67MPa – jute shear*
Minimum fracture limit	*73MPa – sisal shear*
Second type samples (250mm natural fibres)	
Maximum fracture limit	*127,67MPa – jute fibres*
Minimum fracture limit	*89 MPa – sisal fibres*

Impact test at a bending

Next table (Table 6) and graphs on Figure 11 and Figure 12, are showing arithmetical average of needed work for sample breaking and the tenacity. The test has been taken only for first type samples (natural shear).

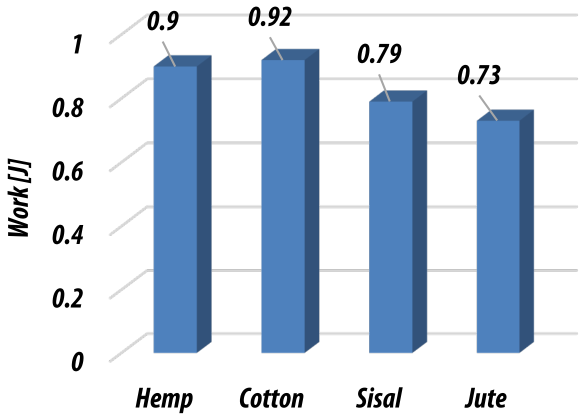

***Figure 11.** Graph of the work in the impact at a bending test*

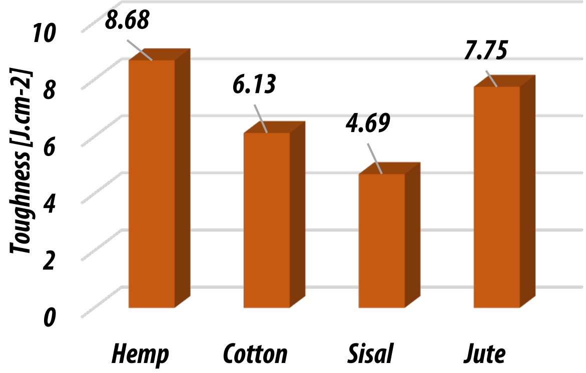

***Figure12**. Graph of the toughness in the impact at a bending test*

***Table 6**. Work and tenacity results*

Maximum work	*0,92J – cotton shear*
Minimum work	*0,73J – jute shear*
Maximum tenacity	*8,68J – hemp shear*
Minimum tenacity	*4,69J – sisal fibres*

COMPOSITES SAMPLES CONFRONTATION

Because one of our goals of the experiment was to define the ability of using the natural materials, we needed some confrontation with pure - in our case carbon composite. We´ve used the result of another experiment made on our department [3].

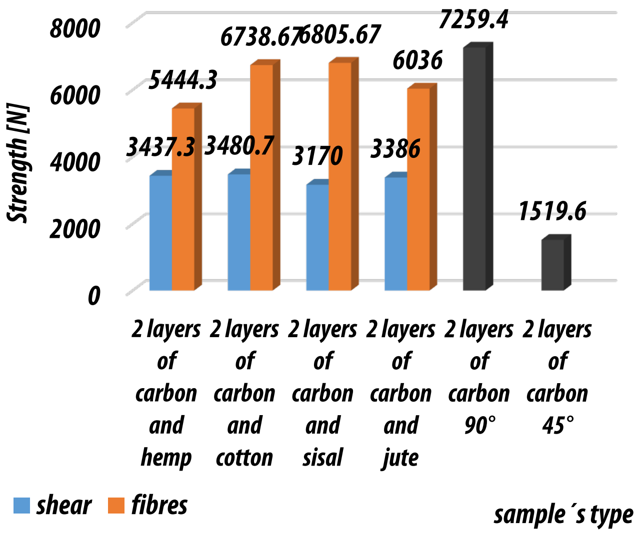

***Figure 13**. The confrontation graph of breaking strength of the samples with natural fibres and the pure carbon samples*

For comparing we´ve choose 2 samples: made from 3 carbon layers laid under 90° angle, and made from 3 carbon layers laid under 90° angle. These samples have had the best results in mentioned experiment [3]. The comparing of tension test results can be seen in the next graph.

This graph shows that the samples made from tree carbon layers laid under 90° angle needed the biggest strength of 7259,4 MPa to break[3]. The biggest strength needed to break the hybrid composite is 6805,67 MPa by composite with sisal. That is 6,25% less than pure carbon sample. The carbon samples laid under 45° are very weak also against samples with natural fibres.

The results of samples with sisal fibres are comparable to pure carbon samples, what suggests that the hybrid composites with natural fibres have some potential to be used. The availability, ecological potential, and price of the hybrid composites can compete another composite materials

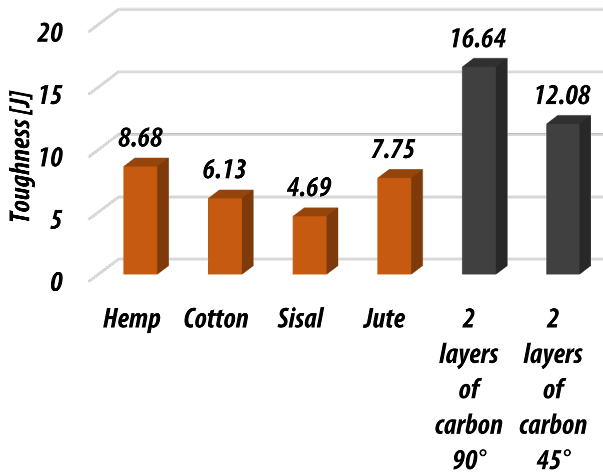

***Figure 14**. The confrontation graph of toughness of the samples with natural fibres and the pure carbon samples*

As you can see on the graph above, the highest tenacity have had the samples made from 3 layers of carbon fibre laid under 90° angle – 16,64J [3]. The hybrid composites samples are in the tenacity comparison much worse. The best results show composites with hemp shear – 8,68J, what is 47,83% less than the best result.

WEIGHT OF THE SAMPLES

One of the main composites advantage is their weight. Weight of the samples made whole from carbon (3 layers, size of sample: 250x25mm) [3] is 4,6g. Hybrid composite samples with the same size made from 2 layers of carbon and for example sisal shear is 8g. Weight of the samples made from 2 layers of carbon and sisal fibers is up-to 16g. That is up-to 76% more by shear and by fibers sample up-to 247% more. This results are disadvantageous, and we can say that hybrid composites are losing in this parameter.

CONCLUSION

In the 21th century, there is an enormous demand to create new, better, harder, lighter, ecologically materials. Especially car industry must complywith more and more reduced natural fuel sources, and new materials are one of the best ways to do it.With focusing on the new materials potential, the primary goal of this work/paper was to find out if the hybrid composites that combined the carbon fibres and natural fibres can compete another materials, especially purely carbon composites, which have the incomparable properties.

The results shows that the hybrid composites aren't able to compete the composites from carbon fibres.Strength needed to break the first type sample was double and by the second type minimal against strength needed to break pure carbon sample and the fracture limit difference was about triple over. Also tenacity results were double to triple less the by pure carbon samples.

The problem can also be the production technology of applying the natural fibres, because as we find out during the experiment, it´s difficult to lay precisely thick layer the natural fibres. Another disadvantage is the weight of hybrid composites. This, for car production important variable, emerge as very problematic. Natural fibres are able to change their volume, and so they can absorb more resin and so to magnify their weight. It´s been showed that pure carbon composites are double to triple lighter as the hybrid composites.

Only benefit of the hybrid composites is that their come from nature and are ecological. Natural fibres will probably never compete the artificially produces fibres in this kind of industry. We can use them in the interior or another part of cars, but their strength properties aren't suitable for applying for example in the construction of a car.

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References

[1.] MORAVČÍK, Roman – HAZLINGER, Marián – HUDAKOVÁ, Mária – MARTINKOVIČ, Maroš – ČIČKA, Roman: Náuka o materiáloch I. Trnava: AlumniPres, 2010. 249 s. ISBN 978-80-8096-123-7

[2.] Composites with ceramic matrix (CMCs) [online]. Available online: <http://www.matnet.sav.sk/index.php?ID=1122>.

[3.] *MURZA, Bc. Mário: Evaluation of selected mechanical properties of fiber composite automotive components. Diploma work. Košice: Technical University of Košice, Mechanical Faculty, 2013. 68 s.*

[4.] *MANGINO, Enrico, Joe CARRUTHERS a Giuseppe PITARRESI. The future use of structural composite materials in the automotive industry [online]. International Journal of Vehicle Design: The Journal of the International Association for Vehicle Design. Geneva: Inderscience Enterprises Ltd., 2007, Volume 44, 3-4, s. 211-232. DOI: 10.1504/IJVD.2007.013640. Available online: <citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.138.1771 &rep=rep1&type=pdf>.*

[5.] *VARGA, Bc. Peter: Testing of components made from composite materials,Diploma work. Košice: Technical University of Košice, Mechanical Faculty, 2013. 85 s.*

[6.] *DÚBRAVČÍK, Michal: Application of Natural Fibres in Hybrid Composite Materials, Materials Science Forum Vol 818 (2015) pp 311-315, (2015) Trans Tech Publications, Switzerland, 10.4028/www.scientific.net/MSF.818.311*

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