

MECHANICAL TESTING OF NATURAL FIBER COMPOSITES FOR AUTOMOTIVE INDUSTRY

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Abstract

In the recent past, considerable investigations have been made in natural fibers as a reinforcement in polymer matrix. Manufacturing companies are in constant search of new materials to lower costs and profit margins. Natural fibers are low-cost fibers with high specific properties and low density. Performance characteristics that predestine polymer use in automotive applications include corrosion resistance, low density, good impact toughness and chemical resistance.

The contribution deals with composites from corn, sunflower and hop fibers, their testing and potential use in the automotive industry.

Keywords: composites, natural fibers, tensile test, automotive industry

1 Introduction

Growing environmental, social and economic awareness, high rate of oil resources depletion, the concept of sustainability and new environmental regulations encourage exploration of new organic materials compatible with the environment. Worldwide availability of natural fibers is responsible for the renewed interest in research on sustainable technologies. Bio-resources drawn from the agricultural sector has gained a significant attention because they can be key components of bio-composites.

1.1 Natural fibre composites for the automotive industry

Natural fiber composites are being used for manufacturing many components in the automotive sector (Taj et al., 2007; Xin et al., 2007; Saxena et al., 2008, 2011). Typical market specification natural fiber composites include elongation and ultimate breaking force, flexural properties, impact strength, acoustic absorption, suitability for processing and crash behaviour. Plant fibers are mainly used in the part of car interior and truck cabins. The use of plant fiber based automotive parts such as various panels, shelves, trim parts and brake shoes are attractive for automotive industries worldwide because of its reduction in weight about 10%, energy production of 80% and cost reduction of 5%.

The major car manufacturers like Volkswagen, BMW, Mercedes, Ford and Opel now use natural fiber composites in applications such as those listed in Table 1.

Table 1 Current well-established applications of natural fibers in automotive industry

Automotive manufacturer	Model applications
AUDI	A2, A3, A4, A6, A8, Roadster, Coupe: Seat backs, side and back door panels, boot lining, hat rack, spare tyre linig
BMW	3, 5, 7 series: Door panels, headliner panel, boot lining, seat backs, noise insulation panels
CITROEN	C5: Interior door paneling
FIAT	Punto, Brava, Marea, Alfa Romeo 146, 156
FORD	Mondeo CD 162, Focus
LOTUS	Eco Elise: Body panels, Spoiler, Seats, Interior carpets
PEUGEOT	406: Seat backs, parcel shelf
RENAULT	Clio, Twingo: Rear parcel shelf
ROVER	2000 and others: Insulation, rear storage shelf/panel
SEAT	Door panels, seat backs
TOYOTA	Brevis, Harrier, Celsior, Raum: Door panels, seat backs, spare tyre cover
VOLKSWAGEN	Golf, Passat, Bora: Door panel, seat back, boot lid finish panel, boot liner
VOLVO	C70, V70: Seat padding, natural foams, cargo floor tray

BMW has been using natural materials since the early 1990's in the 3, 5 and 7 series models with up to 24 kg of renewable materials being utilized. In 2001, BMW used 4 000 tons of natural fibers in the 3 series alone. The combination here is a 80% flax with 20% sisal blend for increased strength and impact resistance. The main

application is in the interior door linings and paneling. Wood fibers are also used to enclose the rear side of seat backrests and cotton fibers are utilized as a sound proofing material.

The present level of car production in Western Europe is about 16 million vehicles per year, what is from 80 000 to 160 000 tons of natural fibers per year. German automotive manufacturers continue to lead the way, with Daimler-Chrysler for example, having a global natural fiber initiative program that benefits third nations by developing products made from indigenous agricultural materials.

2 Experimental details

The following part describes the methodology of composite samples preparation and testing.

2.1 Material details

The corn, sunflower and hop fiber reinforced polyester composites were prepared by the hand lay-up method. The stems have been smashed to allow the tender plant tissues to separate from plant fibers. After extraction, these fibers have been naturally air dried. The natural fibers were cut into pieces with length varying from 20 to 40 mm to allow better impregnation when producing the composite plates.

Matrix material (polyester resin, No.25 and hardener, class 3, 31- UN No 1866) was prepared in a proportion 100g of polyester resin and 5g of hardener. These two materials were mixed and stirred at low speed until it become uniform. The matrix material was poured into a bowl with the cut corn fibers, thoroughly mixed and poured into the mould and pressed. The composite was left to cure at room temperature for 2 days until it was completely dry. The same steps were used to make a sunflower fiber reinforced composite.

2.1.1 Sample 1 – polyester composite with corn fibers

This sample was prepared from 250g polyester resin and 23 g of corn fibers. Fiber volume fraction was $V_f = 24,06\%$. The sample was cut into 11 pieces for testing, see Fig.1.



Fig. 1 Specimens from sample 1

2.1.2 Sample 2 – polyester composite with sunflower fibers

Sample 2 was prepared from 350g polyester resin and 40g of sunflower fibers. Fiber volume fraction was $V_f = 36,23\%$. For the testing the sample was cut into 8 pieces, see Fig.2.



Fig. 2 Specimens from sample 2



Fig. 3 Specimens from sample 3

2.1.3 Sample 3 – polyester composite with hop fibers

This sample was prepared from 400g polyester resin and 20g of hop fibers. Fiber volume fraction was $V_f = 26,11\%$. For the testing the sample was cut into 7 pieces, see Fig.3.

2.2 Work methodology

After the composites were dried, they were cut using an angle grinder. The tensile test specimen were prepared according to ISO TC 71/SC 6N; the details dimension, gauge length and cross-head speed can be found at ISO TC 71/SC 6N.

After testing the values of tensile strength and Young's modulus were evaluated according to the following formulas:

$$\sigma = (dF / dS), \quad (1)$$

where: σ - tensile strength [Pa],
 F - force [N],
 S - cross sectional area [m²]

and
$$E = \sigma / \varepsilon, \quad (2)$$

where: E - Young's modulus [Pa],
 σ - tensile strength [Pa],
 ε - elongation [-].

2.3 Experiments

After the tensile testing of prepared specimen the results were evaluated individually in tables and graphs.

2.3.1 Tensile testing of specimen from sample 1

Total number of tested specimens was 11. During testing, specimen number 9 was broken out of the marked lines, the results were invalid.

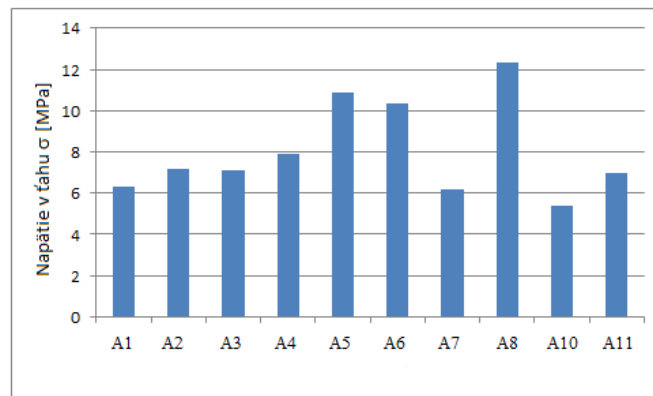


Fig. 4 Average tensile test values of specimens from the sample 1

After the tensile test the lowest value of tensile strength was 5,39MPa and the maximum 12,34MPa, see Fig.4. Results can be compared with the studies of Ishaka, who studied polyester composites reinforced with kenaf fibers.

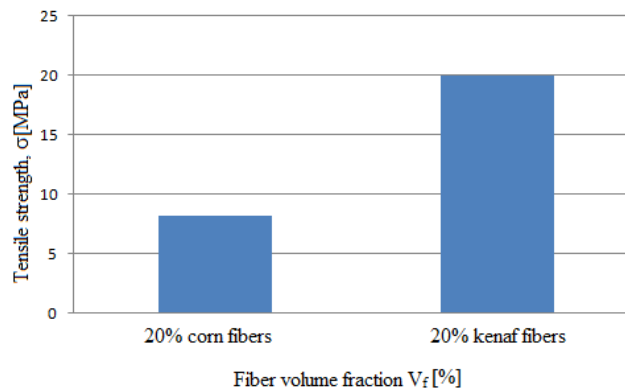


Fig. 5 Tensile strength of composites with kenaf and corn fibers in the case of 20% fiber volume fraction

At 20% fiber volume fraction, the tensile strength of composites was 20MPa. Fig.5 shows the comparison of tensile strengths in case of composite with kenaf fibers and corn fibers. It can be seen, that the value in the case

of composite reinforced with corn fibers does not reaches that one of the composite with kenaf fibers. Despite of that, it is an adequate value for lots of industrial applications.

2.3.2 Tensile testing of specimen from sample 2

Total number of tested specimens from sample 2 was 7. During testing, specimen number 5 was broken out of the marked lines, the results were invalid.

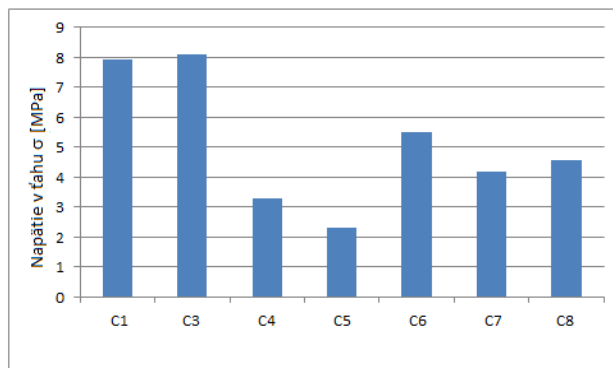


Fig. 6 Average tensile test values of specimens from the sample 2

After the tensile test the lowest value of tensile strength was 3,27MPa and the maximum 8,11MPa, see Fig.6. Compared to the results obtained in the case of sample 1, sunflower fibers show lower values of tensile strength.

2.3.3 Tensile testing of specimen from sample 3

Total number of tested specimens from sample 2 was 7. During testing, specimen number 5 was broken out of the marked lines, the results were invalid.

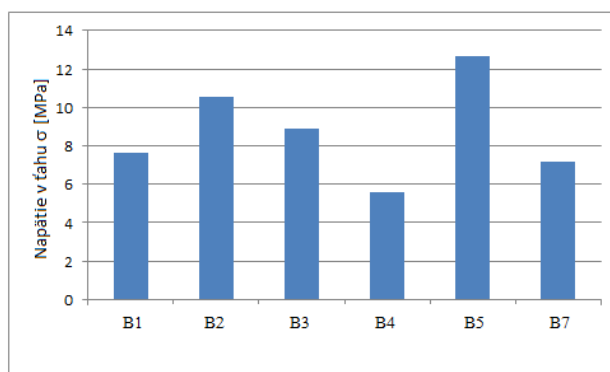


Fig. 7 Average tensile test values of specimens from the sample 3

After the tensile test the lowest value of tensile strength was 5,61MPa and the maximum 12,67MPa, see Fig.7. The results were similar to those gained from the testing of the first sample. The small difference between the tensile strengths can be caused by the 6% fibre volume fraction difference. That in the case of composite with corn fibres was 24,06% and in the case of composite with hop fibres 26,11%.

It can be stated, that corn and hop fibres provide similar mechanical performance. Cannot be definitely said from the performed tests, whether the corn fibres or hop fibres have better mechanical performance.

2.3.3 Analytical evaluation of tensile strength and Young's modulus

The tensile tests were followed by analytical evaluation of tensile strength and Young's modulus. The calculations were performed according to the formulas mentioned above in chapter 2.2 for the three composite samples.

Table 2 Current well-established applications of natural fibers in automotive industry

Composite samples	Average value of tensile strength, σ [MPa]	Average value of Young's modulus, ϵ [GPa]
Sample 1	8,15	3,97
Sample 2	5,04	3,43
Sample 3	8,43	3,82

The values of maximum force were acquired from the graphs. Average values of individual calculations are summarized in Table 2. It is obvious from the table, that composite reinforced with sunflower fibers has the lower value of tensile strength. As a reason could be the dimensions of sunflower fibers, compared to the other two used fibers, were thicker. That can cause bad impregnation with the resin, followed by pores formulation. As it is known from the studies, porosity affects the mechanical properties of materials.

2.3.4 Fractography of the samples

Specimens from the samples 1, 2 and 3 were macroscopically analyzed. The surface of selected samples can be seen in the Fig.8.

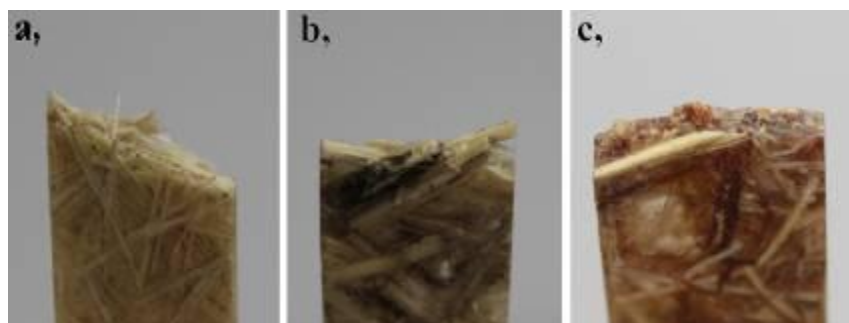


Fig. 8 Fracture surface of selected specimens after tensile testing
a, sample 1 b, sample 2 c, sample 3

It can be concluded that the prevailing fracture mechanism after tensile tests was fiber separation and pull out. In the case of specimens from sample 2, the binding of the fiber matrix surface was weaker, therefore in the matrix were located small manufacturing defects, pores. Fibers from the sunflower stem were thick and the initiation of failure was quick. Crack initiation tended to occur near the thickest fibers.

2.4 Results and discussion

Tensile tests of three composites plates reinforced with different natural fibers were performed. For the first sample corn fibers were used (with 24,06% fiber volume fraction). The second sample was reinforced with sunflower fibers (with 36,23% fiber volume fraction), and for the last sample were used hop fibers (with 23,11% fiber volume fraction). The resulting average values of specimens from the samples are plotted in a common graph, see Fig.9.

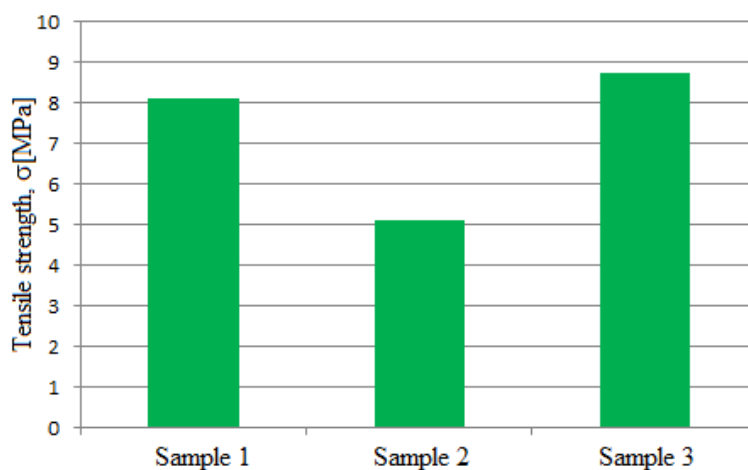


Fig. 9 Average tensile strength values of the tested samples

According to the obtained information from the performed tests on the three tested materials, fibers from corn and hops are suitable for the production of composite reinforcement. These materials have adequate properties to be used as door storage or other less stressed parts of the car interior.

3 Conclusion

Based on the measured and calculated results can be stated, that corn and hop fibres meet the conditions for being used in composites for less stressed components. The average tensile strength values of polyester composites reinforced with corn and hop fibres were around $\sigma = 8\text{MPa}$. Thus, they can be applied for example as composites in the automotive interiors. On the contrary, composites reinforced with sunflower fibres have lower strength values, around $\sigma = 5\text{MPa}$.

As expected, the acquired results are lower than those of common used fibres or glass fibres. Despite of that, the produced polymeric plates with corn and hop fibers have adequate properties for lots of industrial applications. Using these natural fibers, the products become more ecological substitute and environmental friendly than the traditional polymeric glass fiber composites.

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