ISSN 1691-5402
ISBN 978-9984-44-070-5
Environment. Technology. Resources
Proceedings of the 8th International Scientific and Practical Conference. Volume 1

SPECIFIC OF HEMP FIBER'S PLASTIC COMPOSITE PROJECTION

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Abstract. *In the report there are reflected research results of new board type biocomposites creation for furniture and equipment manufacturing for public segment, replacing traditional petroleum-based components with fully or partly renewable, biodegradable raw materials as one of the major global environmental problems today is non-renewable resource depletion and waste of petroleum-based plastic products. Performed research of biopolymer composites development shows that they are cheaper, environmentally friendlier, lighter, more easily to recycle and to dispose at the end of the product life cycle.*
For biopolymer's reinforcement industrial flax and hemp fibers in terms of mechanical qualities are competitive with the glass fiber, they are strong enough in many applications, CO_2 *neutral, have a relatively low cost, low production energy requirements. By creating new biocomposites it is taken into account that the designed material mechanical properties are mainly dependent on the fiber mass in the matrix, orientation and adhesion to the matrix material. The maximum theoretical amount of fiber weight in composite can reach 91%, specific weight of the fiber component used in practice is usually between 45-65%, but can reach also 70%. For improvement of the adhesion the chemical treatment and drying of the fibers need to be done, also adjuvants that promote development of the hydroxyl group links should be incorporated in the matrix.*

Keywords: *biodegradable composite, mechanical properties, natural fiber, polypropylene processing , renewable resources.*

Introduction

One of the most actual environmental issues today is plastic waste. The large amount of plastics manufacturing and product use in every day life creates vast amount of plastic waste. In year 2008 in the world there were about 245 million tons of plastic used that in relation to the year 1950 when 1.5 million tons were used is a huge amount. The increase is much higher than consumption of other materials such as steel or paper [1] that creates comparable fast-growing volumes of waste.

Evaluation of waste is strictly regulated in the European regulations and criterions about cleaner and safer environment, as well scientific research about ecological materials and ecocomposites development are promoted. This trend is particularly topical in the last decade, when more and more attention from both academic and industrial environment is focused on solutions of the problems that are associated with development of renewable, biodegradable components and to pack up into stable composite structures.

So that materials could be classified as biodegradable, they must meet specific criteria set by the European standard EN 13432 [2] and define biodegradable plastics as ones which are experiencing major changes in the chemical structure under specific environmental conditions. Biodegradable plastics submit degradation as a result of influence of the natural micro organisms - bacteria and fungi. In most of the international standards it is required that at least 60% of corrosive product need to be corrosed in 180 days. Plastics can be created as photo corrosive, corrosive as the result of oxidation, hydrophytes - corrosive, or one who may be decomposed [3].

Materials and methods

Filling of the composite materials

Plastic composites that are strengthened with natural fibers are demanded raw materials in many economical sectors including vehicle industry, building and furniture manufacturing. In the former practice while making the plastic composites, the reinforcements from wood or textile fibers (predominantly synthetic) are implemented in the plastic matrixes. Natural fibers are environmentally friendly, completely recyclable, widely available, and regularly renewable, comparatively cheep, with sufficiently good physical and mechanical qualities, with low density as plant fibers are lighter than traditional for technical uses glass, carbon or aramid fibers (Table 1). If the natural ability of decomposition solves ecological problems, then low costs and good qualities makes economical interest. Natural fibers recycling at the end of the life cycle by burning or in the waste polygon, exempted volume of CO_2 balances the volume that is received during the growth. Abrasive qualities of natural fibers are much lower which ensures benefits in the treatment of composite material. Natural fiber composites are completely recyclable at the end of their lifetime which makes them nature friendly materials. These are also renewable resources contrary coal, oil or natural gas. In the composite materials which are made by using unmodified plant fibers required mechanical qualities are not reached very often. To avoid it before the making the composite in many cases additional treatment of the surface or usage of reagents is necessary.

The natural fibers that are more investigated lately are hemp fibers. Although hemp usage in natural fiber composites is relatively new market it has proved itself already in a good way. Hemp composites work well in different ways – if water absorption and exuding is necessary, thermal and acoustic isolation, firmness and hardness. Since hemp and other natural fibers usually are used in the polypropylene matrix (or with other polymers), the saving of manufacturing energy results in the glass fiber replacement and bigger proportion of natural fiber in the matrix. Consumption of energy for manufacturing glass fibers is five times bigger than needed for hemp fiber refinement, for manufacturing epoxy resin it is 10-20 times bigger.[4]

Table 1.

The comparison of physical properties of natural and glass fibre

	Fibre							
	E-glass	flax	hemp	jute	ramie	coir	sisal	cotton
Density (g.cm^3)	2,55	1,4	1,48	1,46	1,5	1,25	1,33	1,51
Tensile strength (MPa)	2400	800-1500	550- 900	400- 800	500	220	600- 700	400
Elongation (%)	3	1,2- 1,6	1,6	1,8	2	15-25	2- 3	3- 10
Young's Modulus (Gpa)	73	60-80	70	10- 30	44	6	38	12
Moisture absorption (%)	-	7	8	12	12- 17	10	11	8- 25

Composite matrixes

Traditional composite materials are stable against biological degradability (are not biodegradable). Micro – organisms that are in the soil can not take down part of the plastic in order to create collapse in the matrix system. In this group of materials there are composites with oil base matrix that is strengthened with carbon or glass fiber. Such materials are recycled and used again.

Research in the field of biodegradable composites is now focusing on two out of three polymer composite material classes: 1) partly biodegradable; 2) completely biodegradable composites.

Partly biodegradable composite materials are created so that they would divide faster than most of the composites from the synthetic materials. In the manufacturing these types of materials, usually natural fibers are used, a polymer from the oil products works as a binder. At the end of the lifetime composite structure gradually decline while micro – organisms recycle natural fiber macro molecules that is the plastic matrix armature. As a result micro – organisms penetrate inside the composite and stimulate degrability of the material.

In the class of completely biodegradable polymer materials there are polymer materials that take down in a biological way. It is a new field and at the moment has big attention from researchers and manufacturers. Matrix polymers are attempted to be created from natural raw materials (starch or microbiologically planted polymers), but armature fibers are created from the renewable resources (flax, hemp, other cellulose based fiber plants). As a result micro – organisms can completely recycle these composite materials in biological processes in two stages. Fiber plants are made from twisted macromolecules' chains that are split in smaller fragments as a result of action of enzymes. In the influence of oxygen and as a result of enzyme action the divided macromolecules take part in the next metabolism processes, as a result of degrability processes they divide in CO_2 and H_2O, that are environmentally friendly side products. [5]

In many usages in a shape of matrix fiber, granule or polythene **PP** (Polypropylene) is used, which is thermoplastic, colorless (white) polymer with high melting temperature (158-170C^o) and high tension durability. It is widely used in engineering industry, textile industry, building, furniture manufacturing and in other industries. PP is resistant against different organic liquids, alkali, acids, poorly absorbs water. Polymer submits well to the recycling and in the composites with natural fibers it is partly biodegradable. PP is the most widely used thermoplastic material in the industry of natural fiber composites because of its low density, excellent processing, good mechanical qualities, high temperature resistance, good shape stability and resistance of the influencing strength. Increase of the PP usage describes also wide research and publications that are dedicated to the research of this material. Advantages and disadvantages of the polypropylene matrix are visible in the table 2 [6].

Table 2.

Advantages and disadvantages of polypropylene matrix [6]

PP advantages	PP disadvantages
Low specific gravity (density) Excellent chemical resistance High melting point (relative to volume plastic) Good stiffness/ toughness balance Adaptability to many converting methods Great range of special- purpose grades Excellent dielectric properties Low cost (especially, per unit volume)	Flammability Low- temperature brittleness Moderate stiffness Difficult printing, painting ang gluing Low UV resistance Haziness Low melt strength

Table 3.

Mechanical properties of polymers that are used a s matrixes in fibre composites [7]

Matrix	Density (g/cm^3)	Melt Temp (°C)	Tensile Strength (Mpa)	Young Mod. (GPa)	Elong. To Break (%)
High density Polyethylene (HDPE)	0,94- 0,96	120- 130	32	1,1	150
Low density Polyethylene (HDPE)	0,91- 0,93	105- 115	20	0,2- 0,3	300- 600
Polypropylene (PP)	0,9	176	35	1,1- 1,6	150
Poly (lactic acid) (PLA)	1,25	140- 152	48	3,8	2,5
Poly (hydroxybutyrate) (PHB)	1,25	175	40	3,5	6
Polybutyleneadipate/ terephthalate (PBAT)	1,25- 1,27	110- 120	35	<0,2	560- 700

Production of composite materials

Fibers in the composite material work as intensifier while the pressure is directed from the matrix to the fibers as a result of interaction. Geometrical factors that separate different fiber composites are:

1) Fiber amount; 2) Fiber length; 3) Fiber allocation; 4) Fiber orientation.

Such layers can consist not only from the adjusted fibers but also from the differently oriented fibers. They can be located differently, for example, in the composite order or in the right angle one against another.

Theoretically the maximum amount in the composite can reach 91% which can be created if fibers are placed in the twisted shape. Fiber amount in the location prevalently reaches 45 - 65%, but it is possible to reach also 70%.

Composite can have various fibers' structure as it is shown in Fig.1.

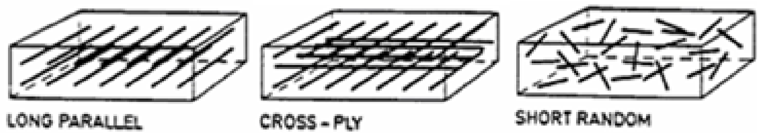
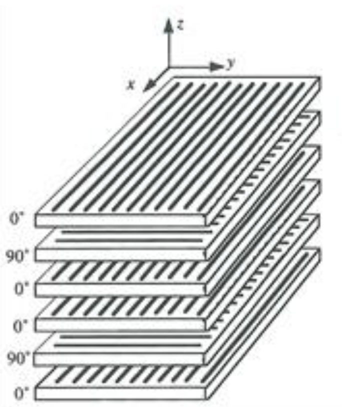


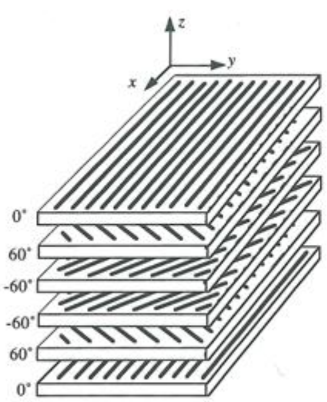
Fig.1. **Fiber structure in composite**

High performance polymer components usually consist of layers or in layers which are arranged in particular order. In order to anticipate total material flexibility, each layer is considered as homogeneous in a way that fiber planking and layout is equal in all the material. Fibers can be short or long, laid out in one or several layers in one or various directions. If the fibers are laid in one layer it is called *ply* but if it is laid in several layers it is called a *laminate*. Flat laminate is made from one direction laid fiber layers that are arranged in the angle of 90^o one above another. This is a typical construction that is used in the aircrafts because of its strength.

Simple condition is used to describe the layer sequences. It is described with simple layers. As you can see in the Fig.2a layers are formed in 0^o/ 90^o/ 0^o/ 0^o/ 90^o/ 0^o, which can be simplified to [0/ 90/ 02/ 90/ 0], where digit 2 means that there are two layers with 0^o orientation. As in this case claddings are in the symmetric relation to the middle layer, then it is possible to simplify the designation [0/ 90/ 0], which means that layers repeat symmetrically. Similar is also the situation that is shown in the Fig.2b where [0/ +60/ -60/ +60/ 0] is shortened to [0/ +60/ -60] or [0/ +-60]. [8]



(a)



(b)

Fig.2. **Arrangement of plies in (a) a crossply laminate and (b) an angle-ply laminate sandwiched between 0^o plies [8]**

Composites reinforced with natural plant fibers have also negative aspects like unconformity between hydrophile natural fibers and hydrophobe thermoplastic and termoset matrix, wherewith it is necessary to use appropriate physical and chemical processing methods to improve adhesion between fiber and matrix.

Experiment

The Composite Materials

For a composite material hemp variety "Bialobrzeskie" was used cultivated in the Latvia's Kraslava district at year 2009 (Fig. 3). As L. Freivalde's research shows [9], this type is very suitable for composite materials and weather conditions in Latvia are also appropriate for its' growth.

As composite matrix material polypropylene fibers „FiberMesh 300" imported from England were used (Fig.4). These fibers are already lengthened by 12 mm. In order to make the more even planking, lengthened fibers were rarefied to make the mono fiber planking out of fiber entirety.

Fig.3. **Hemp fibres**

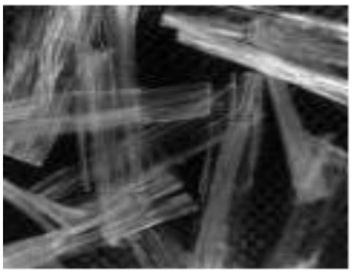


Fig.4. **Fibers of polypropylene "FiberMesh 300"**

Hemp fibers were scutched to clear out shives, separate long fibers from the short ones and get regular fiber planking. For the first samples of the experiment (parallel fiber orientation) long fiber complexes with the length 260mm were used measured by die size. For samples 50% and 70% fiber share from the total sample weight was used. Before samples preparation fibers were dried in the drying cupboard (CHBC-45.4.54) at the temperature of $60^{o}C$ with the exposure time of 4 hours.

Since the process is happening in the fever heat and the polymer is melting, aluminium foil plates in size of 265 x 265mm is used that ensure homogeneous pressed composite surface and possibility to take out ready made composite from the termopress device more easily. Aluminium foil, polypropylene fibers and hemp fibers were put in layers, making the composition of laminate type. (Fig. 5.)

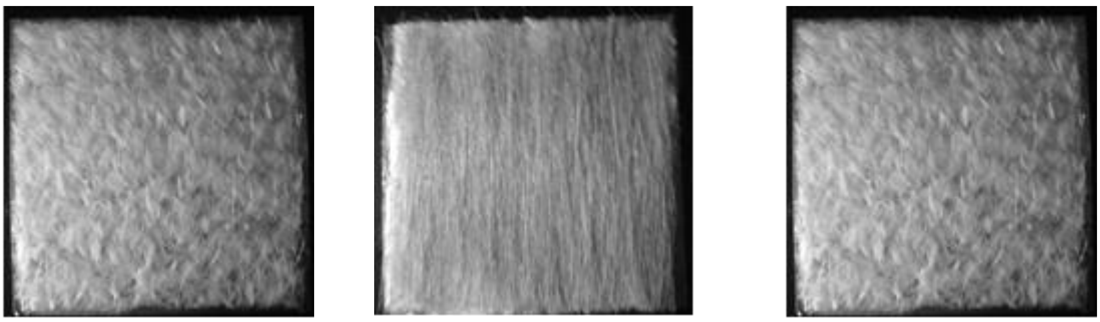


Fig.5. **Sample preparation stages**

Samples were prepared taking into account the experiment plan. Fixed factors were weight - 14g, pressure – 7,66kg/cm^2, time - 20 min. As the independent variables were chosen proportion of hemp in the sample (x_1) and temperature (x_2) - 170oC or 190oC. Sample size 260 x 260 x 0,65 mm.

Tensile Testing

Tension tests of the composite samples from the parallel long hemp fibers and polypropylene matrix were executed on universal testing device ZWICK Z100 (maximum strength 100 KN) using Tension 100kN.ZPV testing method. Tests were carried out with the clamp speed 10 mm/min and clamping distance 90mm at room temperature 22+/-2C^o. Total number of tested samples 16, including 4 samples for each processed set. Obtained test results are shown in graphs of Fig. 6 and 7.

Results and discussion

Tensile Properties

The degree of effectiveness of reinforcement can be characterized by the Young's modulus of the composites (Fig. 6) and tensile strength and elongation (Fig. 7).

As seen from graph of Fig. 7 tensile strength parallel to the fibers direction tended to increase with the increasing hemp fibers share in composite and temperature decrease, with the following tensile elongation increase. Tensile strength lower values for 70% reinforcement and processing temperature 190 ^{0}C witness that such processing temperature is too high for hemp fibres as structure of these fibres are stable till 170 ^{0}C and after this level is exceeded some destruction of fibers could start.

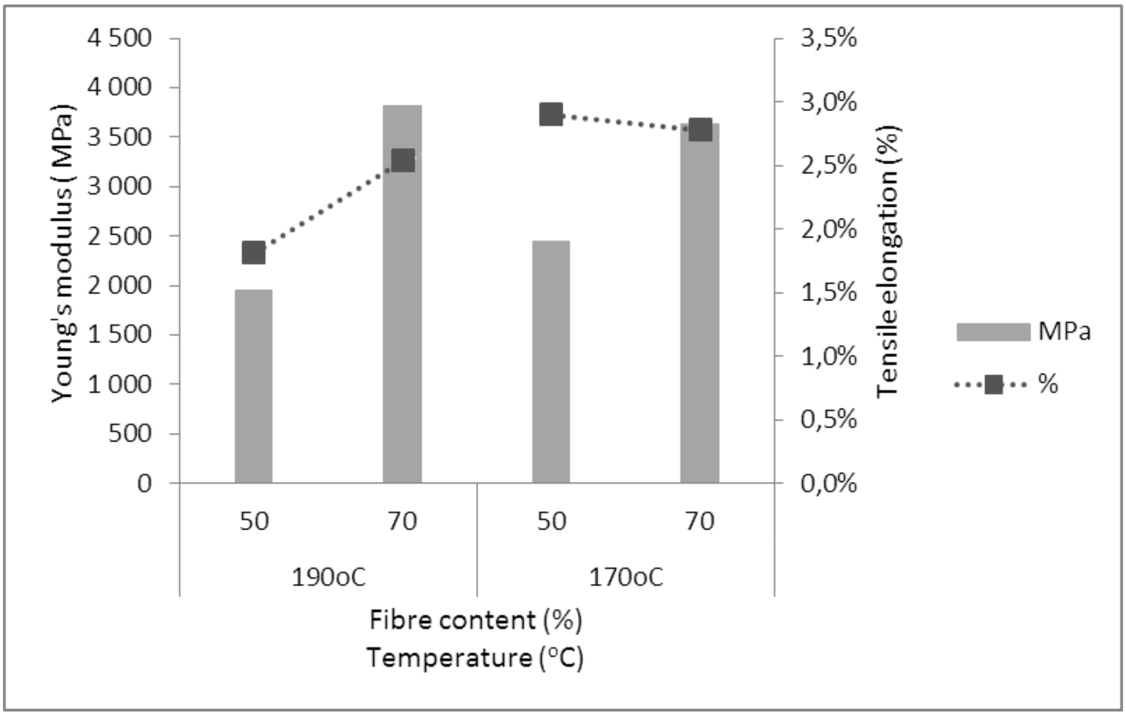


Fig.6. **Young's modulus as function of fiber content, temperature and tensile elongation**

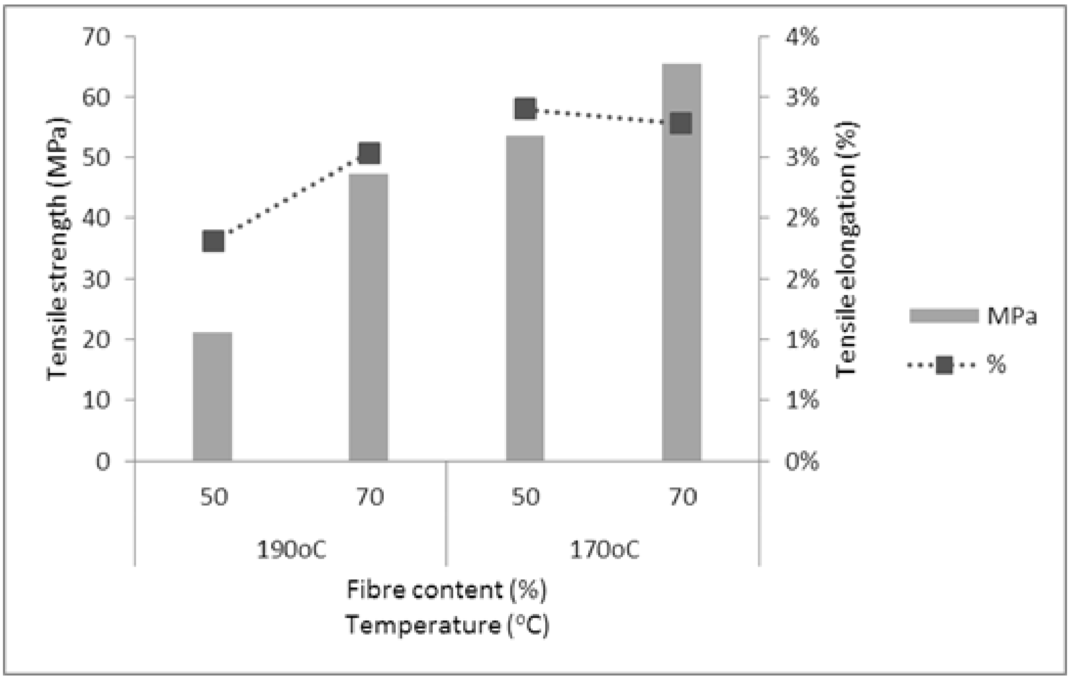


Fig.7. ***Tensile strength as function of fiber content, temperature and tensile elongation***

Comparison of Young's modulus for variants shows that module is a little higher for sample with 70% hemp fibers and processing temperature 190 ^{0}C compared to 70% hemp fibres sample in 170 ^{0}C, but difference does not exceed 5%. For samples with 50 % hemp reinforcement Young's modulus are strong lower 2000 (190^{0}C) and 2500 (170^{0}C) respectively.

Summary

Long hemp fibers as a reinforcement of fiber plastic composites could be used to ensure Young's modulus values in range 1954- 3816 MPa and tensile strength in range 21,16- 65,47 MPa. Higher values of hemp fiber PP composite tensile strength could be provided by long fiber content 70% and processing temperature 170 ^{0}C. Young's module 3816 processing temperatures higher than 170 ^{0}C are not recommended. Hemp fibers reinforcement of PP base composite provides biodegradability of final product at the end of its usage in natural environment.

Further experiments to improve mechanical properties of hemp fiber-PP composites and development of hemp fiber-natural matrixes composites are needed.

Acknowledgements

This work has been worked out by support of Europe Social fund in a project "Support for RTU doctorate program's realization"

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Anotācija. *Šajā publikācijā ir atspoguļoti pētījumu rezultāti jauna plātņu tipa biopolimēra kompozītu izveidei mēbeļu un iekārtu ražošanai sabiedriskajam segmentam, aizstājot tradicionālās naftas bāzes komponentus ar pilnībā vai daļēji atjaunojamām, bioloģiski noārdāmām izejvielām, jo viena no lielākajām pasaules mēroga vides problēmām mūsdienās ir neatjaunojamo dabas resursu sarukšana un atkritumu apjoms no naftas bāzes plastmasas izstrādājumiem. Veiktie pētījumi biopolimēra kompozītu attīstībā rāda, ka tie ir lētāki, videi draudzīgāki, vieglāki, vieglāk pārstrādājami produkta dzīves cikla beigās.*
Rūpnieciskās linšķiedras un kaņepju šķiedras kā biopolimēra pastiprinātāji mehānisko īpašību ziņā ir konkurētspējīgas ar stikla šķiedru. Tās ir pietiekami konkurētspējīgas daudzos aspektos- CO_2 *neitrālas, ar salīdzinoši zemām izmaksām, zemām ražošanas enerģijas prasībām. Radot jaunus biokompozītus, jāņem vērā, ka izveidotā materiala mehāniskās īpašības galvenokārt ir atkarīgas no šķiedru daudzuma matricā, šķiedru novietojuma un adhēzijas ar matricas materiālu. Maksimāli teorētiskais šķiedru masas daudzums kompozītā var sasniegt 91%, ko iespējams izveidot, ja šķiedras iestrādātas savītā veidā. Praksē lietojamais šķiedru komponentes īpatsvars parasti ir robežās 45-65%, bet iespējams sasniegt arī 70%. Adhēzijas uzlabošanai jāveic ķīmiska šķiedru apstrāde un žāvēšana. Arī matricā nepieciešams iestrādāt papildvielas, kas veicina hidroksilgrupas saišu veidošanos.*