Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology No 80, 2012: 157-160
(Ann. WULS-SGGW, Forestry and Wood Technology 80, 2012)

Birch plywood composite material with hemp fibre reinforcement

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Abstract: With growing volumes of utilisation of traditional natural resources, increasing attention is given to new environmentally friendly materials. Worldwide, work is under way on obtaining new materials and upgrading the properties of the already existing ones. New material compounds are created; as a result, composite materials with higher physico-mechanical and service properties have been developed. One of such promising composite materials is plywood, which makes it possible, due to its constructive structure, to reach an enhanced mechanical strength. With increasing application of plywood in the national economy, it becomes necessary to enhance its physico-mechanical properties and to decrease the production costs. Plywood with different coats, varying their surface physical properties, is developed and introduced in production. In industry, plywood coating with different non-wood materials is widely used. An alternative for the so far used methods is the enhancement of the plywood strength with fibre materials of natural origin. The objective of the study was, using a bicomponent binder, to mutually compare the effect of the long fibres of dried hemp and hemp yarn woven technical fabrics on the changes in the physico-mechanical properties of the plywood composite material. It is shown that, for the composite material with the hemp technical textile introduced in its matrix, bending strength index, in comparison with that for the control sample, increases by 21.8 % and modulus of elasticity in static bending increases by 23 %. However, introducing individual hemp fibres, these strength indices are lower. Summarising the obtained results, it may be concluded that, in the future experiments, it will be necessary to investigate the physico-mechanical properties of plywood composite materials, in the matrix of which a technical textile made from hemp is introduced, changing its parameters and the location in different layers of the composite material, as well as the glue, tree species and compressing pressure.

Keywords: birch plywood, reinforced plywood, hemp, phenolformaldehyde resin, polyvinylacetate glue.

INTRODUCTION

For centuries, industrial hemp (plant species *Cannabis sativa)* has been a source of fibre and oilseed used worldwide to produce a variety of industrial and consumer products. Currently, more than 30 nations grow industrial hemp as an agricultural commodity, which is sold on the world market. In the United States, however, production is strictly controlled under the existing drug enforcement laws; there is no known commercial domestic production, and the U.S. market depends on imports (*EIHA*). In Europe, the "European Industrial Hemp Association (EIHA)", officially founded on 23 November 2005, acts. Therefore, the more than five year-old status of a totally informal association, which had been founded on 14 September 2000 in Wolfsburg, was brought to an end and converted into an official association (*Skagale* 2012). Also in Latvia, the area of hemp fibre crops has reached 500 ha (*Skagale* 2012) in 2012 and continues to increase each year.

The most expanding application of hemp fibre is its use as a reinforcing component in composition materials. Hemp fibre is equally well mixable both with thermoplastic materials such as polypropylene and polyethylene, and with thermoreactive fibres such as polyester. A mixture of hemp fibre with polypropylene in nonwoven insulation mats is commonly used. The fibres are also used jointly with mineral bases, which are often polypropylene, glass fibres, concrete, gypsum, etc. The growing prices for electric energy make the production of synthetic reinforcing fibres more expensive, but hemp fibres, which are superior in terms of the properties and cost, are finding new methods for application. One of such examples is combined textile from hemp fibres with plywood. Tests of polymer coatings and films, reinforced with mesh knit fabric, have been carried out in Uzbekistan (*Rakhimov et al.* 2008).

Studies on the physico-mechanical properties of plywood, reinforced with glass fibre, using phenol-formaldehyde resins as a binder, have been successfully carried out in the Czech Republic (*Král et al*. 2008).

In the paper, searches for the solution to the problem of enhancing the strength of hemp fibre reinforced plywood are reflected. A radical possibility to produce a new environmentally friendly material with enhanced strength characteristics is shown.

MATERIALS AND METHODS

Conditions of carrying out the experiment were as follows:

○ the plywood and glue material used in the experiments was identical to that used in production;

○ the hemp textile used in the experiments was fabricated for specific experiment needs;

○ the hemp textile warp thread orientation was parallel and perpendicular to the bundle's outer plywood sheet fibre direction;

○ the hemp textile introduced in the bundle was strained in its warp direction;

○ in the samples made for the experiments, 1.5 *mm* thick birch rotary cut veneer was used;

○ the samples' sizes were 50 × 200 *mm*;

○ in all samples, the rotary cut veneer bundles were formed from 5 sheets. In the bundle's structure, each next rotary cut veneer layer was placed perpendicular to the previous one (Fig. 1);

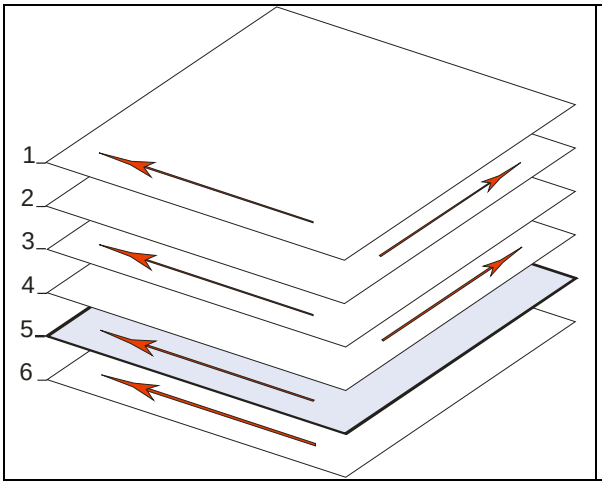

Fig. 1. Bundle structure.
1,3,6 – Birch rotary cut veneer layers, in which the fibre direction in the first samples' group is parallel to the bundle longitudinal edge, but the fibre direction of the second group of samples is perpendicular to the bundle longitudinal edge.
2,4 - rotary cut veneer layers, in which the direction of the first group of samples is perpendicular to the bundle longitudinal edge, but the fibre direction in the second samples group is parallel to the bundle longitudinal edge.
5 – the hemp textile layer, in which the warp direction is parallel to the bundle longitudinal edge.

○ in all samples, among the 1st and 2nd layers of the bundle's rotary cut veneer, a hemp textile layer was placed;

○ in making all experimental samples, a mixture of the bicomponent carbamide resin „*Casco Adhesives' UF 1274*" (*Akzo Nobel*) with the hardener *2545* and polyvinyl acetate D3 group „*Tempo 303*" glue (*KLEIBERIT*) was used;

○ in the prepared samples, the glue was applied to one side of the rotary cut veneer. In the layers, between which hemp textile was placed, the glue was applied to both sides of the rotary cut veneer adjacent to the textile.

RESULTS AND DISCUSSION

Experimental plywood samples were made, using a press with heated surfaces in the following regime: hemp mesh cell size 4 – 12 *mm*, hemp mesh tension 10 – 30 *N*, pressing pressure 1.3 – 1.7 *MPa*, mass of the binder (per 100 g of resin) 17 – 23 *g*, mass of polyvinyl

acetate glue PVA per 100 *g* of resin 10 – 14 *g*, gluing temperature 90 ^{o}C. As a binder, a mixture of phenol-formaldehyde resin (PFR) and polyvinyl acetate glue PVA was used. The results are shown in Table 1.

Table 1. Experimental results' characteristics

Sample	Number of sample	Static bending strength, *MPa*	Modulus of elasticity in bending strength, *GPa*
Control PFR with 15 % PVA	14	78.6	8.098
1 experiment ∥ fibre	10	98.8	10.132
1 experiment ⊥ fibre	10	50.3	3.962
2 experiment ∥ fibre	10	88.2	8.806
2 experiment ⊥ fibre	10	46.6	3.029
3 experiment ∥ fibre	10	99.4	10.517
3 experiment ⊥ fibre	10	48.6	3.445
4 experiment ∥ fibre	10	88.1	9.476
4 experiment ⊥ fibre	10	47.8	3.381
5 experiment ∥ fibre	10	104.3	10.872
5 experiment ⊥ fibre	10	44.8	3.141

It can be seen that static bending strength parallel to fibre for the experimental samples is greater even by 21.8 % than for the control, but modulus of elasticity – by 23 %. Static bending strength perpendicular to fibre for the experimental samples is only 47.62 *MPa* and modulus of elasticity is 3.392 GPa. Static bending strength of water-resistant plywood is 55 – 60 *MPa* (GOST 3916.1-96), which is lower by 66 % than that for hemp mesh knit fabric reinforced experimental birch plywood.

CONCLUSIONS

1. It is shown that the hemp mesh knit fabric reinforcement of birch five-layer plywood allows the production of an environmentally friendly composite material.
2. A composite material with elevated mechanical characteristic in bending $\sigma_{bending}$ up to 21.8 % and modulus of elasticity in static bending up to 23 %, using hemp mesh knit fabric for reinforcing birch plywood, is obtained.
3. Static bending strength for water-resistant birch plywood, according to GOST 3916.1-96, is 55 – 60 *MPa*, which is lower by 66 % than that for hemp mesh knit fabric reinforced experimental birch plywood.

4. It is shown that the static bending strength perpendicular to fibre for experimental samples is only 47.62 *MPa* and modulus of elasticity is 3.392 *GPa.*

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Streszczenie: *Kompozytowa sklejka brzozowa wzmocniona włóknem konopnym.* Praca dotyczy nowego, obiecującego materiału kompozytowego, bazującego na sklejce brzozowej wzmocnionej włóknem konopnym. Zbadano wpływ modyfikacji długim włóknem konopnym oraz tkaniną na własności wytrzymałościowe takich sklejek.

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