Experimental Analysis on Hemp Fiber Reinforced Composite Material

T. Naresh Kumar[a] , S.Shankaranarayanan[b*] and D.David[b],

[a]Assistant professor, Department of Mechanical Engineering, Malla Reddy Engineering College,(Autonomous) under JNTUH, Hyderabad, India
[b]Assistant professor, Department of Mechanical Engineering, Velammal Engineering College, Chennai - 600 066.

Abstract— **With the growth of the environmental pollution and the usage volumes of traditional natural resources, more and more attention is paid to the use of environmentally friendly materials. Scientists of the world are working on acquiring new materials and improving the characteristics of the existent ones. New material fusions have been created and as a result composite materials with better or even completely different characteristics have been developed. During the production of the new generation source materials and equipment, a lot of attention is paid to the environmental impact of the process and to the recycling of the products. More than 100 years ago the invention of the plywood peeling and later also carving hardware revolutionized the woodworking sector. It opened the way to the production of a new material – plywood. With the ever growing usage of plywood in the national economy, the necessity arises to increase its physically mechanical characteristics and reduce production costs. Plywood with different coatings that change the mechanical characteristics of its surface has already been developed and introduced into production. One of the ways for development is to create composite materials – supplement plywood with hemp fibre fabric. The paper reflects the results of a research on a five-layer birch plywood composite material with hemp fabric reinforcement. There is a research on the optimum proportions of the glues, gluing parameters and their influence on the final product. Tests of the physically mechanical characteristics of the material patterns have been carried out and the acquired results have been processed and compared with the existent standards. The average strength index of the material has increased by 13.2%, and the guaranteed index has increased by 42.5% compared to the control patterns. A new use for the hemp fibre has been found. As a result a new, environmentally friendly material with high physically mechanical characteristics has been developed, which and can be used to produce plywood and bent glued wood constructions.**

Index Terms— **Hemp fiber; Plywood composite material; Characterization.**

I. INTRODUCTION

The modern developing society has faced the problem of ever increasing demands for the energy intensity of production and the limited potentialities of meeting them. In recent years, the worldwide demand for the renewable sources of natural resources is growing, governed by the energy saving and environmentally friendly technologies of their production, and the feasibility of their processing to environmentally friendly, biodegradable materials with a high added value due to the decrease of material and energy costs. Particular attention is being given to materials from natural fibres and their wide application in various branches of industry. One of such resources is hemp, which is rather profitable, requires much less amounts of artificial fertilisers than other cultures, has a favourable effect on the agroecosystem, improves the soil structure, and inhibits weeds, pests and diseases. Hemp fibre is one of the strongest natural fibres and its characteristics (high tensile strength, wet state strength, etc.) make it technically feasible for the production of different industrial products. Hence, hemp is regarded as one of the most promising sources of renewable resources as a component for producing a wide range of manufactured goods.

For processing hemp products (fibres and stems) into innovative products, universal studies on the sorts cultivated in local climatic and soil conditions, and their comparative analysis are required. It is shown that the mechanical characteristics of hemp fibres depend on both the sort and the growing conditions (Freivalde et al. 2010). In recent years, crops of hemp for technical purposes are receiving wide acceptance worldwide; especially inexpensive this production is in China, Bangladesh and India (Small et al. 2002). Hemp crops become popular also in the south of the USA and Canada (Small et al. 2002, Ehrensing 1998). In Bolton's (1995) opinion, hemp, so that to become competitive, should meet the following requirements: the material should be produced in sufficiently large volumes; the price should be low enough; the fibre characteristics should be stable within the whole service life, and the used technologies of treating the new raw material should be reasonable and approbated for its processing. When selecting technical sorts of hemp, in contrast to narcotic strains, an important factor is the substantial volume, occupied by the lignified part of the cross-section of the stem of the latter (Meijer 1995). One of the reasons for the wide use of hemp fibre is its length. The length of the primary bast fibres in bark reaches 5-40 mm, which are joined in fibre bundles and can reach the length of 1-5 m (average length of secondary bast fibres is about 2 mm). For example, hardwood fibres are much shorter, namely, about 0.55 mm and are connected with a considerable content of lignin (Bolton, 1995). Hemp fibre can potentially substitute other fibres of plant origin, but cannot compete with minerals from glass fibre, as well as aluminium and other metals. 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).

II. Materials and Methods

In the present study, searches for solving the problem of enhancing the strength of glued birch five-layer plywood, reinforced with a hemp textile, are considered. One of the methods is to reinforce the glued plywood with separate hemp fibres and a hemp textile. To optimise the conditions of the formation of such a composite material, the multi-factor analysis was employed (Tables 1 and 2).

Table 1 Factors, influencing the physico-mechanical characteristics of plywood

	Constant factors		
Designations	Name	Unit of measurement	Value
x6	Moisture of veneer	%	8
x7	Relative humidity of air	%	49
x8	Room temperature	°C	22
x9	Wood density	kg/m³	617
x10	Amount of the binder	g/m²	170
x11	Viscosity of the binder at 24˚C	mPa·s	5842.2
x12	Number of the veneer layers	pieces	5

x13	Veneer thickness	mm	1.5
x14	Veneer sheets' orientation	I – I – I	1
x15	Holding time upon gluing	min/mm	5.42
x16	Gluing temperature	°C	90

As a binder, a mixture of phenol-formaldehyde resin and polyvinyl acetate glue PVA was used. The variation levels of the variable factors were chosen based on the earlier experiment.

Table 2 Factors, influencing the physico-mechanical characteristics of plywood

	Variable factors		Value of the
Designation	Name	Unit of measurement	"0" level
x1	Pressing pressure	MPa	1.5
x2	Hemp mesh cell size	mm	8
x3	Hemp mesh tension	N	20
x4	Mass of the binder (per 100 g of resin)	g	20
x5	Mass of PVA per 100 g of resin	g	12

The experiment was planned as a multi-factor experiment with 5 variables (Table 3).

Table 3 Intervals and levels of the variation factors

	Factors		Variation levels			Inter-vals
Designation	Name	Unit of measurement	-1	0	1	
x1	Pressing pressure	MPa	1.3	1.5	1.7	0.2
x2	Hemp mesh cell size	mm	4	8	12	4
x3	Hemp mesh tension	N	10	20	30	10
x4	Mass of the binder (per 100 g of resin)	g	17	20	23	3
x5	Mass of PVA per 100 g of resin	g	10	12	14	2

For each group of the variable factor of the experiment, 10 samples 200 mm in length and 50 mm in width were made, in which the direction of the fibres of the veneer of the outer layers of the sheets was parallel to the sample's length, and the same number of samples, in which the direction of the fibres of the veneer of the outer layers of the sheets was perpendicular to the length of the sample. For all samples, birch rotary cut veneer with a width of 1.5 mm was used. To make experimental samples, a bicomponent mixture of the resin "Casco Adhesives' UF 1274" with the hardener 2545 and polyvinyl acetate glue D3, group "Tempo 303" were used. Based on the experimental data, a mathematical variation modelling of the intervals of variable factors was performed.

III. Discussion

Values of coefficients were calculated, and the the regression equation was set up: Y= 95.94 – 3.26*x1 – 1.71*x2 – 1.99*x3 + 2.61*x4 + 1.81*x5, from which it can be seen that, with decreasing factors x1, x2 and x3 and with increasing factors x4 and x5, it is possible to improve the deformation indices of the hemp fibre reinforced birch plywood. Levels of significance coefficients are calculated, and the upper and lower limits of the theoretically permissible variables of the variation factors are calculated. The calculations show that, at the described conditions of the experiment, the average index of the value of the ultimate strength in statistical bending σ_{bend} for such a material increases by 13.2 %.

IV. CONCLUSIONS

It is shown that, based on reinforcing birch five-layer plywood with hemp textile (mesh) with the cell size 8 mm, it is possible to produce an environmentally friendly composite material. Optimal ratios of the components and the binder for producing a composite material - hemp textile reinforced birch plywood with enhanced mechanical characteristics in bending σ_{bend} up to 13.2 % and modulus of elasticity up to 10.3 % have been found. The given composite material can be used for the production of curved-glued goods from plywood.

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