Method of increasing percentage of raw wood materials in plywood production

S A Ugryumov¹, N A Vokhmyanin¹, S I Zatenko², S V Spiridonov¹, M B Taraban²

¹ Institute of technological machines and forest transport, Saint-Petersburg State Forest Technical University, 5 Institutsky lane, Saint-Petersburg 194021, Russian Federation
² Institute of forest business and innovation, Saint-Petersburg State Forest Technical University, 5 Institutsky lane, Saint-Petersburg 194021, Russian Federation

* Corresponding email: ugr-s@yandex.ru

Abstract. The article deals with the issue of increasing efficiency of plywood production by recycling waste from format plywood trimming. The study proposes manufacturing a composite material with outer layers of full-format peeled veneer and an inner layer based on slats from format trimming of plywood installed on the edge with a different gap. Results of physical and mechanical properties testing of proposed composite material show that using of the slats from plywood trimming allows forming lightweight material holding sufficient strength. Due to return use of plywood production waste, manufacturing proposed composite material reduces total material consumption, which provides cheaper products with effective waste disposal.

1. Introduction

Plywood and plywood products made on the basis of wood shelled veneer and synthetic adhesive compositions are one of the main structural materials for construction, auto, wagon, container production, furniture production and other industries [1]. Plywood production is an integral part in the system of integrated wood processing, and this is typical not only for Russian industry, but also worldwide. Production and consumption of plywood increase annually, which requires increasing wood harvesting. Deficit of wood raw materials noted at the end of the twentieth century is still in present. The main direction of covering this deficit lays in deep processing of wood, including processing of secondary wood resources and waste products. Development of methods to reduce the resource consumption in plywood production is a part of a valuable multifaceted work to create new types of materials with controlled properties depending on intended areas of further usage, with improved utilization and processing of wood raw material and return using of the woodworking waste.

At plywood enterprises, in the process of preparation of wood raw materials, peeling and processing of veneer, gluing and processing of finished products, woodworking waste in form of scraps of various sizes or small particles is formed inevitably. The amount of the waste depends on the level of organization of production and its equipment, but the share of the waste in any case is quite large and is up to 50% or more relative to initial volume of timber received by an enterprise [2]. In modern technological processes of plywood production, a significant part of resulting waste is processed in the main production cycle or sent to processing particle boards and other pressed
materials production for structural purposes. Often, waste from debarking of raw wood materials, veneer-flaw, substandard lump veneer and other waste are sent to combustion in production furnaces to obtain heat energy used in the main production cycle, e.g. for heating the pools during hydrothermal wood processing, drying the veneer, heating heat carriers of the presses other purposes [3]. However, a more efficient use of the waste is its processing into materials with a certain added value. So, in recent years, many plywood enterprises organize workshops for fuel pellets and briquettes production, which allows processing significant share of the waste and receiving additional profits.

When cutting plywood in a format required, lump waste in form of slats, which length and thickness corresponds to the size of the cut sheet of plywood, and the width ranges from 2.5 to 4.0 cm, is formed. The volume of such waste is from 7 to 11% of the volume of unedged plywood, depending on the format of the plywood produced and specified allowance for trimming. Recycling and disposal of such waste is difficult. Burning is not allowed due to emission of toxic substances from the decay of the cured adhesives during combustion. Therefore, the waste is usually grinded into wood chips used in production of particle boards. It should be borne in mind that presence of adhesive layers and high density of format scraps negatively affect processes of wetting, spreading and absorption of glue, as well as compaction and contact of the particles in piezothermic treatment process, which leads to deterioration of particle boards strength. Therefore, the chips obtained from the format scraps of plywood are used only as an additive to the main raw material. In the absence of plate production in transport accessibility from plywood production, the problem of processing and disposal of these wastes is an urgent task.

There are various technological methods of using wood waste, including waste plywood production and composite wooden materials. For example, production of flat lattice panels based on woodworking processing industries waste with facing layers of cardboard or other sheet materials can significantly reduce material consumption while reducing density of the material [4]. However, the strength of the material is insufficient due to the low density and the presence of voids in the structure.

There has been developed a method of manufacturing a laminated wooden plate material, consisting in forming the inner layer and strips from lumpy wood waste. The veneer or scraps are used laying edge-to-edge or with an offset in width. [5]. This design allows the waste to be recycled while reducing the density and material capacity in the products, but its performance properties are low due to heterogeneity of the inner layer structure, which results in dissection and cracking of the material, especially in alternating temperature and humidity conditions.

In recent years, lightweight materials, such as particle boards "DendroLight", with an inner layer of woodworking waste, connected to a rack or lattice structure, are produced and used in construction and furniture production [6]. Such boards can be made of almost any thickness, have a low density, but their strength and ability to withstand shock loads are insufficient.

A prospective direction for return use of format plywood trimming waste is production of composite materials, in the inner layer of which plywood trimming slats are used, and the outer layers consist of one or more layers of veneer [7]. In the framework of this study, the structural features of the formation of such materials are analysed and their physical and mechanical properties are experimentally evaluated.

2. Methods and materials

Slats from plywood trimming should be re-cut to form a uniform width. In this study, slats with nominal widths of 10 and 20 mm were used. From the structural point of view, the composite material is formed with outer layers of mutually perpendicular sheets of format peeled veneer and inner layers formed by installing the slats obtained from the trimming on their edge, laying with an offset.

Urea-formaldehyde glue based on KF-G resin and acid curing catalyst was used as the main binder in this material, taking into account adhesive properties of the glue [8, 9].

To form the outer layers, shelled birch veneer of grade I was used with a nominal thickness of 1.5 mm, slats with a thickness and width of 10 mm. Nominal thickness of the finished composite material was 14 mm.
The assembly of plywood packages consisted in selection and laying the veneer sheets and slats of the inner layer with different distances between them in accordance with a given design. The glue was applied on both sides of the inner (even) layers of veneer and on the end surface of the rails. In addition to these samples, plywood samples were made from format veneer as a standard.

Hot pressing of the collected packages was carried out with a laboratory hydraulic press at the modes recommended by technical literature [10]:
- pressing temperature 125°C,
- specific pressing pressure (based on the total area of contact of the surfaces of the rails with the veneer) 2 MPa,
- moulding time under pressure 7 min.
Cutting on the samples for testing was carried out in a day after unloading.

The bending strength was estimated according to GOST 9625-2013, the tensile strength when chipping on the adhesive layer was estimated according to GOST 9624-2009 [11, 12].
To assess the bending strength along the fibers of the outer layers, samples were made with a width of 50 to 60 mm in such a way that in the cross section there were at least two rails in the inner layer. The bending strength across the fibers of the outer layers was evaluated on samples with a thickness of 250 mm and a width of 50 mm.

3. Results and Discussion
At the first stage of research, a composite material with an inner layer of vertically mounted rails with a displacement was manufactured and tested, with the displacement varying from 0 to 20 mm. The assembly scheme of the material is presented in figure 1. Figure 2 shows appearance of a composite material with an inner layer of vertically mounted offset rails.

**Figure 1.** Composite material construction: 1 - veneer layer with longitudinal direction of fibers; 2 - veneer layer with transverse direction of fibers; 3 - plywood trim strips; 4 - adhesive layers.

**Figure 2.** Appearance of plywood panel with an inner layer of vertically mounted slats.
Table 1 presents summary physical and mechanical characteristics of the material.

**Table 1. Physical and mechanical properties of the composite material.**

| Material                        | Distance between rails, mm | Density, kg/m³ | Tensile strength at bending, MPa | Breaking strength, MPa |
|---------------------------------|----------------------------|----------------|---------------------------------|------------------------|
| General purpose plywood         | -                          | 723            | 110.6                           | 69.2                   |
|                                 |                            |                |                                 | 4.16                   |
|                                 |                            |                |                                 | 2.21                   |
| Composite material with inner layer of slats | 0                          | 678            | 102.1                           | 37.9                   |
|                                 |                            |                |                                 | 2.74                   |
|                                 |                            |                |                                 | 1.71                   |
|                                 | 5                          | 521            | 62.5                            | 25.8                   |
|                                 |                            |                |                                 | 2.52                   |
|                                 |                            |                |                                 | 1.69                   |
|                                 | 10                         | 458            | 43.2                            | 18.6                   |
|                                 |                            |                |                                 | 2.51                   |
|                                 |                            |                |                                 | 1.70                   |
|                                 | 15                         | 417            | 31.9                            | 13.8                   |
|                                 |                            |                |                                 | 2.51                   |
|                                 |                            |                |                                 | 1.65                   |
|                                 | 20                         | 388            | 27.8                            | 11.2                   |
|                                 |                            |                |                                 | 2.41                   |
|                                 |                            |                |                                 | 1.61                   |

Analysis of the obtained results showed that composite plywood with inner layers of slats from format plywood trimming has lower strength compared to general purpose plywood, which is explained by the presence of voids in the inner layer and generally lower density of the material. However, the bending strength along the fibers of all of the samples exceeds its normalized value according to GOST 3916.1-96. The peculiarity of this material is its low density and possibility of recycling plywood production waste.

When forming the strips along the fibers direction in the outer layers of plywood, the greatest strength is achieved in the longitudinal direction of the composite material, but the strength in the perpendicular direction is significantly less. Reaching the equal strength in the format of the composite material is possible by laying the rails in the inner layer in a mutually perpendicular direction. Technologically, this can be achieved by assembling the lattice structure, installing the slats in pre-cut adjacent grooves (figure 3). Slats can be assembled into a grid at intervals of different sizes depending on the required strength of the material and the intended areas of its further use.

Outside the lattice layer, several layers of full-length peeled veneer are glued, forming a composite material. Figure 4 shows appearance of the composite material produced by this method.

![Figure 3](image3.png)  
**Figure 3.** Scheme of the composite material lattice of the inner layer: 1 - longitudinal veneer; 2 - transverse veneer; 3 - lattice of slats

![Figure 4](image4.png)  
**Figure 4.** Appearance of the composite material lattice of the inner layer

Table 2 presents summary physical and mechanical properties of the composite material with the inner layer of the lattice structure.
Table 2. Physical and mechanical properties of the composite material with the inner layer of the lattice structure.

| Material                                      | Distance between rails, mm | Density, kg/m³ | Tensile strength at bending, MPa | Breaking strength, MPa |
|-----------------------------------------------|-----------------------------|----------------|---------------------------------|------------------------|
| Composite material with ribs and inserts      | 15                          | 442            | 52.7                            | 2.51                   |
| Composite material with lattice construction  | 15                          | 508            | 40                              | 2.62                   |

The analysis of the results showed that the bending strength along the fibers of the composite material of proposed design exceeds the normalized value according to GOST 3916.1-96, an is equal to 25 MPa. The use of the lattice in the inner layer allows to increase the strength of the composite material in the transverse direction.

4. Conclusion

The proposed designs allow to form lightweight composite materials with sufficiently high physical and mechanical properties. The materials can be successfully used as flooring and cladding materials, as well as slab materials in various structures manufacture. Recycling the waste of plywood production reduces material consumption and provides more efficient way to use the waste, while decreasing the number of sheets of peeled veneer with the adhesive, results in reducing adhesive consumption per unit of production.

References

[1] Lukash A 2014 The new technology of laminated materials [in Russian – Tekhnologiya novyh kleeyh materialov] (Saint-Petersburg : Lany) p 304
[2] Volynsky V 2003 Technology of glued materials [in Russian – Tekhnologiya kleeyh materialov] (Arkhangelsk : Arkhangelsk State Technical University) p 280
[3] Lyubov V, Popov A, Ivut A, Kondakov S and Sedleetsky N 2016 Increasing efficiency of energy use of plywood production waste Bulletin of Cherepovets state University [Vestnik Cherepoveckogo gosudarstvennogo universiteta – in Russian] 4(73) pp 28-32
[4] Lucash A, Shitikova A and Cherenkov M 2014 Patent 143493 RU Honeycomb wall panel from wood-based materials p 4
[5] Malicki A 2016 Patent 159337 RU Structural panel p 12
[6] Nikolaev A 2010 Dendrolight Plates are environmentally friendly, durable, easy and profitable Equipment and tools for professionals [Oborudovanie i instrument dlya professionalov – in Russian] 1 pp 20-22
[7] Mitrofanov V 2018 Rational use of waste from format trimming of plywood Russia and the world: national security, challenges and prospects [Rossiya i mir: nacional'naya bezopasnost', yzyvov i perspektivy: materialy mezhdunarodnoy mezhdisciplinarnoy nauchnoy konferencii – in Russian] 2 pp 135-136
[8] Malysheva G 2005 Physical chemistry of adhesive materials Materials Science [Materialovedenie – in Russian] 6 pp 38-40
[9] Petrova A and Malysheva G 2017 Adhesives, adhesive binders and adhesive prepregs [in Russian – Klei, kleeye svyazuyushchie i kleevye prepregi] (Moscow : Russian Research institute of Aviation Materials) p 472
[10] Volkov A 2010 Handbook of plywood [in Russian – Spravochnik fanershchika] (Saint-Petersburg : Publishing house of Polytechnic university) p 486
[11] GOST RF 9625-2013 Laminated glued wood. Methods for determination of ultimate and modulus
of elasticity in static bending. 2013 (Standartinform, Moscow)

[12] GOST RF 9624-2009 Laminated glued wood. Method for determination of shear strength. 2009 (Standartinform, Moscow)