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UTILIZATION OF PEELER CORES FOR PRODUCING BEAMS WITH HOLLOW CROSS-SECTION

This study presents an opportunity to utilize peeler cores derived from poplar wood for the production of hollow beams. In this way, final products to meet the needs of consumers can be obtained. The proposed novel methods for sawing and gluing the produced materials allow rational application of the waste raw material in the plywood manufacturing. Another advantage in this case is that products with a square cross-section with dimensions close to or corresponding to the standard ones are obtained from small-diameter round wood. The raw material used to receive the proposed hollow beams is up to 33% less than a conventional beam with the same dimensions. The manufactured products are lighter and with a significantly stable cross-sectional shape, compared to natural wood beams with the same dimensions. Sawing the peeler cores and obtaining materials with a triangular and trapezoidal cross-section helps to achieve volume yields from 60.6% to 71.1% of the raw material initial volume.

Keywords: *Populus* sp., hollow beams, small-diameter logs, veneer, engineered wood

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Introduction

The production of solid wood materials depends mainly on the market requirements, quality of the raw material and sawing method. With the increasingly intensive reduction the diameter of the raw material resources, it is necessary to look for opportunities for rational utilization of wood waste, which inevitably is obtained in the process of developing the veneer logs. The application of peeler cores from plywood production for products sought by consumers will contribute to higher economic results. Therefore, the approach to sawing the raw material is of particular importance, mainly in small-diameter assortments. This study proposes a novel method for sawing of peeler cores from plywood production, as well as technology for obtaining of beams with a hollow cross-section.

One of the largest manufacturers of plywood in Bulgaria is "Welde Bulgaria" AD company, Troyan. Poplar, beech and linden wood are mainly used as a raw material for developed veneer. Of the listed tree species, the largest share in the production of plywood is poplar. The properties of poplar wood are well known. In general, *Populus* is fast growing species, and the wood is easy to process, light, soft, elastic [Castro and Fragnelli 2006; Bayatkashkoli et al. 2016; Van Acker et al. 2016]. The poplar wood has relatively low density (300–390 $kg.m^{-3}$) and diffuse porous structure. The poplars possess very good machining, bonding, and finishing properties. In addition, their wood is very suitable for a variety of conversion technologies, from sawing to veneer peeling and flaking. The relative density of a wood species determines the ideal peeling and flaking temperatures. Consequently, poplar requires little or no preconditioning because of both low density and high green moisture content. The low wood density is a big advantage in the manufacturing of composite panels [Balatinecz and Kretschmann 2001]. In addition, it possesses mechanical properties comparable to some coniferous tree species [Shahverdi et al. 2012; Sinković et al. 2017].

The quality and diameter of the logs entering the production line is of particular importance, as the quality and yield of veneer depends on them, as well as the percentage of peeler cores [Tenorio et al. 2011; Huang et al. 2012; Olufemi 2012; Kawalerczyk et al. 2019; Więckowska and Grzegorzewska 2019]. In the process of developing the logs and extracting the veneer sheet, a significant amount of wood waste, veneer pieces and peeler cores is inevitably obtained.

The peeler cores are waste biomass after development of the veneer sheet. Several studies have shown different possibilities for application of peeler cores [Wolfe et al. 2000; Ross et al. 2005; Torgovnikov 2014; Darzi et al. 2020]. Possible ways for their more rational utilization in products that meet the needs of consumers are sought. There is a considerable amount of juvenile wood in the central part of the logs, as well as in small-diameter ones [Yang 1994; Zobel 1998]. It is known that the presence of a large percentage of juvenile wood greatly reduces the physical and mechanical properties of the resulting products. Due to these factors, this wood is not particularly preferred in the production of finished products. The application of peeler cores in our industry is most often for the production of pallets, less often packaging (Fig. 1), as well as their cutting into technological chips used as a raw material in other industries.

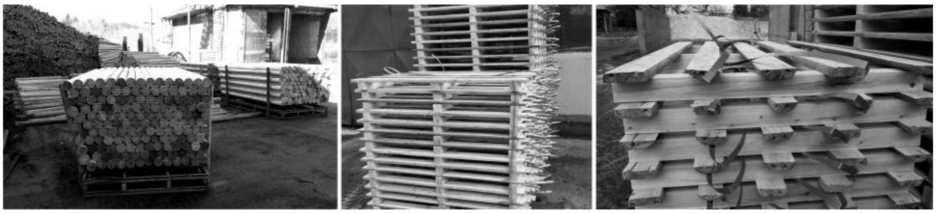


Fig. 1. Utilization of peeler cores for pallets production

The total volume of peeler cores per month can exceed 120 m^3 of wood depending on the production capacity of the enterprise. In Bulgarian industry, the utilization of peeler cores is mainly in the form of assortments with a square cross-section or thin boards with lengths equal to the lengths of the developed sections. In the presented case (Fig. 1) a part of the peeler cores is cut into materials with a square cross-section for the production of thin beams for pallets with cross-section dimensions of 70 × 70 mm. The other part of the peeler cores is cut into three materials and thin boards with a thickness of 28 mm are obtained. In many cases, the shape of their cross-section is incorrect.

Different methods have been used in order to achieve high volume yields and optimize the sawing of small-diameter round materials [Levinsky and Levinskaya 2002; Heräjärvi et al. 2004; Hamner et al. 2006; Rongrong et al. 2015; McGavin et al. 2021]. The considered methods for cutting small-diameter round wood show limited use of the obtained materials. The final products (beams and boards) are very small and also with incorrect cross-sectional dimensions.

Some researchers have studied the strength properties of beams with hollow cross-section [Shang et al. 2018; Zhang et al. 2019].

The aim of this research was to evaluate options for more rational sawing and utilization of peeler cores. The same are used in the manufacture of glued beams with hollow cross-section for receiving finished products sought by consumers. The obtained results are an important basis and prerequisite for determining the optimal methods for cutting both peeler cores and small-diameter logs. Opportunities for obtaining glued products with square cross-sections at lower weight compared to assortments with the same dimensions of natural wood will be sought. The resulting products will be significantly strong and with a stable cross-sectional shape.

Materials and methods

The raw material of this study consisted of wood peeler cores (*Populus* sp.) that were supplied by "Welde Bulgaria" AD company, Troyan. The dimensional characteristics and the volume of the specimens were measured.

According to approximate data of "Welde Bulgaria" AD company, more than 2000 m^3 of wood in the form of peeler cores is discarded all year round. This represents a serious raw material potential for rational utilization of this waste wood. In the present study, poplar wood peeler cores was used, as the company mainly processes this wood species in the production of plywood. The method for sawing the peeler cores and obtaining hollow beams can be used for peeler cores of other tree species, as well as for small-diameter round wood.

The applied methods for cutting and utilization of peeler cores were compared with those used in practice. Volume yields for different sawing methods have been calculated and the most optimal ones for the needs of the research have been proposed. Several beams were glued in laboratory conditions in order to determine whether the method is applicable in practical conditions.

The initially provided experimental peeler cores were based on jointer. In this way a basis for their subsequent cutting on a circular machine is created.

In the present study, four peeler cores of each option with a diameter of 100 mm and a length of 1.40 m were used to obtain hollow beams. They were cut according to the accepted methods shown in Fig. 2 and Fig. 3. The resulting materials were left to air dry for several months until an equilibrium humidity of 20% was reached.

According to the proposed Option I, four unedged boards were obtained from one peeler core (Fig. 2-1). After cutting, the details were arranged in figures for atmospheric drying lasting 3-4 months until their water content dropped below 20%. The detailed figures were weighted on top in order to reduce warping and twisting. After that, the assortments were dried in laboratory convection dryer to a final humidity of 8%.

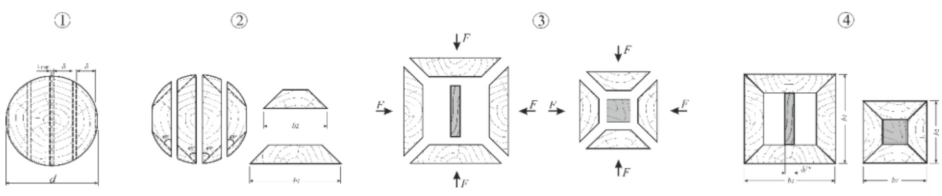


Fig. 2. Option I

The same were processed in jointer and planer in order to obtain accurate dimensions in thickness. The materials were cut at an angle of 45°, using a circular machine with possibility of tilting the shaft. As a result, trapezoidal cross-sectional boards were produced (Fig. 2-2). In this sawing approach, the volume yield (*R*) of trapezoidal cross-section materials reach 71.1 %.

After the final processing of the obtained assortments, they were combined and glued by hand with a roller in laboratory conditions (Fig. 2-3). The gluing was carried out only on the edged part of the details.

In case of subsequent mechanical loading of these products, there is a high probability of their destruction in the area of the glued contact surface. There is a possibility for creep in the wood at the zone of the adhesive joint. Therefore, in order to increase the mechanical strength and stability of the resulting beams, one or more girders in the hollow part can be applied. These girders can be oriented longitudinally or transversely in the direction of the wood fibers, depending on the direction of loading of the beams (Fig. 2-3 and Fig. 2-4). In order to decrease the amount of wood raw material applied in the production of this type of hollow beams, the thickness of the beams can be reduced to δ / 2. With regard to the strength properties of hollow beams in the transverse arrangement of the girders (Fig. 2-4), the number and distance between them must be established experimentally.

Polyvinyl acetate (PVAc) adhesive Jowacoll 103.06 produced by Jowat was applied, while the amount of applied glue was 200-220 g.m^{-2}. The gluing pressure was 0.8 MPa, and the time required to cure the test specimens was 3 hours. The combination and gluing of the manufactured elements was achieved with laboratory clamps and presses. After final bonding, all beams were conditioned for one week. In this way, from two peeler cores, two beams with dimensions $b_1 \times b_1$ and $b_2 \times b_2$ are obtained. Depending on the performance of these products, other adhesives can be used [Réh et al. 2019; Antov et al. 2020; Réh et al. 2021; Yusof et al. 2021].

At calculating the consumption of wood used in the production of this type of hollow beams, values up to 33% lower are found, compared to a beam made of natural wood with the same dimensions. It is important to note that despite the small diameter of the peeler cores, one of the hollow beams (Fig. 2-3) had a cross-section close to that of a beam with standard dimensions – 100 × 100 mm [BDS 427: 1990]. Regarding the length of the final product, the materials in the production of hollow beams can be extended by finger-joint splicing of the lamellas.

Figure 3 illustrates Option II for sawing of the peeler cores and gluing of a beam with hollow cross-section. According to the presented method (Option II), when cutting one peeler core, two semicircles were obtained (Fig. 3-1).

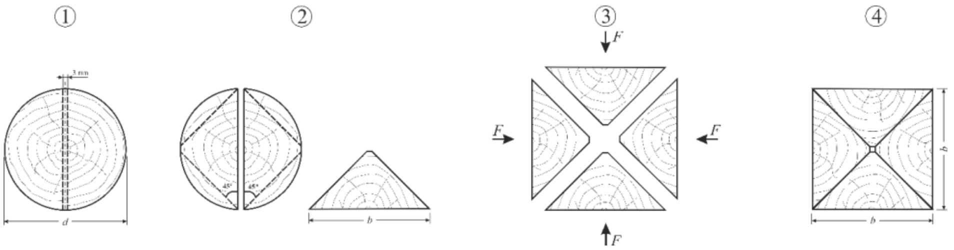


Fig. 3. Option II

The technology for their drying is the same as for Option I. After reaching a final humidity of 8%, the semicircles were edged at an angle of 45°. In this way, segments with a triangular cross-section were formed (Fig. 3-2). The resulting details were oriented and combined as shown in Figures 3-3. Gluing was carried out only on the beveled part with a roller. After pressing with laboratory presses and clamps, a beam with dimensions: b x b was obtained (Fig. 3-4).

This type of glued beam is expected to have greater bending strength than natural wood, as well as resistance to twisting and distortion. The utilization of the raw material in quantitative terms reaches 60.6% (*R*).

As in the previous proposed Option I, the desired length of the products can be realized by finger-joint splicing.

The accepted methods for sawing the peeler cores and subsequent gluing of the lamellas in order to obtain beams with a hollow cross-section were applied in laboratory conditions (Fig. 4).

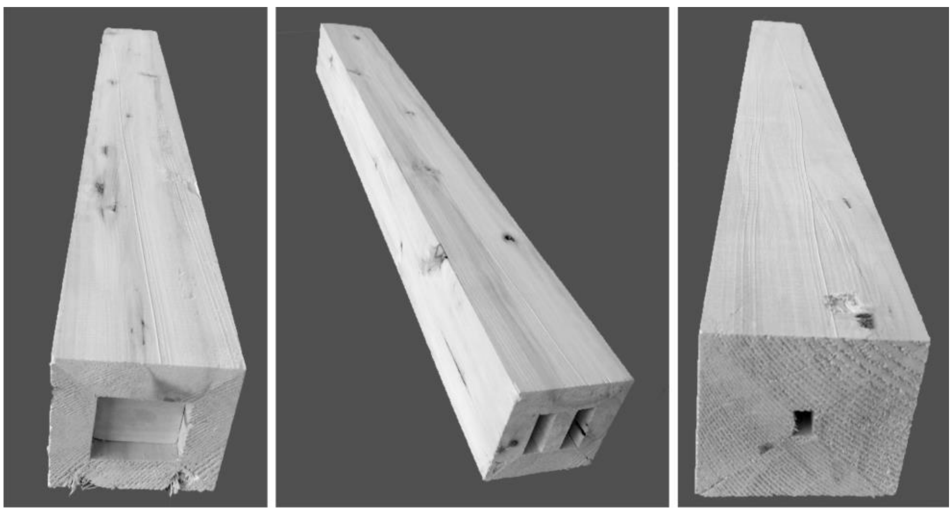


Fig.4. Glued beams with a hollow cross-section

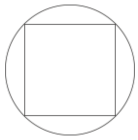
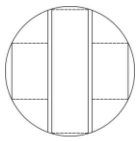
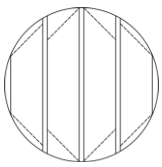
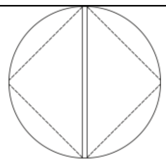
The physical and mechanical processing of the obtained materials at an average diameter of approximately 100 mm was carried out. Two hollow beams with cross-sectional dimensions: $b_1 \approx 95 \times 95$ mm and $b_2 \approx 79 \times 79$ mm were obtained from two peeler cores. The thickness of the boards was $\delta \approx 20$ mm. In Option II, one beam was obtained from two peeler cores, but with a cross-sectional size $b \approx 95 \times 95$ mm. With an initial cross-sectional diameter of more than 100 mm, a beam with a standard cross-sectional size of 100 × 100 mm will be easily formed.

Results and discussion

In the process of veneer development, a peeler cores with a final diameter is inevitably obtained, depending on the available technology of the enterprise. Their processing is not very rational, as the peeler cores ones are used mainly in the form of: pallets (with an irregular shape of the cross-sections of the boards), packaging, technological fevers, raw material for combustion, etc.

Due to the factors listed above and with the intensive reduction of raw material resources, it is necessary to look for opportunities for more reasonable application of this waste raw material. It is also necessary to offer options for obtaining materials and products that meet the needs of consumers. Moreover, methods for more optimal sawing and production of glued wood products with desired physical and mechanical properties should be proposed. These products must be produced at a lower cost of raw materials and labor, have a stable cross-sectional shape and lower weight compared to natural wood with the appropriate dimensions. The results of peeler cores sawing by several methods presented in table 1 clearly show that the difference in volume yields is insignificant (R = 60.6%- 71.1%).

Table 1. Volume yields at different methods of peeler cores sawing

№	Sawing method	Diameter *d* (mm)	Sections of the materials δ/b (mm)	Volume of the peeler cores V (m^3)	Volume of the materials v (m^3)	Volume yield (%)	Mean yield (%)
1		99	69/69	0.01539	0.00952	61.9	61.8
		102	71/71	0.01633	0.01008	61.7	
2		100	28/42; 28/95; 28/42	0.01570	0.01002	63.8	63.7
		101	28/43; 28/96; 28/43	0.01602	0.01019	63.6	
3		98	21/70; 21/97; 21/97; 21/70	0.01508	0.01054	69.9	71.1
		101	21/80; 21/100; 21/100; 21/80	0.01602	0.01159	72.4	
4		100	99	0.01570	0.00950	60.5	60.6
		102	101	0.01633	0.00990	60.6	

In the first two sawing methods, which are most often used in the industry for the production of pallets from peeler cores, the volume yield ranges from 61.8% to 63.7%. In the first method, one thin beam with an average cross-sectional size of 70/70 mm is obtained from each peeler core. In the second method, three thin boards with a thickness of 28 mm are obtained. Subsequent cutting results in materials with very small widths - from 42 mm to 96 mm, respectively. For this reason, they most often remain with an irregular cross-sectional shape. In both methods, very small materials are produced, which limits their consumption.

The utilization of the raw material in quantitative terms at third and fourth sawing methods (Option I and Option II) ranges from 60.6% to 71.1%. In these cases, thin boards with a thickness of 21 mm or those with an irregular cross-sectional shape are again obtained. This creates a prerequisite for their rational use in the production of hollow beams. Products with dimensions close to the standard ones are received.

The dimensions of the beams obtained in laboratory conditions are slightly smaller than the theoretically calculated ones. This difference is due to the loss of wood at inaccurate centering during processing, as well as curvatures that occur after drying the materials. Also, after gluing the beams went through final operations. The utilization of the peeler cores with the application of the described methods is significantly rational. It is possible to obtain products with a square cross-section, stable shape, without significant distortions or twists, as well as with expected dimensions according to the needs of the consumers.

The raw material used for the production of plywood is with very high quality, which leads to the absence or maximum limitation of defects in the wood. The area from which the peeler cores are obtained is in the approximately geometric center of the logs, which is also a factor in the absence of knots and other defects, in addition to the presence of a core and an juvenile wood.

The proposed methods produce beams with significantly larger end cross-sections in comparison to traditional sawing methods for the production of beams. The consumption of wood in the manufacturing of this type of products is up to 33% lower than a natural wood beam. This type of beams will be lighter and with a stable cross-sectional shape due to the presence of girders in the hollow part (Option I). The proposed Option II is particularly suitable for peeler cores and small-diameter logs with diameter more than 110 mm. In addition, beams with cross-sections meeting the standards will be obtained. Also, this is impossible to achieve with a traditional sawing method using logs of this diameter.

Conclusions

Following conclusions were made based on the results of the present study:

1. The proposed novel sawing methods aim maximum utilization of the small-diameter round wood volume.

2. There is an opportunity for rational application of the peeler cores, which inevitably occurs during the development of veneer.

3. Methods for obtaining a product with a square cross-section from peeler cores at significantly high volume yields are presented.

4. The resulting hollow beams are lighter and are also formed at a wood consumption of up to 33% less compared to natural wood beams at the same dimensions.

5. There may be inconvenience and difficulty in creation the adhesive package, but with proper organization these problems can be avoided.

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List of standards

BDS 427:1990 Materials shaped from coniferous tree species. Beams, joists and slats

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