Radially sawn timber.

Gluing of star-sawn triangular profiles into form-stable products with vertical annual rings.

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Summary

A method is presented for the gluing of star-sawn triangular profiles of pine (*Pinus silvestris* L.) into form-stable wood products with vertical annual rings. The triangular profiles are free from pith and from most of the juvenile wood.

The method is based on dried and conditioned triangular profiles. Undesired defects are removed and the wood is finger-jointed into long lengths. In the finger-jointing, consideration is given to the appearance and annual ring orientation of the jointed materials. After the jointing, the triangular profiles are planed and glued into rectangular blocks with vertical annual rings. These blocks can then e.g. be used as construction beams or be sawn up into solid wood panels.

A pilot plant has been built for the manufacture of knot-free solid wood panels based on the proposed method. Results show a total volume yield of 53.8%. Three critical production stages can be distinguished: removal of knots and defects, planing, and division of blocks into boards. These three operations are together responsible for more than 93% of the total losses in the manufacture.

The removal of knots and defects meant a volume loss of 12.8%. 13% of the manufactured units were 2.1 m long without finger-jointing and free from knots and other defects. The average length of the remaining pieces used for finger-jointed units was 0.41 m.

Sternsägen - Verleimen von sterngesägten Dreikantprofilen zu formstabilen Produkten mit stehenden Jahrringen

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Diese Arbeit beschreibt eine Methode zum Verleimen von sterngesägten Dreikantprofilen aus Kifernholz zu formstabilen Produkten mit stehenden Jahrringen. Die Dreikantprofile sind frei von Mark und überwiegend auch von juvenilem Holz. Verwendet werden getrocknete und konditionierte Profile. Unerwünschte Holzfehler werden ausgeschnitten. Danach werden die Werkstücke durch Keilzinkung längs verleimt, wobei auf das Aussehen und die Ausrichtung der Jahrringe geachtet wird. Nach dem Hobeln werden diese Dreikantwerkstücke zu rechteckigen Blöcken mit stehenden Jahrringen verleimt. Die Blöcke können z.B. für Konstruktionszwecke verwendet oder zu Bretten oder Platten aufgesägt werden. Im Pilotmaßstab werden inzwischen astfreie Platten nach dieser Methode hergestellt. Insgesamt wird eine Volumenausbeute von 53,8% erzielt. Drei kritische Produktionsschritte sind dabei zu beachten: Entfernen der Äste und sonstiger Fehler, Hobeln sowie Auftrennen in Bretter. Bei diesen drei Produktionsschritten fallen über 93% des Massenverlustes an. Das Entfernen der Holzfehler führt zum Verlust von 12,8% des ursprünglichen Volumens. 13% der Werkstücke hatten eine Länge von 2,1 m (astfrei, vor dem Verleimen). Die durchschnittliche Länge der übrigen zum Verleimen verwendeten Stücke betrug 0,41 m.

1 Introduction

The function and properties of wood products are greatly influenced by the natural properties of the wood and how these are used in the product concerned. There are four main conditions which are characteristic of wood. It is an anisotropic and heterogeneous material, a material with great variability and a material with pronounced hygroscopicity. All this is related to the fact that the wood material is built up in an optimum way to meet the specific requirements of the living tree. When the log is divided into planks and boards to be used in different products, complications can arise if one does not use the available knowledge. By starting from an understanding of the properties of the wood material, it is in many cases possible to manufacture a product which meets the specific demands of different uses.

For wood, such requirements are often related to accuracy in measurements and geometry, crack-freeness and controlled movement during moisture changes. Changes in the moisture content below the fibre saturation point cause changes in shape and dimensions. The wood swells and shrinks, and this takes place mainly across the fibre direction. However, the longitudinal moisture movement of the wood can be considerable in reaction wood, juvenile wood, and in areas with severe fibre disturbances. For pine and spruce, it is usually assumed that the tangential movement is approximately twice as large as the radial movement. This means that changes in shape appear as distortions and angular changes in the cross-section if the side surfaces of the wood are not parallel with the main directions of the wood.

The importance of the annual ring orientation for moisture movement of furniture boards has been investigated by several researchers, e.g. Peck et al (1950), Selbo (1952), Perry (1953), Marian et al (1955). They state that in order to obtain a dimensionally stable furniture board, it shall be constructed of wood with vertical annual rings, i.e. the annual rings shall be largely perpendicular to the surface of the board.

Sandberg (1996a, 1997) has shown that for pine and spruce, there is a clear connection between the occurrence of cracks in wood from butt logs and the distance from the pith from which this wood has been sawn. Wood containing pith, and wood without pith where the shortest distance between the pith and the piece of wood is less than 30 mm, have considerably more cracks than wood sawn at a greater distance from the pith. Star-sawing, figure 1, is a sawing method for the production of wood with vertical annual rings which is free from pith and most of the juvenile wood (Sandberg 1996b). The yield from star-sawing consists of wood pieces with both rectangular and triangular cross-sections, all with vertical annual rings. In star-sawing, as in all radial sawing methods, the radial saw cuts cleave the knots in the length direction and a greater proportion of so-called splay knots is obtained than in through-and-through sawing and block-sawing. These knots are often unacceptable aesthetically and from a strength viewpoint, and they must be removed. Sandberg et al (1996) have mapped the knot appearance and knot frequency in star-sawn triangular profiles of pine and spruce.

In the present investigation, a method is presented for gluing together star-sawn triangular profiles into form-stable products with vertical annual rings and radial surfaces.

Fig. 1. Star-sawing, sawing pattern for producing wood with vertical annual rings

Bild 1. Sternsägen: Sägemuster zum Herstellen von Werkstücken mit stehenden Jahrringen

2 Principles for gluing triangular profiles into a block with a rectangular cross-section

The further refining of the triangular profiles takes place in five main steps:

1. Removal of unacceptable knots and other defects.
2. Finger jointing of cut units
3. Planing of triangular profiles.
4. Gluing of triangular profiles into blocks.
5. Further treatment of blocks through planing and polishing, or division of the blocks into boards or other components.

2.1 Removal of defects

Depending on what final product is to be produced, the extent of defects, e.g. knots, pitch pockets, reaction wood, allowed in the product will vary.

A large proportion of the knots found in a star-sawn triangular profile, primarily from butt logs, have proved to be less suitable for further refinement of the wood and must be removed (Sandberg et al 1996). A great advantage of a triangular profile over conventionally sawn wood when knots are to be removed, is that the knots in the triangular profile are always visible on at least one of the surfaces. This means that, after the knots which are visible on the surface have been removed, no knots remain hidden in the profile to appear in subsequent operations.

Fibre disturbances around knots reduce the strength and can cause pick-up when finger jointing and planing. In the manufacture of e.g. high-quality furniture, fibre disturbances can be troublesome because they locally give different moisture movements, and can lead to undesirable visual changes in the surface. For certain applications, it can therefore be advantageous to remove the surrounding fibre disturbance together with the knots.

2.2 Finger-jointing to obtain long lengths

Finger-jointing of a triangular profile is in principle carried out with the same methods as are used in the finger-jointing of conventional wood. Certain modifications of the equipment are necessary to adapt e.g. transport and holding devices to the triangular shape of the wood. Different finger lengths are used in the joint depending on whether the jointed wood is to be used for construction purposes or in applications where the strength of the joint does not have high

Fig. 2. The annual ring orientation in jointed boards is very important for the appearance of the joint and for moisture movements in the joint. Two pieces from the same piece of wood with vertical annual rings finger jointed (see arrow)

Bild 2. Die Orientierung der Jahrringe ist von großer Bedeutung für das Aussehen und die Feuchtebewegung der verleimten Proben. Zwei verleimte Teile (Pfeil) aus demselben Holzprofil mit stehenden Jahrringe

priority. The wood can either be jointed continuously and then cut into desired lengths or jointed directly into predetermined length modules. In each joint, one of the jointed pieces shall be displaced half the division of the fingers to avoid displacement in the joint which in subsequent treatment operations can cause volume losses.

In the jointing, one should try as far as possible to keep together the wood sections cut from the same triangular profile to obtain a homogeneous annual ring structure (pattern fitting) across the finger-joint. In order also to minimize stresses which arise in the joint because of different swelling and shrinking movements in the different directions of the wood, the annual ring orientation shall coincide in the jointed pieces (Sandberg 1996c). Figure 2 shows examples of a finger-joint where two pieces from the same wood section have been jointed after an intervening knot has been removed. In general, it is more favourable to have radial surfaces than tangential surfaces when pattern fitting is desired between the jointed pieces.

The finger-joint can be oriented in two different directions in relation to the annual ring orientation in the cross-section of the triangular profile: parallel to the tangential surface

of the triangular profile or parallel to one of its radial surfaces, figure 3. In principle, the orientation of the joint can be chosen arbitrarily if this is proven to be advantageous from a technical or aesthetic point of view. This is not discussed in greater detail here, however.

Fig. 3a and b. The direction of the finger cutting in relation to the annual ring orientation in a triangular profile. (a) Parallel with the tangential wood surface. (b) Parallel with one of the radial wood surfaces. DFJ - direction of finger-joint, AR - annual ring

Bild 3a und b. Verlauf der Zinkschnitte in bezug auf den Jahrringverlauf (AR) in einem Dreikantprofil; (a) parallel zur Tangentialfläche; (b) parallel zu einer Radialfläche, DFJ: Richtung der Keilzinkung

In jointing tests, it has been found advantageous to orient the finger-joint parallel with the surface which in subsequent treatment steps is to be glued into the construction, figure 3a. This is, on the one hand, because errors develop in the surface in the transition between the jointed wood pieces and, on the other hand, because the joint can become wave-shaped in the surface because a lack of full parallelism between the direction of the fingers and the surface leads to an uneven pressing pressure, figure 4.

The orientation of the finger-joint parallel to the surface in the triangular profile which will later be glued into the block means that the characteristic zigzag pattern of finger-joints becomes visible on the surfaces of the block, figure 5.

*Fig. 4. Waviness in a finger joint because of uneven distribution of pressure in the finger-jointing
Bild 4. Welligkeit aufgrund ungleicher Druckverteilung innerhalb der Verbindung*

*Fig. 5. Block glued from finger-jointed triangular profiles. The finger joints are oriented so that the characteristic zig-zag pattern (see arrows in figure) becomes visible in the surface of the block
Bild 5. Verleimter Block aus Dreikantprofilen. Die Zinken sind so orientiert, daß die typischen Zickzacklinien auf der Oberfläche erscheinen (Pfeile)*

2.3 Planing of triangular profiles

The finger-jointed triangular profiles are planed on all sides. In order to facilitate the subsequent pressing of the profiles into blocks and to determine the height of the glued block, one of the edges of the profile is also planed off. The triangular profile is oriented before the planing so that the surface obtained when the edge is removed can be used to achieve the correct annual ring orientation in the glued block.

2.4 Gluing of triangular profiles into blocks with a rectangular cross-section

After the planing, glue is applied to two of the four surfaces of the triangular profile and the profiles are placed together into a block with the same annual ring orientation, figure 6. The tangential surfaces of the triangular profiles are glued into the block.

Fig. 6. Block with uniform annual ring orientation glued from star-sawn triangular profiles
Bild 6. Verleimter Block aus Dreikantprofilen mit einheitlich orientiertem Jahrringverlauf

2.4.1 The choice of glue and the design of the glue joint

The choice of glue is, in the first place, dependent on the function of the final product and on the environment in which it will be used. In supporting building constructions, high demands are made on the strength and permanence of the glue joint. In these contexts, resorcinol-formaldehyde-based glues are often used. In the gluing of components for indoor use, where the loads on the glue joint are considerably less than in building constructions, PVAc-glue can be used. Depending on the production rate required in the gluing, a suitable method of curing for the glue must be chosen, e.g. pre-

heating of the glue surfaces or high-frequency curing.

A further aspect regarding the choice of glue is whether or not the glue shall give a coloured joint. With a colourless glue, an almost invisible joint is obtained. With a coloured glue, visible joints are obtained. This can be used to create aesthetically attractive patterns in the glued products.

Because of the shape of the triangular profiles, the glue joint forms an angle towards the side surfaces of the glued block, figure 6, which means that the glue surface becomes larger than if the glue joint were perpendicular to the surface. The larger glue surface means that the stress on the glue joint is reduced.

2.5 Treatment of blocks and repair of pitch pockets

The glued blocks can after gluing be either directly planed and polished or split into sheets or boards.

Pitch pockets can be very troublesome, especially in furniture and furnishings. In contrast to knots, pitch pockets can be concealed inside the triangular profile without being visible on any of its surfaces. This can mean that the pitch pockets in subsequent treatment become visible, with accompanying trouble. Discarding the product in a late refinement stage involves high costs, and repair is often the most economic solution.

The extension of the pitch pocket in the tree means that in the radial surface of the sawn wood, the pitch pocket will appear as an oblong, elliptical cavity, extending between two annual rings (Weslien 1993). Since the main extension of the pitch pocket in the radial wood surface, as opposed to the tangential surface, lies in the length direction of the wood, almost invisible repairs can be carried out. These repairs are also relatively simple and can be made rationally.

2.6 Pilot plant for further refinement of a triangular profile

A pilot plant has been built to remove defects from triangular profiles and for jointing, planing and gluing of these profiles into blocks. The aim is to create on a small scale new production technology for the gluing of a triangular profile. Properties of different products manufactured by the proposed method will also be tested.

2.6.1 Design of the pilot plant

The triangular profiles, dried to a moisture content of 8 to 10 percent, arrive from the sawmill or storage. At the crosscut saw, undesired knots and defects are removed. The defect-free pieces are then jointed together continuously to lengths of 2.10 metres in order, as far as possible, to achieve good pattern fitting between the jointed pieces. Triangular profiles without defects and which need not be jointed to attain a length of two metres are placed aside for the manufacture of products without finger joints. The

smallest length which can be used in finger jointing is 80 mm. The fingers are cut parallel to the tangential surface of the triangular profile. After being pressed together, the jointed boards are stored until the glue has hardened.

Planing takes place in a five-spindle universal planer (Weinig 17215, 1960). In order to manage the planing of the triangular profile in one step, the press and feed have been redesigned. One of the edges of the triangular profile is planed off in the top cutter. After the planing, glue is placed on two of the four surfaces of the profile and a number of profiles are placed together into a block. In the press used, only rectangular blocks can be pressed, which means that one of the profiles must be cleaved into two halves and be used as side pieces on the block. The manufactured blocks have an area of $2.10 \times 0.35 \text{ m}^2$ and the thickness can be varied between 50 and 100 millimetres, depending on the dimensions of the triangular profiles included.

The pressing of the triangular profiles into blocks differs considerably from the conventional gluing of wood with a rectangular cross-section since a large pressure is required on all of the surfaces of the block. In the prototype press used, active pressure is applied to the edge sides of the block, whilst the thickness is fixed, figure 7. Because of friction, this means that the pressure is not constant over the width direction of the block. This problem is avoided if an active pressure is applied on all surfaces of the block.

Fig. 7. Side view of a press module for gluing of blocks of a star-sawn triangular profile. The press consists of five modules which are connected by two press plates. A, B - locking device for part E that can be opened, C - beam for distributing the press force along the side surfaces of the block, D - hydraulic cylinder for lateral press force, E - part that can be opened, F - block of triangular profiles, G - upper press plate

Bild 7. Seitenansicht eines Preßmoduls zum Verleimen der Blöcke aus Dreikantprofilen. Die Presse besteht auf fünf Modulen, die durch zwei Preßplatten miteinander verbunden sind. A; B - Verschlussvorrichtung für teil E; C - Balken zum Verteilen der Preßkräfte längs der Seitenfläche; D - Hydraulikzylinder für die seitliche Preßkraft; E - verschließbare Klappe; F - Block aus Dreikantprofilen; G - obere Preßplatte

3 Volume yield in the manufacture of a pine solid wood panels from a star-sawn triangular profile

In general, board materials manufactured by gluing together pieces of wood side by side are called solid wood panels. A solid wood panel is usually manufactured from planks which are cleaved in the length direction into lamellae and are planed before being glued together into a board. This method of manufacture gives large volume losses and lamellae are glued together with different annual ring directions.

In the present study, star-sawn triangular profiles have been used for the manufacture of a knotless solid wood panel with vertical annual rings. The volume yield has been studied in the manufacture of two grades of material, one with a finger-joint and one without a joint.

3.1 Materials and methods

Star-sawn triangular profiles of saw-falling qualities have been used. The timber from which the triangular profiles were sawn came from Jämtland in Sweden and had a top diameter of between 260 and 340 mm (Holmberg et al 1996). Altogether, 7.8 m³ triangular profiles with side measurements between 60 and 110 mm have been made into solid wood panel blocks.

The wood quality for the triangular profiles used has not been determined, but the quality was estimated by determining the quality of adjacent rectangular boards from the same log. According to table 1, quality classes S1, S2 and S3 are specially adapted for star-sawn wood, but correspond roughly to the quality classes U/S, V and VI in the Nordic sorting regulations for sawn-wood products (Timber Grading Committee 1976). A detailed description of the quality classes for star-sawn wood is given by Holmberg et al. (1996). Measurements have been carried out manually at four different stages in the production:

- I. The dimensions of all incoming triangular profiles have been determined with regard to the largest and smallest side and length.
- II. After cutting, the cut pieces have been placed continuously together into modules with a length of 2.10 m.
- III. Random samples have been taken for the measurement of dimensions before and after planing.
- IV. For each finished solid wood panel block, the thickness, width and adjusted length have been determined and also the dimensions of the triangular profiles included.

The glued blocks have not been divided into finished boards in this investigation. Losses in the division of the blocks into boards have been determined on the basis of experience of values for sawcuts and polishing losses.

Table 1. Quality distribution for the rectangular boards, (Holmberg, Sandberg 1996)
Tabelle 1. Ergebnisse der Gütesortierung für rechteckig verleimte Blöcke

Top diameter interval of the logs	Proportion of the total number of sawn boards		
	Quality S1	Quality S2	Quality S3
260 - 340 mm	0.35	0.45	0.20

3.2 Results and discussion

3.2.1 Yield

The yield is shown for each part operation, i.e. the analysis of each operation is based on 100% input material to that operation, table 2. In the investigation, the length of the jointed boards has varied depending on the number of joints. A large number of joints gives a shorter length than when the number of joints is few. The losses in the final adjustment of the block length have therefore been greater than can be expected in an industrially adapted plant.

The yields of the final production stages, division and polishing, are based on the following assumptions: if the block has a height which is greater than 60 mm, three boards are produced from this block, otherwise only two boards are produced. Each sawcut is assumed to remove 3 mm and the polishing loss is assumed to be 1 mm per board surface, i.e. 2 mm/board. The losses in format cutting of the boards and in edge polishing have not been included in the yield calculations.

As shown in the table, the most demanding steps are the removal of defects, planing, division and polishing of the blocks into finished boards. Altogether, these production steps cover more than 93% of the total loss in the solid wood panel manufacture.

Table 2. The yield for each production operation and the operation's share of the total loss
Tabelle 2. Ausbeuten der einzelnen Produktionsschritte und ihr jeweiliger Anteile am Gesamtverluste

Operation	Yield (%)	Proportion of total loss (%)
Cutting	87.2	27.7
Finger jointing	98.3	3.0
Planing ¹⁾	76.6	43.5
Gluing of blocks	100	0
End cutting in blocks ²⁾	97.4	3.7
Division, polishing ³⁾	84.2	22.1
Total of all operations	53.8	100

1) The yield in the planer is based on the total loss for all planed units, cf. table 3.

2) The variation in the length of the triangular profiles included in the blocks has been much greater than can be expected in an industrial plant.

3) Yield calculation based on: blocks with a height $h \leq 60$ mm give two boards, blocks with $h > 60$ mm give three boards. Sawcut 3 mm and polishing loss 1 mm per surface.

3.2.2 Defect removal and jointing

In the defect removal stage, all knots with surrounding fibre disturbances, and defects which affect the appearance of the finished board have been removed. This gave a loss of 12.8%.

The length yield in the cutting is shown in table 3 and figure 8. Of the total incoming volume, 13% is defect-free and unjointed 2.1 m units. If shorter lengths than 2.1 m are extracted, the volume of material to be jointed decreases. This will be natural in practice.

The finger-jointing causes a loss which depends on the finger length, in this case 10 mm. In total, the finger cutting has given a loss of 1.7%. This loss can be reduced if shorter fingers are used. The shortest length of the pieces which has been jointed is 80 mm.

Fig. 8. Distribution of the number of joints per 2.1 m length
Bild 8. Verteilung der Anzahl von Verbindungen auf 2,1 . Länge

Table 3. Number of joints after knots and other defects have been removed and the average length of the cut pieces

Tabelle 3. Anzahl der Verleimungsstellen und durchschnittliche Länge der Werkstücke nach Ausschneiden der Äste und anderer Fehler

	Number of joints per metre	Average length of pieces per unit
Including unjointed boards	1.73	0.45
Excluding unjointed boards	1.99	0.41

3.2.3 Planing

The yield for the material which has been measured before and after planing is shown in table 4, with regard to the smallest and largest sides and with regard to their average value.

Table 4. Yield (%) in planing based on the different dimensions of the jointed pieces before planing
Tabelle 4 Ausbeuten (%) bei Hobeln bezogen auf unterschiedliche Dimensionen der Werkstücke vor dem Hobeln

Number of units	Yield in the planer based on:		
	smallest dimension	largest dimension	average dimension
138	83.7	75.0	79.2

The yield varies between 75 and 84%, which suggests that the dimensional accuracy of the triangular profiles was very poor. If the accuracy can be improved, the yield in the planing will probably be improved.

The planing of the triangular profiles is the operation which gives the greatest volume loss in the solid wood panel manufacture. It is therefore very important that the planing is carried out with as high precision as possible.

Figure 9 shows the yield in the planing for different planing depths. The planing depth is very important for the yield, especially if the triangular profiles are small. The average dimension of the triangular profiles in this investigation was 90 mm and the yield in the planing was 76.6%, as shown in table 2. This suggests, figure 9, that the average depth of the planing was more than 3 mm.

Fig. 9. The yield in planer based on unilateral triangular profile planing with the same planing allowance, k , on all sides

Bild 9. Volumenausbeute beim einseitigen Hobeln von Dreikantprofilen mit der gleichen Toleranz (k) für alle Seiten

In the planing, one of the edges of the triangular profile is also removed, primarily to guarantee a satisfactory gluing of the blocks and to fix the thickness of the block. The cutting of this edge causes no great volume loss. Figure 10 shows the theoretical yield when one of the edges of the planed triangular profile is removed. The loss is 1-2%, which is neutralized by the advantages which are obtained.

The thickness of the block is determined by the heights of the triangular profiles. If the height of the triangular profiles is limited already in the planing, large volume losses can be avoided compared with when the thickness of the block is adjusted on the finished glued block.

Fig. 10. Volume yield in removal of only one edge on each triangular profile. The width of the bevel obtained when the edge is removed is designated "b"

Bild 10. Volumenausbeute nach Abhobeln einer der Ecken des Dreikantprofils. Die Breite des resultierenden Stumpfes ist mit "b" bezeichnet

Figure 11 shows the theoretical yield when the thickness of the block is reduced by "h" mm. This can be achieved on the one hand by planing the edge of the triangular profile, or on the other hand by reducing the thickness of the finished glued block by "h" mm. When the edge of the triangular profile is planed, only 1-2% of the volume is lost. When instead the thickness of the block is reduced, the losses are at least twice this and can in some cases amount to 10% of the volume of the block.

In the drying, the cross-sections of the triangular profiles become deformed slightly so that the edge angles deviate from the angle which they had after sawing, i.e. normally 60°. Angular deviations can also occur as a consequence of incorrect sawing and these errors are often considerably greater than the angular errors arising in the drying.

Angular errors mean that the side surfaces of the triangular profiles must be treated further in the planing so that surfaces suitable for gluing are obtained. It can be seen in figure 12 that this loss is independent of the dimensions of the triangular profile and that large angular errors give considerable volume losses. Angular errors which arise in the drying are of the order of 1° , which according to figure 11 gives a volume loss of 2%.

Fig. 11. Volume yield after correction of the angular error, α , in planing triangular profiles
Bild 11. Volumenausbeute nach Korrektur des Winkelfehlers beim Hobeln von Dreikantprofilen

Fig. 12. The dependence of the volume yield on the number of extracted boards, n , and the block thickness.

Bild 12. Abhängigkeit des Volumenausbeute von der Anzahl (n) der ausgeschnittenen Bretter und der Dicke des Blocks

3.2.4 Gluing of triangles into blocks, and division of the blocks into boards

In the gluing of the blocks, one of the triangular profiles has been divided lengthwise to be used as sides of the block, so that the cross-section becomes rectangular. The volume loss in this division is less than 1 % and has not been included in the account of the volume yield, table 2.

The losses which arise in the division of the block into boards depend on how many boards are to be extracted from the block, whether the division of the block works out evenly, the thickness of the sawcuts and the polishing losses.

In the present investigation, the blocks have not been divided.

From experience, it is known that the sawcut requires 2.5-3.0 mm and that a polishing loss of 1 mm is sufficient to give a fine surface.

Figure 12 shows the volume yield in the division of blocks into 2, 3 or 4 boards. "1 board" means that the block is polished only on the side surfaces. Division of the blocks and the polishing normally reduce the yield by between 10 and 20% but the losses increase drastically if many boards are cut from thin blocks.

4 Conclusions

The triangular profiles obtained in star-sawing constitute a high-quality raw material for the manufacture of wood products. Triangular profiles have vertical annual rings and are without pith and most of the juvenile wood. This means that the profiles are stable in shape, but the appearance and nature of the knots are often such that they cannot be accepted in the final product and must be removed.

The wood pieces obtained after knots and other defects have been removed are finger-jointed into long lengths. By taking the annual ring orientation into consideration in the finger-jointing, the stresses which arise when the moisture ratio of the wood changes are minimized. The uniform annual ring orientation in the finger joint also facilitates pattern fitting between the jointed pieces regarding the structure of the wood surface.

The method presented for the gluing of triangular profiles into blocks shows how triangular profiles can be further refined into form-stable products on an industrial scale. The tests which are now being carried out in a pilot plant show that knotless solid wood panels can be manufactured according to this method and with a high volume yield.

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Fig. extra. The volume yield when the thickness of the block is reduced by h mm, by planing one of the edges of the triangular profile, and by planing the finished glued block

Bild extra. Volumenausbeute nach Verminderung der Blockdicke um h mm beim Abhobeln einer der Ecken des dreikantprofils und bei Hobeln des verleimten blocks