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RADIALLY SAWN TIMBER -

**THE PRIMWOOD METHOD FOR IMPROVED
PROPERTIES**

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THE PRIMWOOD METHOD FOR IMPROVED PROPERTIES

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Abstract

A new manufacturing system, the PrimWood Method, has been proposed to improve the utilization of wood. A basic concept within this method is the sawing pattern called star sawing, which produces timber with both rectangular and triangular cross sections. This method facilitates an efficient production of radially sawn timber with vertical annual rings, without juvenile wood.

The sawn timber produced in the PrimWood Method is used to produce high quality, knot-free solid wood panels with vertical annual rings. In this process, the timber is finger jointed to form knot-free lengths which are glued together into a block. This block can then be divided according to thickness into thinner panels with vertical annual rings. In star-sawing, a certain volume of clear pieces are obtained which are relatively long, i.e. longer than 1 metre. It is not desirable to finger-joint these pieces, but instead to use them to manufacture products without any finger-joint.

The PrimWood Method has been tested in an industrial plant. The manufacturing system was designed for a sawing capacity of about 30 000 m³ logs, which corresponds to 16 800 m³ of star-sawn timber per shift per annum. The production of solid wood panel was then designed to give a volume of 5 800 m³ per annum.

1. Introduction

A basic idea within the PrimWood Method is the ability to produce, on an industrial scale, timber and solid wood panels with vertical annual rings for products in which e.g. small and controlled moisture movements are important. Within the R&D-program Value Activation, an idea was developed to saw timber with rectangular and triangular cross-sections in a pattern which gives a high volume yield (Sandberg 1998). This method, which gives timber with vertical annual rings, is called star-sawing, Figure 1.

A number of investigations have been made on the sawing technique (Sandberg 1996a, 1997a, 1998), on the utilization in particular of the timber with a triangular cross section (Sandberg et al. 1996, 1997a, 1997b, 1998), and on properties which are important for the use of the material in different products (Holmberg 2000, Sandberg 1996b, 1997b, 1997c, 1999, 2003). On the basis of this knowledge, a new industrial manufacturing system, the PrimWood Method, has been developed.

The PrimWood Method has been tested in an industrial plant and the results of this test are presented in this paper.

2. The PrimWood Method

The PrimWood Method is a patented method which utilizes the star-sawing principle, where the log is sawn into timber with vertical annual rings and where the pith and the surrounding juvenile wood are removed. The yield from star-sawing is timber with both rectangular and triangular cross-sections. The rectangular timber is taper edged and it then becomes more straight-grained.

Figure 1. *Star-sawing - a sawing pattern to produce timber with vertical annual rings free from pith and most of the juvenile wood.*

2.1 General remarks

The PrimWood Method has primarily been developed in relation to pine, but tests have also been carried out with spruce and some common hardwoods.

Some of the timber with a rectangular and all the timber with a triangular cross section are cut free from knots and defects. Thereafter the short pieces are jointed together. Knot free panels with a radial texture with or without finger joints are produced from timber with triangular and rectangular cross sections respectively.

The final products obtained by the PrimWood Method are hereinafter called rectangle, triangle, prism and panel, Figure 2.

2.2 The star-sawing pattern

The star-sawing pattern is well adapted to the circular cross-section of the log. Test sawings suggest that the method offers a high volume yield and, at the same time, quality-raising advantages with the sawn product. The quality improvement is a consequence of the vertical annual rings and the fact that the timber becomes more straight-grained, completed with the fact that the pith and surrounding juvenile wood can be removed with greater certainty than is possible with conventional sawing methods.

The volume yield for star-sawing has been determined through simulations and test sawings, Figure 3. Results show that the total volume yield, i.e. both rectangular and triangular profiles, is high in comparison with conventional sawing methods.

On the basis of simulations and test sawings carried out prior to 1995, Sandberg (1996a) proposed a general yield curve for star-sawing. This yield is shown as an unbroken line in Figure 3. The average total yield for logs with a top diameter around 30 cm is between 65 and 70 % with respect to the top cylinder volume.

Figure 2. The products manufactured according to the PrimWood Method: rectangle (a), triangle (b), panel (c) and prism (d).

Figure 3. Volume yield with respect to the top cylinder volume for star-sawing from simulations and test sawings between the years 1993 and 1998 (Sandberg 1998). Unbroken curves are estimated volume yield according to Sandberg (1996a).

The sawn dimensions of rectangle are: thickness 30, 40, 50, 60 and 70 mm and width 70, 80, 90, 100, 110, 120, 130, 150 mm, and of triangles: side 70, 80, 90, 100, 110, and 120 mm.

The triangular shape has meant that it has been necessary to modify stacking. In order to obtain a more even load distribution between stickers and triangles, the triangles were placed either in blocks across the whole width of the package or in groups of three, Figure 4. The tangential sides were turned inwards to reduce moisture evaporation.

Crosscutting the triangles before edging has been tested as a means of increasing the volume yield. The results shows a 1.5 % higher volume yield than if edging had been carried out in a single stage (Sandberg (1997a)). This method of cross cutting the triangles has not, however, been used in the industrial plant presented here.

When the log is split radially, knots are cleaved lengthwise and then appear as splay knots or spike knots in the timber surface. In star-sawing, as in all other radial sawing methods, splay knots occur considerably more frequently than in e.g. block sawn boards, where they in principle occur only in the central section. The radial sawing methods also frequently use large logs and, in such logs, parts of the knots in pine and spruce are often dry or decayed towards the periphery of the log, (Sandberg et al. 1996). This part of the knot will always be found in star-sawn timber, but this need not be the case in the main yield from block sawing.

Star-sawn timber is intended in the first place for carpentry, furniture and furnishing components where the quality of the whole length of the timber is often less important than how large a part of the board can be used for different components. As an example, a few “ugly” knots on an otherwise knot-free board of wood are less important for users of knot-free timber than if the knots are small, fresh, and evenly distributed throughout the timber.

Figure 4. Two methods of arranging the triangles during seasoning: as a block (a) and in groups of three (b).

2.3 Refinement of the sawn products

One stage in the PrimWood Method is gluing the rectangles and triangles into solid wood panels. Prisms are triangles glued together into a block so that the annual rings in the cross-section of the block form a S-curve. Panels are formed in an analogous manner where rectangles are glued together into a block. In a panel, heartwood is glued to heartwood, and sapwood is glued to sapwood. The method is based on the use of dried and conditioned rectangles or triangles at a moisture content of 8 %. All knots and 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 rectangles and the triangles are planed and glued into blocks with vertical annual rings. These blocks can then be divided into solid wood panels thinner than the block.

The volume yields of the different operations in the prism production have been investigated by Sandberg et al. (1998). The average volume yield from a dried triangle of pine to a sanded solid wood panel was 53.8 %. This is a high volume yield for defect-free pine solid wood panel.

A great advantage in using triangles in the manufacture of solid wood panels is the flexibility which is obtained, since the height of the block is determined by the height of the triangles, which in turn can be determined in the planing without any great volume loss. Flexibility is thus also created in the sawmill where rectangular timber can be sawn on demand and triangles suitable for prism manufacture can be produced at the same time.

2.4 Surface texture in the panel and prism

Finger jointing can be carried out in different ways to yield different appearances in the final product (Sandberg et al. 1998). The intention is that panels and prisms will be aesthetically attractive, of high quality with regard to shape stability and tightness of glue line, and that their production will be rational and industrially applicable. In pine, there is a great difference in colour between sapwood and heartwood, and it is important that the proportion of heartwood is more or less the same in the jointed pieces in order to obtain a good fit with regard to colour. This can probably be achieved with a visual system and an advanced handling system for the clear pieces. However, in the industrial plant, the problem is solved as follows: When a knot or defect is removed, the pieces on each side of the defect are monitored so that these pieces can be jointed together. This leads to almost perfect pattern fitting, i.e. the proportion of heartwood in the jointed pieces is practically the same and the annual ring pattern on the radial surfaces coincides on the jointed pieces. The annual ring width and the texture of the timber on both sides of the joint are then similar. This is only valid however when pieces from the same board are jointed. When pieces from different boards are jointed, a slightly poorer pattern fitting is of course obtained because of the variation in the texture between different boards. This effect is reduced the more homogeneous the material is with regard to texture.

In star-sawing, a certain volume of clear pieces will be obtained which are relatively long, i.e. longer than 1 metre (Sandberg et al. 1996). It is not always desirable to finger-joint these boards it may instead be better to manufacture solid wood panels without a finger-joint. If long pieces which are not to be finger-jointed are selected more or less at random, it will be difficult to obtain a good pattern fitting of the remaining pieces. As a result, three varieties of solid wood panels are manufactured with regard to pattern fitting.

These three varieties are all knot- and defect-free:

- I. Solid wood panels without finger-joints and with a certain pattern fitting in the width of the panel.
- II. Solid wood panels with a pattern-fitted finger-joint and a certain pattern fitting in the width of the panel.
- III. Solid wood panels with a finger-joint where no consideration has been given to texture.

A rough calculation made on the basis of empirical investigations Sandberg et al. (1996, 1998) suggests that the distribution between the different varieties is approximately 30 % of I, 50 % of II and 20 % of III.

3. Production system

The PrimWood Method can be divided into three more or less separate, production processes:

1. Division of the log and seasoning of the sawn timber, star-sawing.
2. Manufacture of solid wood panels from rectangles, panel. The panel production includes a part of the volume being used as components or finger-jointed without any further refinement into a solid wood panel.
3. Manufacture of solid wood panels, prism, from triangles.

The PrimWood Method has been tested in an industrial plant in northern Sweden. The manufacturing system was designed for a sawing capacity of about 30 000 m³ logs, which correspond to 16 800 m³ of star-sawn timber per shift per annum. The production of solid wood panel was designed to yield a volume of 5 800 m³ prisms and panels per annum.

3.1 Log quality

As a consequence of the sawing pattern and the fact that the most of the yield from the sawing is manufactured to knot- and defect-free products, the quality requirements for the logs differ from that of traditional log grades. The quality requirements regarding knots for the logs used in star-sawing are for example very low. Table 1 shows the requirements for pine logs used for star-sawing.

Table 1. *Quality requirements for pine logs for star-sawing according to the PrimWood Method.*

Diameter	min. 28 cm
Length	3.3 - 5.5 m
Knots	No restrictions
Compression wood	Maximum 20 % of the scaling volume
Rot	Not allowed
Felling or cross cutting damages	Not allowed
Buttress	Maximum 50 mm from mantle surface allowed
Shortening of length	Butting to the shortest length allowed at following defects: - small butt crook - rot spot in the cross section - discoloured cross section - felling comb

3.2 Conversion of the log

The PrimWood Method for sawing the log according to the star-sawing pattern is intended for operation on an industrial level and all sawing steps have, after certain modification, been carried out using conventional machines. The sawing procedure is shown schematically in Figure 5 and the different steps are:

- I. The log is positioned with consideration taken to its crook and ovality so that the pith can with certainty be enclosed within the centreboard.
- II. Two parallel saw kerfs are made along the periphery of the log so that they just touch the mantle wood at the top end of the log. Two further saw kerfs divide the log into a centreboard and two so-called “coffin lids”.
- III. The centreboard is cleaved into two, as close to the pith as possible.
- IV. The two pieces obtained from the centreboard are thereafter taper edged, i.e. the saw kerfs are placed parallel to the wane sides of the timber. Through this procedure, more straight-grained timber is obtained and more of the high-quality sapwood is obtained than in conventional edging. Furthermore, the pith and the juvenile wood are removed. The taper edging thus increases the probability that all the pith is removed at the butt end of the timber, since the pieces which are edged away on the pith side become wedge shaped.
- V. The “coffin lids” are edged to give two control surfaces for the subsequent sawing. The edging is done very sparingly and the saw kerfs just touch the sides of the coffin lid at the top end.
- VI. The “coffin lids” are then sawn into a rectangle and a triangle in a band saw tilted at an angle of 30° from the vertical plane.
- VII. The remaining, rhomboid piece is sawn in the same way as in VI. The rhomboid is then either turned around 180° and sawn in the same band saw or it is sawn in another band saw tilted at an angle of -30° . In the sawmill here described, the first alternative was used.

Figure 5. A schematic presentation of star-sawing in practice.

After sawing, the rectangles and triangles are stacked separately and seasoned in a drying chamber using a traditional technique. After drying, the rectangles are graded into two main grades: for sale and for further refinement into solid wood panel. The whole volume of triangles is used for prisms.

VIII. The boards from the “coffin lids” are taper-edged in the same way as in IV, except that an extra edging to remove the pith and the juvenile wood is not normally necessary.

IX. The triangles are edged and the saw kerf is then parallel to the pith side of the triangles.

In the industrial plant where the PrimWood Method has now been tested, the machinery used in the different production steps according to Figure 5 included:

Steps I and II: A double band saw combined with a pair of chippers to reduce the mantle wood.

Steps III and V: A pair of chippers (V) combined with an up and down movable centre circular saw (III).

Steps IV and VIII: A double circular edger, with a modified control program.

Steps VI and VII: A double band saw tilted at an angle of 30° from the vertical plane, combined with a return transportation for the rhomboid pieces.

Step IX: A horizontal band saw with transportation devices adapted for the triangular shape.

3.3 Production of solid wood panels

The system for the production of solid wood panels from rectangles is based on conventional techniques. Hence, the description of this part of the PrimWood Method is omitted here.

The fundamental ideas for manufacturing triangles into prisms are thoroughly described in a study by Sandberg et al. (1998) and the procedure is here only briefly described. The manufacture of prisms takes place in six steps, Figure 6:

- i. Sorting of triangles into two groups with respect to the frequency of defects. Triangles with a few knots and defects (group A) are used for prisms without finger-joints and for prisms with finger-joints where no consideration is given to texture (see 2.4). The other group of triangles with more defects is used for prisms with a pattern-fitted finger-joint.
- ii. Removal of defects and, in group A, sorting of defect-free pieces, which will not be jointed.
- iii. Finger-jointing.
- iv. Planing the triangles.
- v. Assembling and gluing the planed triangles into a block.
- vi. Division of blocks into boards, dimension adjustment and sanding.

In the industrial plant where the PrimWood Method has now been tested, the machinery used in the different production steps according to Figure 6 included:

Step i: The triangles are sorted into two groups in connection with the edging.

Step ii: The detection and removal of defects is performed by a visual system in series with a circular saw for cross-cutting adapted to the triangular shape and to short pieces. The visual system applies a line laser (red) in combination with a multisensor technique. This technique momentarily gives three different “images” of the wood: grey scale images, a tracheid image and a profile image. In combination, these images are used for the detection of knots, defects, and dimension-related defects in the triangles.

Figure 6. A schematic presentation of the manufacture of prisms in practice.

When the PrimWood Method uses clear pieces with a length as short as 11-13 cm, it demands special devices for crosscutting and handling the pieces in a correct way. It is important that none of the clear pieces rotate lengthwise or around the length axis in a different pattern than the other pieces before the finger-jointing.

Step iii: The clear pieces are prepared for finger-jointing in a machine for the continuous through-feed of individual pieces with a random length between 11 and 100 centimetres. The fixation of the pieces during milling is adapted for the triangular shape of the pieces. The outfeed section has both a continuous pre-pressing unit and a final pressing station with a cut-off saw.

The manufacturing steps from triangle to defect-free and finger-jointed triangle in customized lengths take place in a single production line, and the capacity is about 20 m/minute.

Step iv: Planing is carried out in a 6-cutterhead moulder. The purpose of planing, is not only to produce a smooth surface and uniform dimensions of the triangles, but also to determine the thickness of the block and thus the thickness of the final panel.

Step v: The planed triangles are continuously fed with adhesive and assembled into a continuous block (in width). The block is pressed in a semi-continuous high-frequency-heated press. After pressing, the block is divided lengthwise to predetermined widths.

Step vi: The block is divided into thinner panels in a horizontal bandsaw that takes a width up to one metre. The dimensions are adjusted and sanding is carried out in conventional machines for these purposes.

According to the dimensions of the final product (prism), decisions are taken in the production layout as follows: the length is decided in the finger-jointing, the thickness in the planing and the width after gluing. This means that the dimensions of the final product are not directly dependent on the dimensions of the incoming triangles, i.e. triangles of different dimensions can be used to create prisms having the same final dimensions.

4. Volume yield

Figure 7 show the material flow with respect to the volume yield of products and the spillage for the PrimWood Method. The data in Figure 7 are taken from the actual production.

The main products, e.g. rectangles, panels and prisms, represent 39.2 % of the log volume taken into the production. The secondary products e.g. fuel and pulp chip represent 54.1 %, and shrinkage, dimension allowance etc. 6.7 % of the log volume.

The sawing stage, star-sawing, has a volume yield of 56 %, and the rectangles then represent 59 % of the sawn volume. The ratio of rectangles to triangles can be changed without any additional volume losses.

60 % of the volume of sawn rectangles (19.9 % of the log volume) is for sale after drying and grading. The rest of the rectangles are used for panels. The volume yield from rectangle to sanded panel is 54 %.

All the triangles are used for prisms and the volume yield from triangles to sanded prisms is 53 %.

The knots were responsible for most of the cutting spillage. In this case, the fibre disturbance around the knots was also removed. In the defect removal stage, all knots with adjacent fibre disturbances, and defects which affect the appearance of the finished product were removed. This gave a loss of 25.0 % in the panel production and 20.8 % in the prism production.

The finger jointing causes a loss, depending on the finger length. In the panel case it was 10 mm and in the prisms 6.3 mm. In both cases there are additional losses for trimming before end jointing. In total, the finger-jointing operation gave a loss of 5.2 % in the panel production and 3.0 % in the prism production.

Rectangles and triangles can be planed with less losses than will conventionally sawn timber because timber with vertical annual rings lacks cupping. The planing and block gluing operation gives total losses of 13.2 % and 18.8 % in the panel and prism production respectively.

5. Economic benefits

The economic calculations, which have been worked out in parallel with the tests in the industrial plant, confirm that the PrimWood Method can be used with high profitability. Table 2 shows business ratios, as a percentage of sales, for the production of one shift in the plant for the PrimWood Method described in this paper.

Two important factors behind the high expected net yield of 17 % are a high volume yield in the production and a high product sales price in relation to traditional sawn products and solid wood panels of pine.

Table 2. *Business ratios, as percentage of sales, for the production of one shift in the plant for the PrimWood Method.*

The PrimWood Method	Total (%)
Sales	100
Raw material cost	- 30
Production and labour cost	- 33
Administration & marketing	- 12
Capital cost	- 5
Depreciation	- 3
Result	+ 17

Figure 7. Yield of products from the PrimWood Method and losses in the different production steps. The volume yield and the losses are calculated with regard to the solid log volume.

The volume yield is about 10 % higher in star-sawing than in conventional sawing methods, and the volume yield in the production of panels and prisms is higher.

The products from the PrimWood Method have unique properties and a quality that differ from that of traditional pine products. These properties and qualities can be quantified in the following way. The products of the PrimWood Method:

- are without knots, cracks or juvenile wood.
- are shape-correct, i.e. the products are straight, plane and have a defined cross-sectional shape,
- are shape-stable, i.e. the shape of the products is well defined during moisture changes,
- have vertical annual rings, which gives for example a better surface for coating,
- have a well-defined orientation of the heartwood and the sapwood, which makes it possible to assimilate these specific properties,
- have two radial surfaces which, compared to tangential surfaces, are slight harder and have better abrasive resistance,
- are more straight-grained.

Regardless of the products produced from such wood, these properties give considerable economic savings in the following production:

- regular losses, e.g. planing losses owing to cupping and distortion, decrease as a consequence of the correct shape,
- downgrading and cassation decrease,
- repairs and filling as a consequence of knots, cracks and pick-up are avoided.

All the these properties and advantages justify a higher price for the products produced by the PrimWood Method. The product prices have been tested on customers with good acceptance. Figure 8 show one example of a product produced from prisms; a high quality showcase.

One problem in the traditional saw-milling industries is that the raw material costs are too high in relation to the net sales. Many saw-milling industries have to deal with a raw material cost which is 60-70 % of the net sale, which can be compared to 30 % for the PrimWood Method. However, these two systems are not directly comparable, especially since the PrimWood Method has a much higher degree of refinement and is expected to generate two to three times the usual value from each log.

6. Conclusions

After many years of development work, star-sawing can now be carried out on an industrial scale. The star-sawing pattern has been developed to a manufacturing system, the PrimWood Method, involving several refinement operations for the conversion of logs to a high quality solid wood panel product.

The products obtained by the PrimWood Method meet several of the most important property requirements of future wood products, including accuracy in size and geometry, no cracks, controlled moisture movement, abrasive resistance and hardness, and aesthetic and tactile factors.

Figure 8. Example of a product (showcase) produced of prisms and designed by professor Olle Pira.

References

- Holmberg H** (2000) Influence of grain angle on Brinell hardness of Scots pine (*Pinus sylvestris* L). *Holz Roh- Werkstoff* 58: 91-95
- Sandberg D** (1996a) Radially sawn timber. Star-sawing – a new method for producing timber with vertical annual rings. *Holz Roh- Werkstoff* 54(3): 145-151
- Sandberg D** (1996b) The influence of pith and juvenile wood on proportion of cracks in sawn timber when kiln dried and exposed to wetting cycles. *Holz Roh- Werkstoff* 54(3): 152
- Sandberg D** (1997a) Utvärdering av sönderdelningsmetod för stjärnsågning. (Evaluation of a conversion method for star-sawing.), KTH, Wood Technology and Processing, Report TRITA-TRÄ R-97-26, (in Swedish with an english abstract)
- Sandberg D** (1997b) Radially sawn timber. The influence of annual ring orientation on crack formation and deformation in water soaked pine (*Pinus sylvestris* L) and spruce (*Picea abies* Karst) timber. *Holz Roh- Werkstoff* 55(3): 175-182
- Sandberg D** (1997c) The influence of annual ring orientation on strength and dimensional changes during moisture variation in finger joints. *Holz Roh- Werkstoff* 55(1): 50
- Sandberg D** (1998) Value activation with vertical annual rings - material, production, products. Dissertation, KTH-Royal Institute of Technology, Dept. of Manufacturing Systems, Wood Technology and Processing, Report TRITA-TRÄ R-98-36
- Sandberg D** (1999) Weathering of radial and tangential wood surfaces of pine and spruce. *Holzforschung* / Vol. 53 / 1999 / No. 4, pp. 355-364
- Sandberg D** (2003) Distortion and crack formation in green and seasoned timber - Influence of annual ring orientation in the cross section. Submitted *Holz Roh- Werkstoff* 2003
- Sandberg D, Holmberg H** (1996) Radially sawn timber. Knots number, type and size in star-sawn triangular profiles of pine (*Pinus sylvestris* L) and spruce (*Picea abies* Karst). *Holz Roh- Werkstoff* 54(5): 369-376
- Sandberg D, Stehr M** (1997a) Bending strength of I-beams with webs of wood-fibre board and flanges of star-sawn triangular profiles. *Holz Roh- Werkstoff* 55:292
- Sandberg D, Wålinder M, Wiklund M** (1997b) The concept of Value Activation - a better utilization of wood. KTH-Royal Institute of Technology, Dept. of Manufacturing Systems, Wood Technology and Processing, Report TRITA-TRÄ R-97-27
- Sandberg D, Holmberg H** (1998) Radially sawn timber. Gluing of star-sawn triangular profiles into form-stable products with vertical annual rings. *Holz Roh- Werkstoff* 56(3): 171-177