ICEUPT '99 IAWPS

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## THE CONCEPT OF VALUE ACTIVATION - THE PRIMWOOD METHOD FOR IMPROVED PROPERTIES

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Value Activation is an integrated R&D programme carried out for the last eight years at the Royal Institute of Technology, Wood Technology and Processing. The name Value Activation refers to the basic understanding of wood, where at present there are properties that are not fully exploited, but with help of a new sawing pattern could be fully utilized. The basic idea lies at an industrial level producing radially sawn timber with good profitability and with a lesser and mostly a controllable moisture movement. In short it implies an activation of values of timber, that has not been exploited in ordinary industrial production to date. This paper gives one example how the basic ideas in the concept of *Value Activation* have been implemented to the industry.

A new manufacturing system, the PrimWood Method, has been proposed in order to improve the utilization of wood. One basic idea within this method is a new sawing pattern called star-sawing, which produces timber with two different shapes, viz., timber with rectangular and triangular cross sections. This method facilitates an efficient production of radially sawn timber with vertical annual rings, and without pith and juvenile wood.

The triangles produced in star-sawing are used for producing high quality, knot free panels with vertical annual rings, PrimWood Prism. In this process, the timber is finger-jointed to form knot-free lengths and glued together into a block. This block can then be divided according to thickness into boards with vertical annual rings. In star-sawing, a certain volume of clear pieces will be obtained which are relatively long, i.e. longer than 1 metre. It is not desirable to finger-joint these boards, but instead to manufacture PrimWood Prism without a finger-joint.

The first full-scale industrial plants based on the Value Activation concept are now in production in nothern Sweden. At full capacity, the saw mill will produce around 18 000 $m^3$ of star-sawn pine a year and shift. The plant for PrimWood Prism will produce around 5 000 $m^3$ a year and shift. The company is expect to generate two to three times the usual value from each log.

### 1. Introduction

Research at KTH-Trä has since 1991 been focused on an integrated R&D-program called *Value Activation* [1]. The program is based on a fundamental view of wood material, namely that there are wood properties which are seldom used today but could be useful with new procedures. The work soon showed that properties of wood products that are most highly appreciated are: shape stability, abcence of cracks, strength, hardness and appearance. It was shown that these requirements are best accomplished by radially sawn timber.

A basic idea within Value Activation is to the ability to produce, on an industrial scale, timber and boards with vertical annual rings for products in which e.g. small and controlled moisture movements are important. An idea that was developed at an early stage within Value Activation was to saw timber with rectangular and triangular cross-sections in a pattern which gives a high volume yield. The method which gives timber with vertical annual rings is called star-sawing, (Figure 1). After many years of developmental work the idea is developted into an industrial production system for wood products, the PrimWood Method and the situation is currently that one company, Nova Wood AB have built a full-scale industrial plant based on the Value Activation concept.

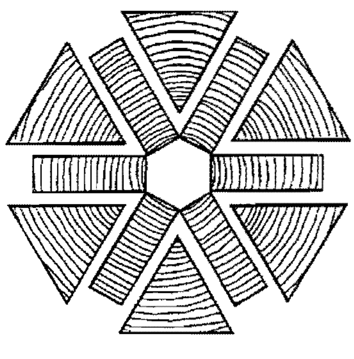

Figure 1. Star-sawing - a new sawing pattern to produce timber with vertical annual rings free from pith and most of the juvenile wood.

## 2. The PrimWood Method

The PrimWood Method is a patended method which implies star-sawing the log into timber with vertical annual rings and that the pith and the surrounding juvenile wood is removed. The rectangular timber are taper edged and then becomes more straight-grained. Short pieces without knots and defects are joined together. Knot free panels with radial texture, PrimWood Prism, with or without finger joints are produced.

### 2.1 The new saw pattern star-sawing

It seems obvious that if the timber is sawn radially from the log, without pith and juvenile wood, properties are obtained which are much better than those of conventionally sawn timber (Sandberg 1998). Star-sawing is a new method for producing such timber. The yield from star-sawing consists of timber sections with both rectangular and triangular cross-sections, all with vertical annual rings and without juvenile wood.

#### 2.1.1 Sawing the log according to the star-sawing pattern

The star-sawing pattern is well adapted to the circular cross-section of the log. The sawing pattern in its basic design gives six pieces with a triangular cross-section and six pieces with a rectangular cross-section but, depending on the desired timber thickness and the dimensions of the triangular profiles, several more rectangular pieces can be sawn to maintain a high volume yield.
Test sawings suggest that the method offers a high volume yield at the same time as quality-raising advantages are obtained with the sawn product. The quality improvement is a consequence of vertical annual rings and the fact that the timber becomes more straight-grained and that the pith and surrounding juvenile wood can be removed with greater certainty than was possible with conventional sawing methods.

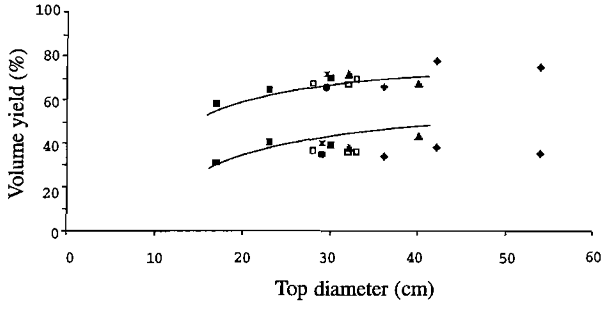


Figure 2. Volume yield with respect to the top cylinder volume for star-sawing from simulations and test sawings between the years 1993 and 1998 [1]. Unbroken curves are estimated volume yield according to Sandberg [2].

The volume yield for star-sawing has been determined through simulations and test sawings [1]. Results show that the total volume yield, i.e. both rectangular and triangular profiles, is high in comparison with conventional sawing methods.
Sandberg [2] on the basis of simulations and test sawings carried out until 1995 proposed a general yield curve for star-sawing. This yield is shown as an unbroken line in Figure 2. This figure also shows average values for volume yields from test sawings and simulations which have been carried out so far. There is good agreement between the estimated curve for the total yield and later test sawings. The total yield for logs with a top diameter above 25 cm is as an average slightly less than 70 % with respect to the top cylinder volume.
It has been very easy to dry the sawn timber without any drying damage. However, the shape of the triangular profiles has meant that it has been necessary to modify stacking. Four different ways of stacking the triangles has been tested; simple stacking, in blocks, in groups of three, and unedged triangles in groups of three, Figure 3.
Simple stacking means that the triangular profiles are arranged one by one with a space of about 2 cm between, no consideration being given to annual ring orientation. The method was shown to have a number of disadvantages, e.g. compression damage arises on the profile corner which lies against the row above [1]. This becomes particularly obvious if the drying package is placed far down in the drying batch.
In order to obtain a more even load-distribution between stickers and triangular profiles, the profiles were placed in blocks across the whole width of the package. The tangential sides were turned against each other to reduce moisture evaporation. It was shown, however, that the moisture content variation between the profiles was large with this method.
When the profiles were placed in groups of three with the tangential sides inwards in each group, the moisture evaporation from the tangential surfaces was reduced at the same time as the air percolation was increased. The method gave no or very small compression damage. The method has been used for most of the triangles which have been dried.
As the sawing method was developed, the idea of edging the triangles after drying arose. This should be done for two reasons. On the one hand, it was desirable to try to crosscut the triangles before edging to increase the volume yield. On the other hand, it was desirable to reduce the risk of crack formation on the tangential surface. To crosscut the triangles before drying was considered to be impracticable and the control surfaces which were sawn on the "coffin lids" (see Figure 4) also meant that drying batches can be placed with unedged triangles. To dry the triangles with the edge surface intact and without any cracks is not any problem with modern kilns. However, there is a risk that very small cracks arise on the edge surface. By edging the triangles after drying, these cracks could be removed. The method has been tested and the results showed a low degree of crack formation and 1.5 % higher volume yield than if edging had been carried out in a sin-

gle stage [3]. The primary disadvantages are that circa 15 % larger volume is dried and that the volume which is edged away cannot be used as pulp chips.

When the log is split radially, knots will be cleaved lengthwise and 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. square-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 are often dry or decayed towards the periphery of the log [4]. 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 a large part of the piece 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 in the timber.

In an attempt to produce a grading instruction for star-sawn timber, especially for timber with rectangular cross-section. For the triangles, no general grading instruction has been produced because there is as yet no market for this timber. For the use of triangles in defect-free solid wood panels, initial tests have begun by dividing the triangles into classes according to how long defect-free boards can be obtained from each triangle.

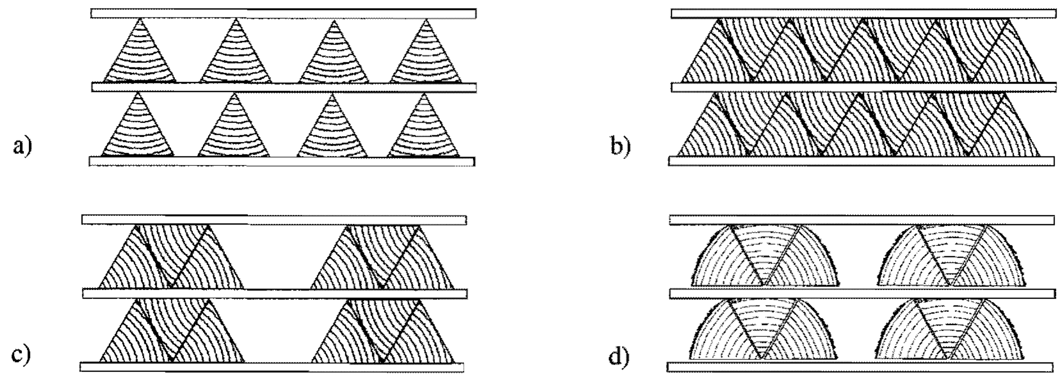


Figure 3. Arrangement of triangular profiles; (a) simple stacking, (b) in blocks, (c) in groups of three, (d) unedged triangles in groups of three.

## 2.1.2 Sawing method

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 can after certain modification be carried out using conventional machines available on the market. The sawing procedure is shown schematically in Figure 4. 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 centre plank.

II. Two parallel sawkerfs 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 sawkerfs divide the log into a centre board and two so-called "coffin lids".

III. The centre board is cleaved into two, as close to the pith as possible.

IV. The two pieces obtained from the centre board are thereafter taper edged, i.e. the sawkerfs are placed parallel to the wane sides of the timber. Through this procedure, higher straight-grained timber is obtained and more of the high-quality sapwood than in conventional edging is achieved. Furthermore, the pith and the juvenile wood are removed. The taper edging thereby increases the certainty that 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 obtain two control surfaces for the subsequent sawing. The edging is done very sparingly and the sawcuts touch the sides of the coffin lid at the top end.

VI. The "coffin lids" are tilted 60° and a board and a triangular profile are sawn. One alternative is to tilt the band saw 30° from the vertical plane.

VII. The remaining, rhomboid piece is sawn in the same way as in VI.

VIII. The boards from the "coffin lids" are taper-edged in the same way as in IV, except that an extra degree of edging to remove the pith is normally not necessary.

IX. The triangular profiles which will be used for knot-free products will to a great extent be cut free from defects and will be finger-jointed. For these triangular profiles, a slightly different edging procedure has been used. The triangular profiles are divided at approximately half their length close to a knot or other defect which has to be removed at a later stage. The two parts are thereafter edged separately. With this method, the tapering of the log can be utilized to a greater extent than if the triangular profiles are edged in one piece.

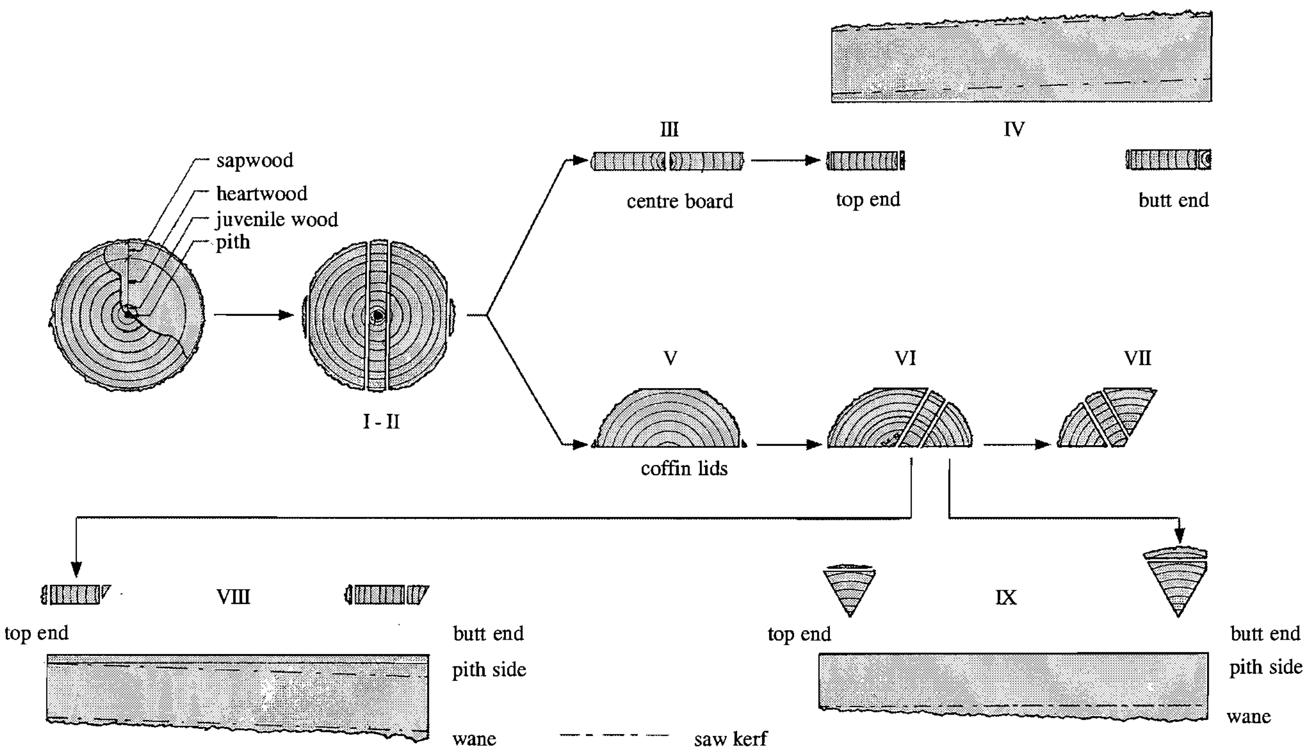


Figure 4. A schematic presentation of star-sawing in practice.

## 2.2 PrimWood Prism

One part of the PrimWood Method is gluing the PrimWood Triangle into different products. PrimWood Prism is triangles glued together into a block so that the annual rings in the cross-section of the block form an S-curve. 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 joined materials. After the joining, 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 divided into solid wood panels.

The work was concentrated primarily towards producing PrimWood from pine, but tests have also been carried out with spruce.

Finger-jointing can be carried out in different ways resulting in different appearances in the final product. The intention with PrimWood Prism was that it would be aesthetically attractive, of high quality with regard to shape stability and tightness of glue line, and that the production would be rational and industrially applicable. It was therefore decided to cut the fingers parallel with the tangential surface of the triangles, (Figure 5a). This means that in the surface of the PrimWood, the finger-joint will be visible as a zigzag pattern, (Figure 5b). The primary reason for this direction of the finger-joint was that the block glued from triangles can be divided into an arbitrary number of boards without the joint in the surfaces of the boards becoming crooked.

A further question remained and that was which pieces should be joined together. In pine, there is a great difference in colour between sapwood and heartwood, and it is important that the proportion of heartwood is practically the same in the joined pieces in order to obtain a good fit with regard to colour. This can probably be solved with vision system and an advanced handling system for the clear pieces, but in our case the problem was solved as follows: When a knot or defect was removed, the pieces on each side of the defect were monitored so that these pieces could be joined together. This results in an almost perfect pattern fitting, i.e. the proportion of heartwood in the joined pieces is practically the same and the annual ring pattern on the radial surfaces coincides between the joined pieces. The annual ring width and the texture of the timber on both sides of the joint are also similar. This is only valid however when pieces from the same triangle are joined. If a triangular board is changed, a slightly poorer pattern fitting is of course obtained because the texture varies 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 [1]. It is not desirable to finger-joint these boards, but instead to manufacture PrimWood Prism without a finger-joint. If long pieces which are not to be finger joined are selected more or less at random, it will be difficult to obtain a good pattern fitting of the remaining pieces. This is a problem which results in the manufacture of three varieties of PrimWood with regard to pattern fitting.

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

I. PrimWood Prism without finger-joint and with a certain pattern fitting in the width of the block.

II. PrimWood Prism with a pattern-fitted finger-joint and a certain pattern fitting in the width of the block.

III. PrimWood Prism with a finger-joint where no consideration has been given to pattern fitting.

A rough calculation made on the basis of empirical investigations Sandberg and Holmberg [4, 5] suggests that the distribution between the different varieties will be approximately 30 % of I, 50 % of II and 20 % of III.

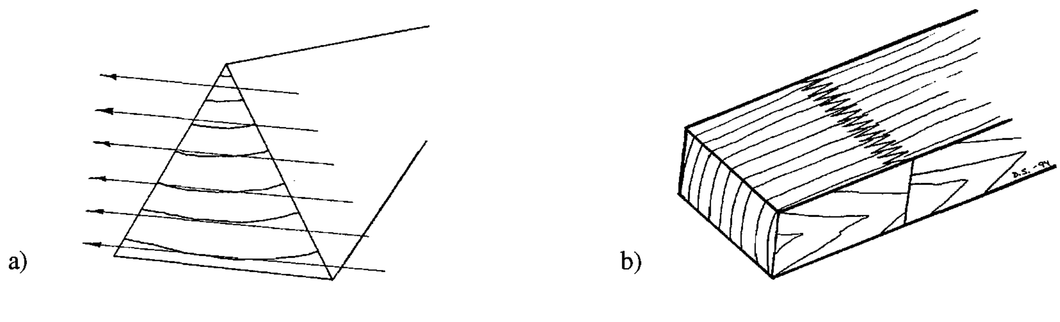


Figure 5. Finger-jointing of the triangles can be carried out in different ways giving a different appearance of the join in the visible surface. Finger cutting parallel to the tangential surface of the triangles (a) gives a zigzag pattern in the surface when the triangles have been glued together (b).

The manufacture of PrimWood Prism takes place in six steps, Figure 6:

1. Sorting of triangles into two groups with respect to the frequency of defects.
2. Removal of defects and sorting of defect-free pieces which will not be joined.
3. Finger joining
4. Planing
5. Assembling and gluing into blocks
6. Division of blocks into boards and possible dimension adjustment and sanding.

The volume yield for the different operations has been investigated by Sandberg and Holmberg [4, 5]. The average value for the volume yield from a dried triangle of pine to a sanded PrimWood Prism board was 53.8 % [5]. This is a high volume yield for defect-free pine board. It can be established that three operations are decisive for the yield, the removal of defects, the planing and division of blocks, and the sanding of the panels.

In the investigation by Sandberg and Holmberg [5], the losses in removal of defects constituted less than 15 % of the volume of the triangles. The knots were responsible for most of the cutting spillage. Because of the appearance of the star-sawing pattern, long lengths of timber are obtained which are knot-free. The proportion of knot-free material that can be obtained from star-sawn pine and spruce timber has been investigated for timber from different parts of Sweden [4]. In the investigated material around 25 % knot-free pine with a length greater than 2 metres was obtained from southern and central Sweden. For the wood from northern Sweden, the corresponding figure was 5 %. In this case, the fibre disturbance around the knots had also been removed.

PrimWood can be planed with lesser losses than conventionally sawn timber because timber with vertical annual rings lacks cupping. The height of the triangle, and thus the height of the glued block, must agree exactly with the board dimensions into which it is desirable to divide the block, so that there are no excessive volume losses. By deciding already in the planing stage which thicknesses are to be extracted from the finished block, these losses can be avoided.

A great advantage in using triangles in the manufacture of 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 great volume losses. Flexibility is thereby also created in the sawmill where rectangular timber can be sawn according to demand and triangles suitable for PrimWood manufacture can be produced at the same time.

## 3. Conclusions

The Value Activation program has so far shown that there are great possibilities of utilizing the properties of wood in a better way than our conventional wood production concept can achieve. New wood products with desirable properties can be developed. Most of these products are expected to give a greater added value to the wood. The R&D-program will continue with the further development of improved products and also with the development of cost-efficient production systems for implementing the ideas from our R&D in profitable production units.

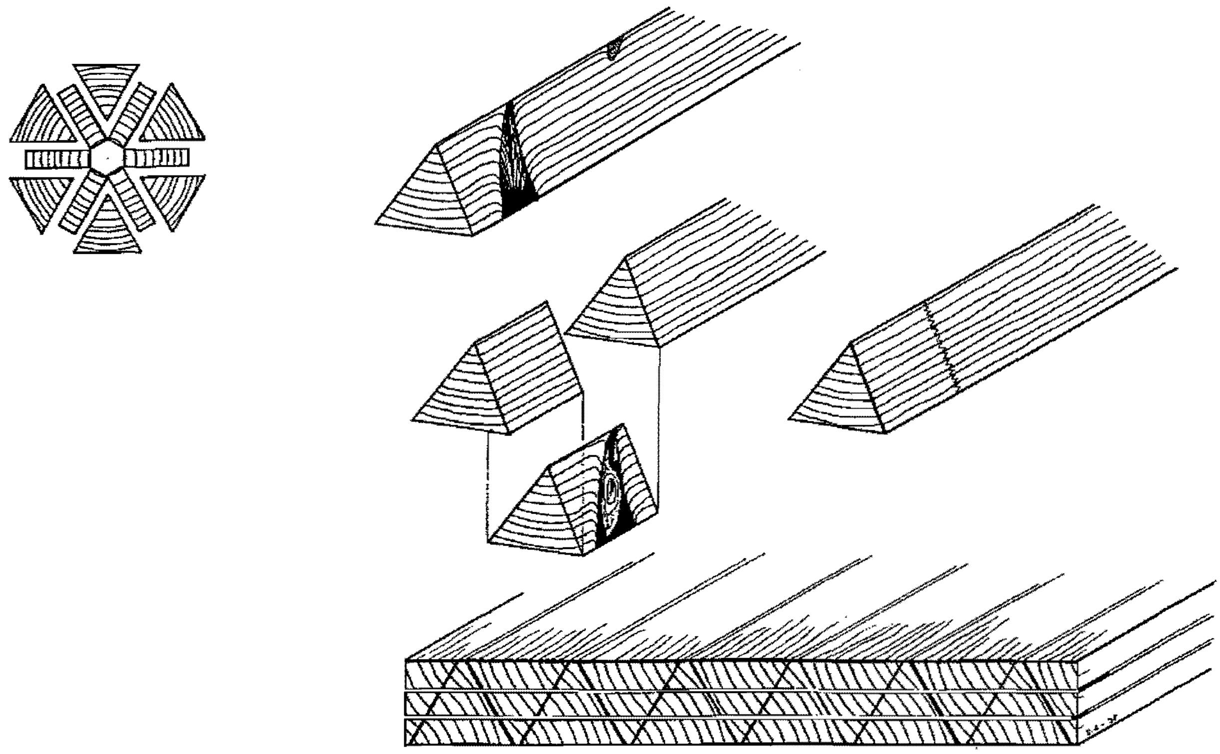

Figure 6. PrimWood Prism, defect-free triangles glued together into a block.

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