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RADIAL STICK SAWING OPTIMIZATION

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Abstract

Stability in wood is related to moisture content and annual ring direction. Many manufacturers choose radial material for less shrinkage and swelling ratios and uniform shape change avoiding deformations especially for layered and joined materials. Sawmill operators usually prefer quarter sawing diagram to obtain radial boards from logs for this purpose. However, quarter and another diagrams give solutions for only boards that have larger dimensions than sticks, which are commonly used layered materials.

In this study, radial stick sawing optimization from logs was aimed. For this purpose, commercially preferred logs with 200mm, 300mm, 400mm and 500mm diameter, and cylindrical shape, were drawn in CAD program. Commonly used sawing diagrams (live, quarter, around) were tried empirically basing on cross sections. However, studies showed that when tangential boards were sawn to obtain radial sticks, all sticks could not be radial due to annual ring direction, especially at the end of boards. Therefore, some diagrams were modified to obtain maximum radial stick yield.

Results showed that the radial stick yield can reach 57,8% and the yield increment reached max. 28,9% (12,97% in average) when the all diagrams for all logs were considered. Especially around sawing method gave maximum radial stick yield. It is originated from the diagram, which normally gives radial sticks from tangential boards. Furthermore, modified sawing diagrams gave better yields from commercially preferred diagrams. However, sawing process is becoming extended and complicated with them.

Otherwise, it is suggested that log sawing optimization programs should calculate lower dimensions than boards with considering secondary sawing process and annual rings can be drawn in program or scanned for evaluating board is radial or tangential.

Keywords: Log Sawing, Sawing Optimization, Around Sawing, Radial Stick

1. Introduction

Solid wood material changes dimensions according to moisture exchange with atmospheric environment within certain limits. Dimensional changes and shape deformation are serious problem especially in laminated and bonded wood products. They may not be considered in structural wood products e.g. Glulam. Otherwise they are more considered at multi-layered parquets, wooden door and window laminated profiles which are more sensitive changes at millimetric level. For example, stability of sticks is important at multi-layered parquets due to cupped sticks generates ondulation problem on finished flooring (Fig. 1). Ondulation isn't defined as a deformation in standards (TS 5204 EN 13756 (2004), TS EN 13647 (2015), TS EN 14342 (2008), TS EN 13489 (2017) etc.). Especially, convex and concave cup deformations are defined, however they were evaluated for all parquet width or length. Although it isn't considered in standards, end-users don't want to see it due to aesthetic problems.

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Figure 1: Above: Ondulation at finished multi-layered (laminated) parquet surfaces
Below: Tangential stick array in parquet

Dimensional change ratio is mainly related to wood specie, anatomic characteristics, defects and annual ring angle. For example, many angles at cross-section preserve cross section shape after drying. However cupping can occur at tangential lumbers having less annual ring angle than 45^{o}, while diamonding can occur at square lumbers having annual ring angle is 45^{o}. Most of factors affecting dimensional stability can be eliminated while choosing right raw material (log or lumber) or choosing right production process.

Optimization studies for log sawing are focused primarily quantity yield or quality yield with evaluating defects as fissure, knots. However, quarter sawing and around sawing were developed with evaluating sawing methods due to annual ring angle and solid wood material anisotropy. Then radial or tangential lumber began to take part in quality yield. On the other hand, in conventional log sawing methods, operators aim manufacturing lumbers with larger dimensions (e.g. 25mm x 50mm). However, many factories which are integrated with value-added wood products having narrower cross-section sizes as sticks. Because the aim change can production process. For example, it is known that narrowing cross-sectional dimensions decreases quantity yield (Kantay, 2005).

In this study, radial stick sawing optimization from logs was aimed. Otherwise quantity and quality (tangential or radial) yield change were evaluated with different sawing pattern.

2. Materials and Methods

Commercially preferred Fir logs with 200mm, 300mm, 400mm and 500mm diameter were drawn in drawing software (AutoCAD). Only cross sections of logs and sticks were considered determining effect of pattern while sawing sticks. Conventional live and around sawing diagrams were used. These diagrams normally give best solutions for produce boards, which have larger dimensions than sticks. In addition to all these, radial sawn were modified to determine alternative tangential lumber sawing method at the 400mm diameter log drawings (Fig. 2).

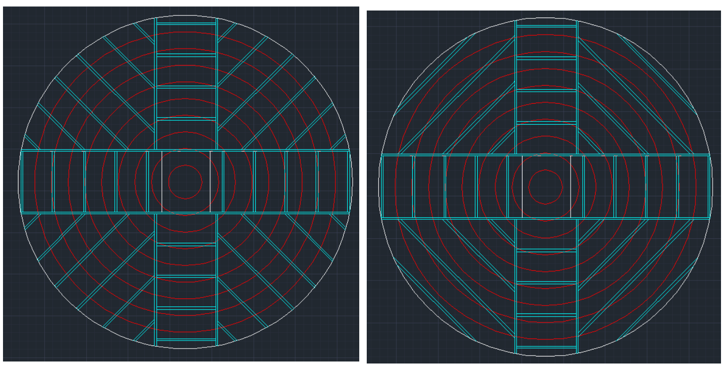

Figure 2: Left: Standard Radial Sawing Diagram, Right: Modified Diagram
(Red: Annual Rings, Blue: Saw kerf line)

The diagrams were determined empirically with aiming maximum stick number. 2,5mm saw kerf for board sawing and 3,15mm saw kerf dimensions for stick sawing were considered. Centre board with 77,5mm x 90mm dimensions was excluded to avoid stability and strength problems due to annual ring shapes and pith for each log. Sticks having dimensions with 35mm x 9mm and without wane were aimed.

Surface exit angles (α) of annual rings (20 mm width for each log) were considered to determine sticks were radial (α>45°) or tangential (α <45°). The angles were measured with drawing temporary lines in software as shown in Fig. 3.

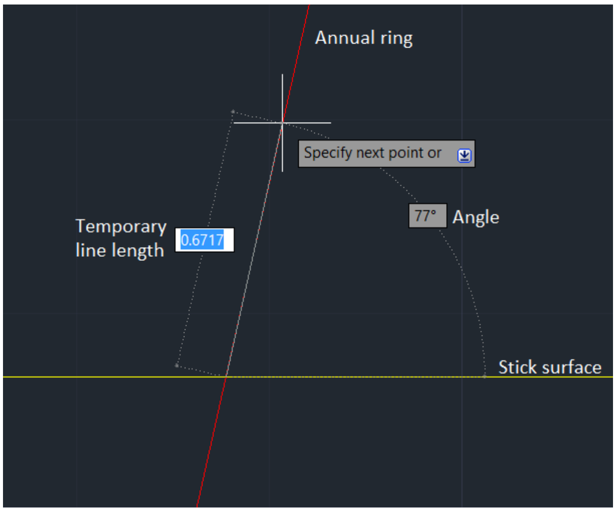

Figure 3: Surface exit angle measurement

Total sticks area was divided to log cross-section area for quantity yield, while total radial stick area was divided log cross-section area for quality yield (as shown in Eqs.1, Eqs.2, Eqs.3, Eqs.4 and Eqs.5).

Total Stick Area (mm^2) = Number of sticks x Stick cross section area (1)

Radial Stick Area (mm^2) = Number of radial sticks x Stick cross section area (2)

Cross Section Area (mm^2) = π x [Log radius]^2 (3)

Quantity Yield (%) = [(Total stick area / Cross section area of log)] x 100 (4)

Quality Yield (%) = [(Radial stick area / Cross section area of log)] x 100 (5)

Furthermore, radial sticks ratio in all sticks was determined (Eqs.6) due to laminated parquet companies reported that tangential sticks can't be utilized except burning to heat drying kilns.

Radial Stick Ratio (%) = [(Radial stick area / Total stick area)] x 100 (6)

Moreover, economic gain was calculated with yield to compare sawing diagrams. For this, 2nd grade Fir log price (561 TL at 25th November 2017) was considered (Web-1) and sawmill capacity was based on 1250m^3/month log sawing capacity.

3. Results

The drawing tests were performed for each diameter of logs and they were shown at Fig. 4, Fig. 5, Fig. 6, and Fig. 7. After the figures, all results were shown in Table 1.

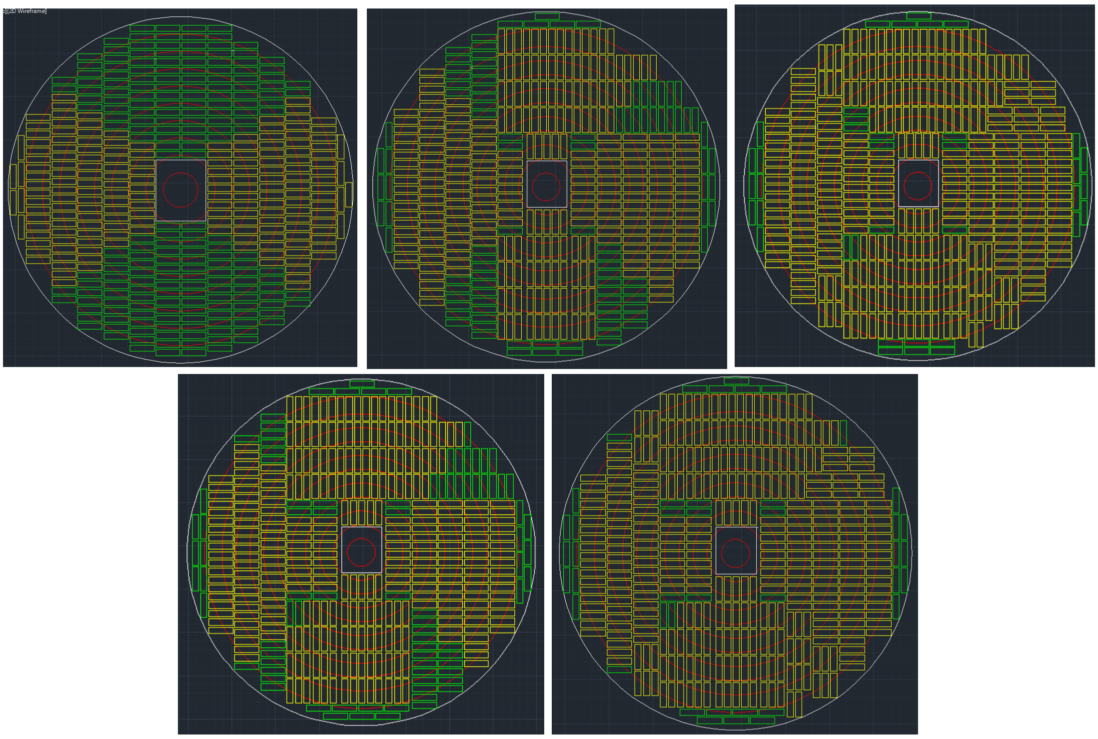

Figure 4: Sawing Diagram Possibilities for 500mm Diameter Log
(Live, Tangential-1, and Modified tangential-1, Tangential-2, and Modified tangential-2 sawing methods, respectively.)

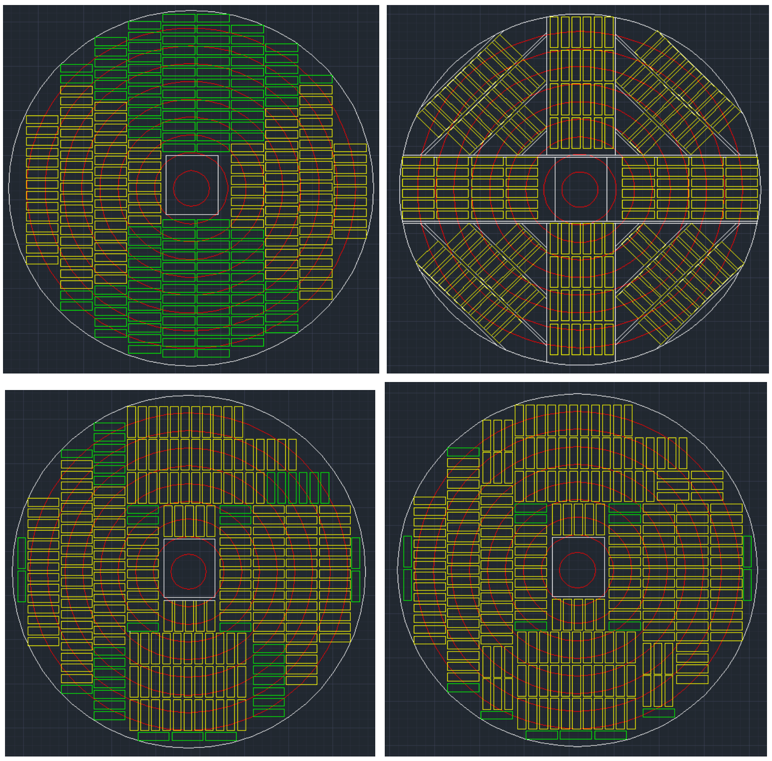

Figure 5: Sawing Diagram Possibilities for 400mm Diameter Log
(Live, Modified radial, Tangential and Modified tangential sawing methods, respectively.)

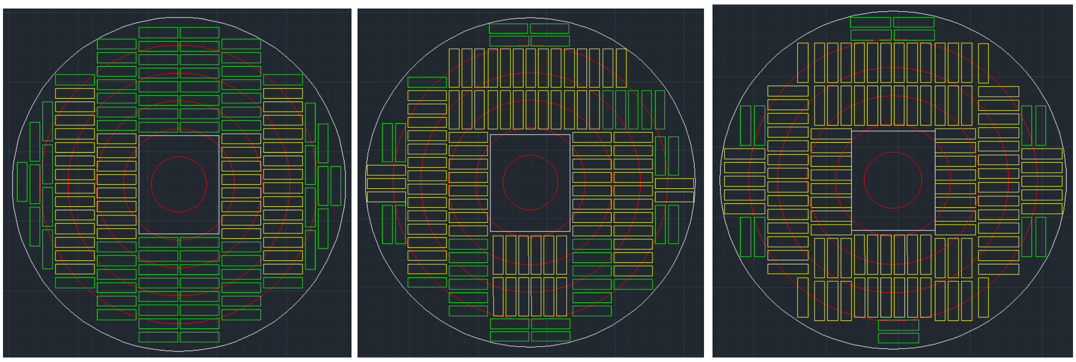

Figure 6: Sawing Diagram Possibilities for 300mm Diameter Log
(Live, Around sawing, Modified around sawing methods, respectively)

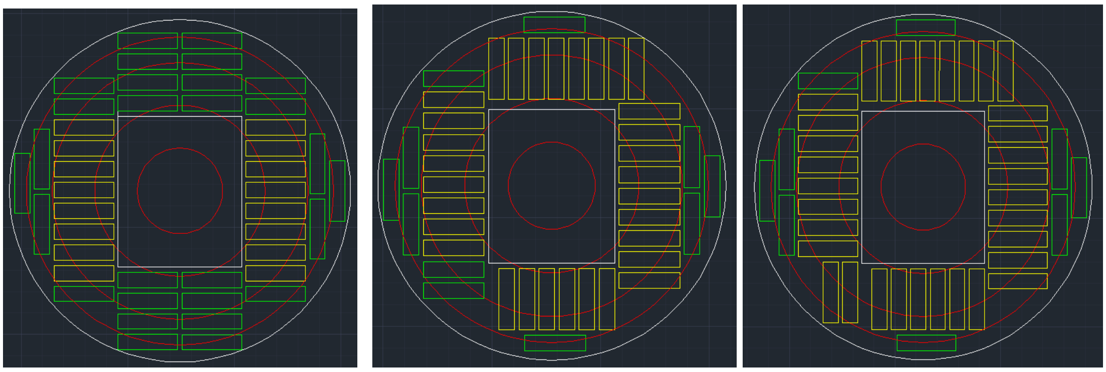

Figure 7: Sawing Diagram Possibilities for 200mm Diameter Log
(Live, Around, Modified around sawing methods, respectively)

Table 1: All results for each log diameter and each diagram

Log Diameter	Sawing Diagram	Total Radial Stick	Total Tangential Stick	Total Stick	Radial Stick Ratio (%)	Quantity Yield (%)	Quantity (Radial Stick) Yield (%)
500 mm	Live	180	200	380	47,4	61,0	28,9
	Around 1-1	283	101	384	73,7	61,6	45,4
	Around 1-2	344	37	381	90,3*	61,2	55,2
	Around 2-1	328	87	415**	79,0	66,6**	52,7
	Around 2-2	360**	53	413	87,2	66,3	57,8**
400 mm	Live	116	128**	244*	47,5	61,2*	29,1
	Modified Quarter	196	0	196	100**	49,2	49,2
	Around 1	194	41	235	82,6	58,9	48,7
	Around 2	218*	17	235	92,8	58,9	54,7*
300 mm	Live	44	80*	124*	35,5	55,3*	19,6
	Modified Live	106*	14	120	88,3*	53,5	47,3*
	Around	84	36	120	70,0	53,5	37,5
200 mm	Live	18	26*	44*	40,9	44,1*	18,1
	Around	31	11	42	73,8	42,1	31,1
	Modified Around	33*	9	42	78,6*	42,1	33,1*

Starred (*) values are the highest value of each diameter. Double starred (**) values are the highest value of each column for all diameters.

According to results, profit per month of sawmill with between choosing the best sawing pattern instead of the worst sawing pattern for radial stick production were calculated (Table 2).

Table 2: Radial stick yields and change with different sawing pattern for each log diameter

Log Diamaeter	Min. Radial Stick Yield (%)	Max. Radial Stick Yield (%)	Difference (%)	Profit* (TL)
500 mm	28,90	57,80	28,90	202661
400 mm	29,10	54,70	25,60	179520
300 mm	19,60	47,30	27,70	194246
200 mm	18,10	33,10	15,00	105188

*The profit was calculated with using monthly production values

4. Conclusion

Wood is an engineering material. Anisotropy, dimensional change, variety of tree species or wooden product etc. affecting factors should be considered and each production process of wood should be considered with detail. As seen in this study, changing sawing pattern with changing quality understanding can cause yield increase up to 28,9% with up to 202661 TL profit per month. When the ecological factors come into the forefront, the production can be performed with less log usage. In terms of economy, laminated parquet industry has many companies and even if 1TL difference for end-product price is important for getting ahead of rivalry.

In this study, the radial stick yield and profit change were compared to min. radial stick yield that can be determined with live sawing. The change can decrease when compared another sawing methods. Moreover, the waste utilization of the sawmills weren't considered. Many sawmills can use wastes for heat source for drying kilns and waste usage is calculated for reducing the heat costs.

Otherwise the production process is getting complicated with increasing radial stick yield. Because log-turning time increases in sawing patterns having better yield. It causes more production time and it needs more operator attention.

Conventional sawing diagrams give solutions to produce boards which have larger dimensions than sticks. Because these diagrams generally were prepared for headrig in primary breakdown process. However, diagrams can include end-products as radial sticks which can be produced in secondary breakdown process. Otherwise, it can be thought that diagram gives max. tangential boards can be used, cause of radial sticks can be produced with sawing tangential boards. But, this study showed that all tangential boards can't be fully sawn radial sticks due to annual ring shape. Furthermore, it is found that when the log diameter increased, radial stick yield increased. Because annual ring angle changes is getting more at the centre area of logs having smaller diameter.

In addition, sawing optimization programs developed in recent years started to consider annual ring to determine radial – tangential lumber. Today, determining annual ring shape of each log is difficult and it is calculated empirically. However, developed non-destructive evaluating devices as computed tomography can help to transmit the information of each log to the programs and healthier results can be obtained.

5. Acknowledgments

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