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EVALUATION OF LUMBER YIELD AS FUNCTION OF THE SAWING EQUIPMENT

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Abstract:
The main outcome of this research was to compare the lumber yield obtained from a sawlog of given dimensions by means of different types of sawing equipment. First, the main types of saws used for the conversion of logs into lumber are presented, along with a synthetic presentation of their pro-s and con-s, which enhances the reader to understand easier the advantages and limitations of each sawing alternative. Then, based on a chosen cutting pattern and imposed dimensions of the lumber pieces, by varying the sawblade type, calculations were made to evaluate the lumber yield in each situation. The use of band saws (as such, or as mobile sawmill with band saw, or as reducer band saw) lead to the best results, with a total lumber yield of 67.86%, out of which 38.5% central boards. The presented results may serve as a valuable reference for students and specialists in the field, to acknowledge the performances that can be achieved by means of the main types of equipment used in sawmills for the conversion of sawlogs into lumber.

Key words: *sawing, frame saws, band saws, circular saws, reducer saws, sawmilling lines, lumber, yield.*

INTRODUCTION

The conversion efficiency of sawlogs into lumber is influenced by several factors, such as (Steele 1984):

- the log diameter, length, taper, and quality;
- the kerf width;
- the dimensions of the products (boards) to be obtained;
- the condition and maintenance of mill equipment;
- the sawing method.

The present study has been focussed on the influence of the kerf width, and in direct relation to this, to the type of the sawing equipment used, which may be frame saws, band saws, circular saw, or combinations.

The frame saw blades have a thickness (*g*), ranging between 1,8mm and 3,4mm, but due to the compulsory tooth set (*c*) of 0,7-0,8mm for green resinous wood)(Dogaru 1981), the kerf width ($b = g+2c$) becomes 2,5 ... 4,2mm.

A comparison between pro-s and con's of frame saws is given in Table 1.

Table 1

Pro-s and con-s of frame saws used for the log conversion into lumber

Pro-s	Con-s
• Tool maintenance is cheaper and easier than with other sawing machines, which means that it can also be handled by less qualified personnel; • The frame saw operator must not high knowledge of wood properties and how to deal with possible wood defects, since he has relatively little influence on the cut process compared to the band saw operator; • The tension of the saw blades is optimal; • The tool spacing is very precisely defined by the saw blade register and very easy to use; • Up to 40 cm cutting height, the specific cutting work is up to 25% lower than other primary machines (Fronius 1981). • The feed speed is linearly adjustable;	• Compared to circular and band saws, the average cutting speed of 8m/s is very low and limited; • A smooth cutting surface cannot be achieved; • The frame saw has very little flexibility and the tool adjustment speed is also very low compared to modern sawing machines; • If the feed rates are too high, the gullet area of a saw teeth cannot be completely emptied, which leads to a pressing of the chips and to a reduction in the surface quality; • The production of thin boards is not possible because the high cutting performance would lead to an overload and rapid wear of the machine; • The performance is limited by design reasons (high mass leads to high inertia forces which increase exponentially with the rotation speed);

• In order to increase the yield, curved logs can be cut with a repositioning at the horizontal axis during cutting; • No extraordinary work is required to convert to winter operation, only the feed rate has to be reduced.	• A solid foundation must be provided in order to prevent cracks in surrounding buildings.

Band saw blades are the thinnest, and so they provide the narrowest kerf widths, ranging between 1,47mm and 1,83mm.

The band saw only became a high-performance production machine through constructive improvements and additional equipment (such as an upstream chipper canter). The main feature of the band saw in comparison to other sawing machines is the high cutting dimension flexibility. For that reason, is mostly used for high quality and expensive lumber.

A comparison between pro-s and con's of band saws when used for the log conversion into lumber is given in Table 2.

Table 2

Pro-s and con-s of band saws used for the log conversion into lumber

Pro-s	Con-s
• The band saw enables a higher yield due to a small kerf; • Due to the better intervention during the cutting process, any wood defects can be taken into account and the quality of the sawed products can be improved; • The band saw allows an individual cut; • No pre-sorting of the logs is required in the workflow of a log band saw, less space needed for sorted log piles. Reduction of the labor cost by eliminating the separate log grading on log yard; • With the band saw, special cutting pattern are possible; • By using both-sided sawblade cutting process is allowed in both directions; • The cutting of big log diameters is possible; • The production of thin boards is very easy compared to the frame saw; • The delivery times can be shortened by the flexibility in the cutting pattern; • By avoiding of inertia forces in contrast to the frame saw, the solid, expensive foundation can be saved.	• The saw operator is required to have a high level of professional qualification and quality awareness; • The band saw can only be used economically with large diameters or only as a pre-cutting machine in conjunction with a high-performance post-cutting machine; • The maintenance of the band saw blade is very complex and has to be carried out very precisely for a high cutting quality. Special machines are also required, *e.g.* for straightening and applying the internal tension • Special squared cuts can be done on the frame saw in the same time or even faster than on the band saw; • Especially in the case of resin-rich woods, the saw blade must be moistened with a resin-dissolving emulsion in order to avoid additional heating and also to clean the resin deposits that collect dust, sawdust etc. Otherwise, these impurities are transferred to the flywheels, with negative effects on the cutting quality. In extreme situations, the blade may even jump off the flywheel; • With the band saw, processing of frozen wood is difficult, as at temperatures below -10°C the sawdust is freezing onto the cut surfaces and cause severe dimensional inaccuracies.

Circular saw blades are the thickest type of sawblade. Their kerf width ranges between 2,8mm and 5,5mm Same as the two previous types of log saws, circular saws also have their specific advantages and disadvantages as well, as presented in Table 3.

Table 3

Pro-s and con-s of circular saws used for the log conversion into lumber

Pro-s	Con-s
• Easy to handle in maintenance; • Greatest dimensional accuracy of all sawing machines. • The exchange of the tool sets takes little time; • Instead of one, two saw blades can be arranged on two shafts one above the other; this leads to a	• In order to increase the stability of the saw blade, the saw blade must be relatively thick, which reduces the yield; • With double-shaft circular saws, a kerf offset can occur; • Due to small tooth pitches, there is a risk that the

reduction in the saw blade diameter and thus to an increase in the yield; • The edge cleanliness can be increased by small tooth pitches; • More central boards yield, less side boards; • High sawing accuracy; • High feed speeds • No vibrations.	narrow gullet area clog quickly, especially at high feed speeds and cutting heights.

Sawmilling lines as a combination of chipping units and circular saws are becoming more and more important. They are used mainly for softwoods and for small and medium diameter (10…65cm) logs. Depending on the equipment, a distinction is made between the following lines:

- Reducer lines
- Profiling lines
- Compact lines

Reducer lines are using a separate board edger plant for sideboards while profiling and most of the compact lines are running without. The center boards are splitted also in line with a circular resaw.They are mainly used for standard assortments and the log length is ranging from 2,5 up to 12m.

Profiling lines are the most efficient lines for high production volumes. They are equipped with chipper canters, milling units and circular saws. The machines are allowing high speed rates and still perfect cutting results. The lines are also equipped with 3D measurements for sideboard optimization, by means of moveable, flexible milling heads which are profiling the sideboards correlated to the input of measurement and optimization program. The sideboards are already edged, and can be forwarded to sorting and packaging without passing another processing equipment like a board edger.

Compact lines have similar processing steps like profiling lines, but single aggregates are equipped with more production processes, which make the machine very compact and the length of these lines is shorter than on others. Maintenance and tool change are on limited space, cutting speed and accuracy are on a very high level. Compact lines are installed mainly for small diameters (up to 28cm) productions but are also in use for bigger diameters (up to 80cm).

The most important pro-s and con-s of sawmilling lines are presented in Table 4.

Table 4

Pro-s and con-s of sawmilling lines

Pro-s	Con-s
• High throughput and cutting performance; • High cutting accuracy; • Developed measurement and software support assures high yield and a high value-added production; • The feed speed is linearly adjustable; • In order to increase the yield, curved logs can be cut with a repositioning at the horizontal ax during cutting; • Chips geometry adjustable by speed of chipper canter and milling heads.	• In winter period feed rate is limited by the milling and cutting tool; • High investment costs, necessary infrastructure (building, foundations, by product processes); • High qualified people are needed; • Due to high speed and forces appeared damages are cost intensive; • To increase the recovery different tools (kerf and saw body thickness -depending on cut diameter) are needed.

OBJECTIVE

The main outcome of this research was to compare the lumber yield obtained from a sawlog, depending on the sawing equipment employed.

MATERIAL, METHOD AND EQUIPMENT

The present research is a theoretical approach and it comprises the calculation of the lumber yield for a sawlog of given dimensions, when using different types of sawing equipment.

The log dimensions are given in Table 5, and the cutting pattern is presented in Fig. 1.

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Table 5

Log dimensions

Length, m	Small-end diameter, [mm], measured in two perpendicular directions (see Fig. 1)		Butt-end diameter, [mm]	Taper, [mm/m]	Log volume, [m^3]
3	290	309	330	8	0,23

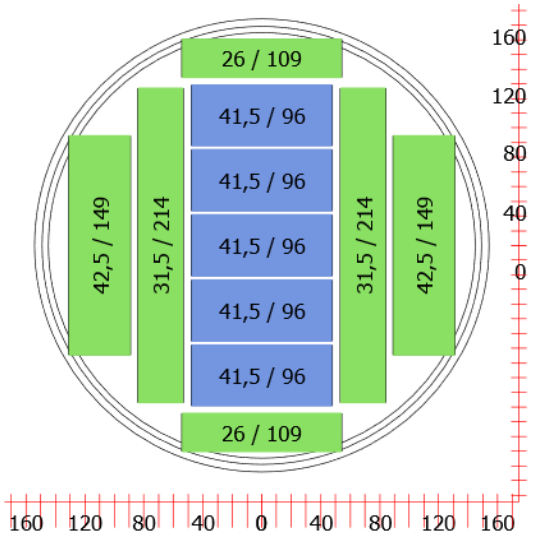
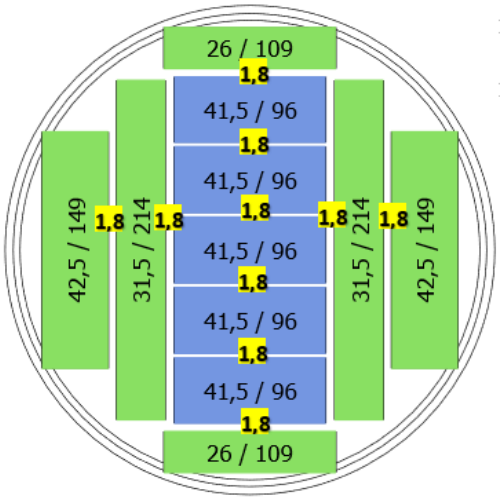
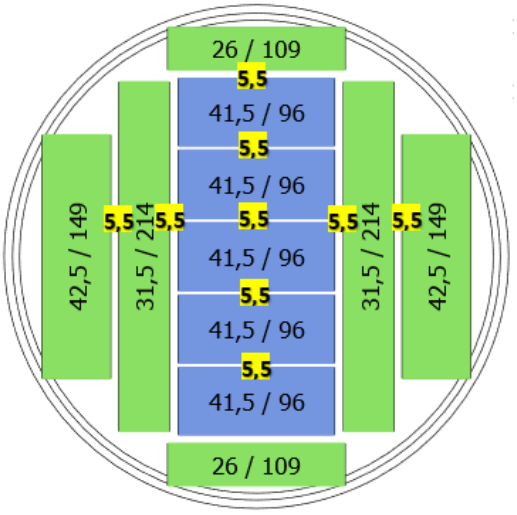


Fig. 1.
Cutting pattern.

The comparison envisaged strictly the influence of the kerf width, which is specific to each sawblade (*e.g.* 1,8mm for bandsaw blades, 5,5mm for circular sawblades etc.) (Fig. 2).



a. mobile sawmill equipped with band saw (kerf width = 1.8mm)



b. mobile sawmill equipped with circular saw (kerf width = 5.5mm)

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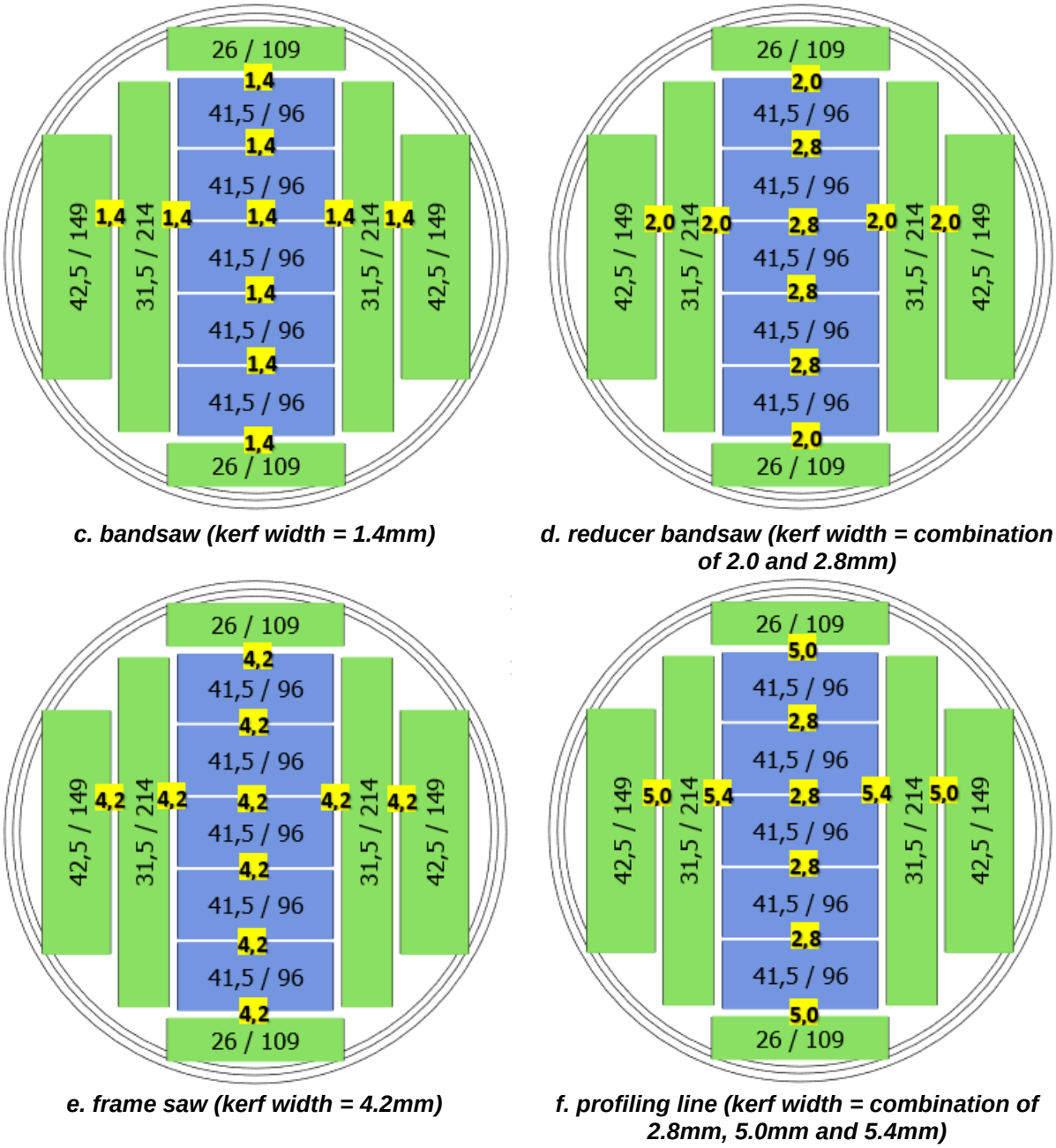

c. bandsaw (kerf width = 1.4mm)

d. reducer bandsaw (kerf width = combination of 2.0 and 2.8mm)

e. frame saw (kerf width = 4.2mm)

f. profiling line (kerf width = combination of 2.8mm, 5.0mm and 5.4mm)

Fig. 2.
Cutting pattern for demonstrative log, cut by means of different saw blades and the corresponding kerf width.

The accepted wane on the resulted lumber boards was max. 25% of the board thickness or width (Fig. 3). Each lumber board that had more than wane than allowed, was not considered for the yield calculation.

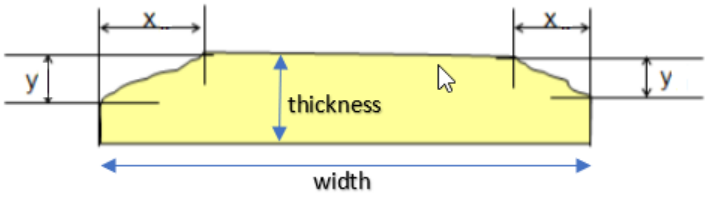

Fig. 3.
Accepted wane: X ≤ 25 % of the width, Y ≤ 25% of the thickness.

RESULTS AND DISCUSSION

The lumber yield obtained in each case is presented in Table 6.

Table 6

Yield of logs, simulated with six different types of sawing equipment

Sawing equipment	Top -end diameter [mm]	Length [mm]	Center boards [pcs.]	Side boards [pcs.]	Yield center boards [%]	Yield side boards [%]	Total lumber yield [%]	Sawdust [%]	Chips [%]
Mobile sawmill with band saw	290-309	3000	5	6	26,13	41,73	67,86	10,24	21,9
Mobile sawmill with circular saw	290-309	3000	5	6	26,13	36,49	62,62	15,2	22,18
Band saw	290-309	3000	5	6	26,13	41,73	67,86	9,67	22,46
Reducer band saw	290-309	3000	5	6	26,13	41,73	67,86	10,8	21,34
Frame saw	290-309	3000	5	6	26,13	39,11	65,24	13,52	21,23
Profiling line	290-309	3000	5	6	26,13	40,24	66,37	14,16	19,47

By analyzing the results presented in Table 6, one may notice that the worst result is generated with the mobile saw equipped with a circular saw. Because of the bigger kerf, the sawdust amount has the highest volume. As this machine is used mainly for cutting big diameter, sometimes only for precutting the logs to be suitable for other sawmilling machines, we should not take too much attention on it.

A mobile saw equipped with a band saw has a very good log conversion efficiency, less sawdust is produced as in most cases the slabs are preferred as firewood or as raw material for a chipper unit. The higher amount of chips shows also, that the cutting pattern can fit for smaller top diameters as well.

The figures of the bandsaw are very good as here the sawdust is with the smallest volume. Same as in the previous case, the cutting pattern can fit for smaller top diameters as well.

In practice, bandsaws are mostly used for hardwood, a lot of time also for high price raw material. Here the advantage of a small kerf is much more important than to have a fast feed rate. It is also preferred for flexible dimension cuts, depending on the appearance of the cut surface and defects which get visible.

The frame saw yield is lower than from bandsaw and profiling line. This is the reason why this machine is losing market shares.

Very interesting is the comparison of the reducer bandsaw and the profiling line. While the profiling line didn't reach the highest possible yield of 67,86%, the combination of reducer bandsaw and circular resaw increases the yield by 1,5%.

A smaller kerf dimension can increase the yield of lumber, and on the other hand it can allow the production planning to decrease the needed small-end diameter, enlarging thus the group of eligible sawlogs.

The suppliers of cutting tools are hardly investigating to get the smallest kerf possible. The most important parameters for them are the sawblade stiffness and the sawblade oscillation in the cutting plane. With additional chrome coating significantly less friction on the body and thinner kerfs are possible.

CONCLUSIONS

According to the computed values, the best results in terms of the lumber yield from a log with given dimensions is achieved by means of a band saw, followed by the profiling line endowed with circular saw unit to split mainboards accordingly to cutting pattern. Worst result is achieved by a mobile circular unit, which is caused by the bigger sawblade diameter and the need of stronger saw body.

The lumber yield amounts at 67,86% the most, out of each less than half are center boards (large sections). Sideboards finally achieve a higher yield. By having bigger cutting height, the circular saws are having the disadvantage of needing a bigger kerf.

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