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CONVERSION EFFICIENCY OF FIR SAWLOGS INTO LUMBER

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Abstract:
The paper presents data regarding the conversion efficiency of resinous sawlogs into lumber, gathered within industry-realistic conditions in a modern Romanian sawmill. The target for any sawmill is to get out the highest percentage of lumber from the log volume input. However, this target is strongly influenced by the quality of the logs, their cylindricity, and also by the available grading and cutting equipment. The presented results may serve as a valuable reference of the performances that can be achieved today, as well as to open new ways of improvement, through the recommendations formulated at the end of this survey.

Key words: *log conversion; lumber; taper; yield.*

INTRODUCTION

Resource-saving actions in lumber production are becoming more and more important, as the demand for wood is constantly increasing. High competitiveness in the sawmill industry leads to improvements in production efficiency and yield recovery.

The log conversion efficiency is one of the most important business and production indicators for wood industry. It represents the ratio between the summed-up volumes of all pieces of lumber resulted from a log and the log volume (without bark). It is calculated according to Eq. (1) (Zeleniuc 2010):

$$\eta = \frac{V_{lumber}}{V_{\log}} \cdot 100 \quad [\%] \qquad (1)$$

The target for sawmills is to get out the highest percentage of lumber from the log volume input. Lumber achieves higher sales prices and the sales market of produced by-products, like chips and sawdust is actually under high pressure.

In Romania, 4 million m^3 of coniferous roundwood are annually converted into sawn wood. Similar to other countries with large quantities of coniferous wood resources, it is important to maximize the utilization of this green resource, and to reduce the total wood waste as much as possible. According to statistical data, the conversion efficiency of resinous sawlogs into lumber generally ranges between 45% and 60% (Fig. 1) in large modern mills, where the generated sawdust volume should not exceed 10% (Blackwell *et al.* 2006).

Fir wood (*Abies alba* Mill.) will gain more importance in future, as a resinous wood resource in Central Europe, due to the big problems encountered by spruce wood (*Picea abies* L.) with bark-beetle (*Scolytidae, Ipidae*) infestation, and also due to increasing demands in the building industry. This is the reason why fir wood was selected for the research.

Next to optimal tools (*e.g.* optimal sawblade thickness), perfectly configurated production lines are needed. 3D-infrared scanners (www.microtec.eu) and x-ray computed tomography (Stangle *et al.* 2015) are used to get maximum information about the raw material and to establish the optimal position for the logs before entering the cutting line. In this way, it is possible to identify wood defects (*e.g.* cracks, resin pockets and knots) on coniferous logs before the cutting processes and to establish the cutting pattern so as to eliminate them but still reach the highest possible yield and targeted product quality.

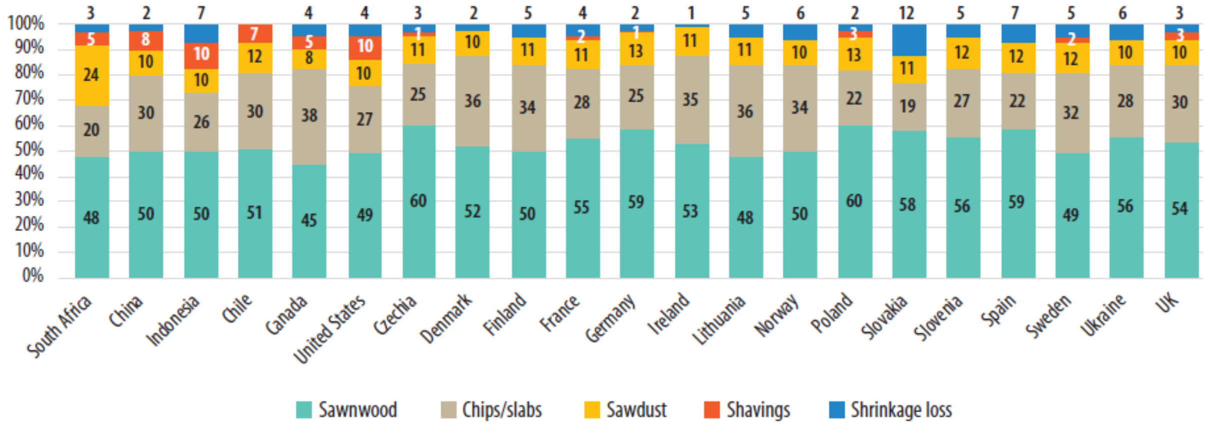

Fig. 1.
Material balance in the sawmilling process for coniferous sawnwood, by reporting country (FAO 2018).

The log conversion efficiency is significantly depending on the shape - 3D model - of the log and the presence of shape defects, such as curvature and taper. Also, the log conversion efficiency is decreasing with the length of the log (Steele 1984), as on longer logs more by-products are produced; this correlates to taper. The origin position of the log before crosscutting the stem has also an influence on the value of taper. The diameter inside bark is decreasing rapidly with increasing stem height near the butt end. The rate of decrease is less on the main part of the stem, coming close to tree top the diameter decreases again rapidly (Chao *et al*. 2013).

OBJECTIVE

The main outcome of this research is to bring a contribution to modern sawmilling technologies, by assessing industry-realistic values of the conversion efficiency of fir sawlogs into lumber, by taking into account several influencing factors (*e.g.* log diameter and taper, measuring devices and cutting patterns), and by proposing new solutions of increasing it.

MATERIAL, METHOD AND EQUIPMENT

The wooden material used within this study consisted of eleven fir (*Abies alba* Mill.) sawlogs, originating from the Romanian geographic region of Bicaz, Piatra Neamt County. They were selected from a bigger batch of freshly harvested roundwood, so that their mid diameter (without bark) fitted within the range 0,30 – 0,35m and their length ranged between 3,00 and 3,30m, which classified them as being eligible for conversion on the VM50 line (by Linck), owned by the company where the measurements were performed.

The shape and dimensions of the selected logs were measured by means of a log shape scanner from Microtec (Italy), functioning on the principle of the 3D laser triangulation: infrared sources are covering the shape of the log, high resolution cameras are providing the iRas XY-position into the program and thus, the scanner provides a true shape scanned image (Fig. 2).

Each single log passed through the measurement unit which provided the most important figures, like: length, top-end diameter, mid-diameter, butt-end diameter, volume, curvature and taper. An example is provided in Fig. 3. The Microtec scanner evaluates the taper according to the following equation:

$$Taper = \frac{MD - d}{L/2} \ [\text{mm/m}] \quad (2)$$

where: *MD* is the mid diameter of the sawlog, in mm;
d – top-end (small end) diameter of the sawlog, in mm;
L – length of the sawlog, in m.

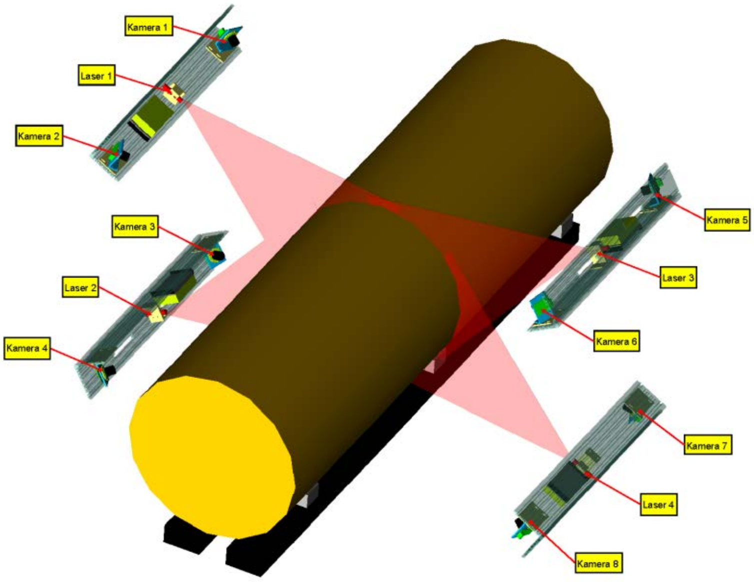

Fig. 2.
Principle of a DiShape scanner: 3D laser triangulation.

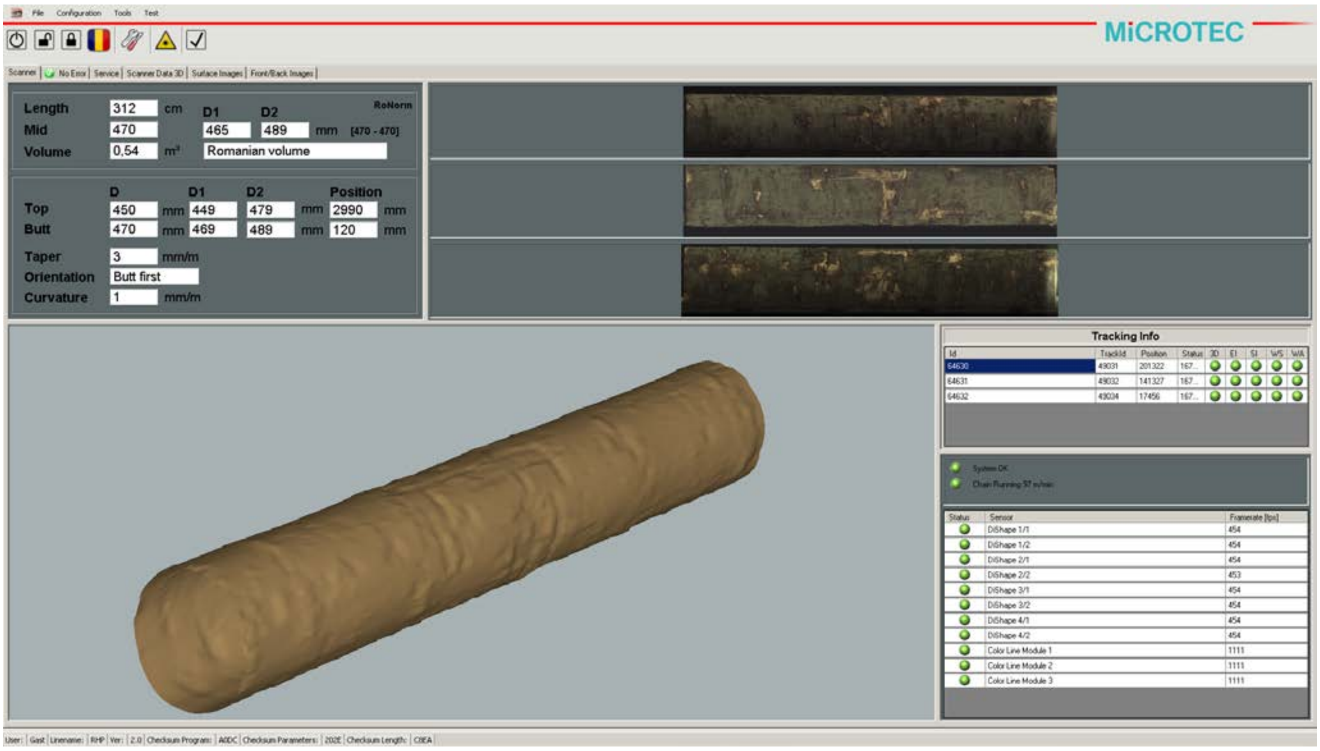

Fig. 3.
Visualization of the measured log, by Microtec (Italy).

The sawlogs were converted into lumber on a cutting line VM50 (Fig. 4), manufactured by the German company Linck. This technological line is endowed with fixed circular sawblades and movable milling units. Sideboards are produced wane-free by the milling units, there is no need for a separate board edger. The chipper and the milling units are equipped with knives and cutter segments; the sawblades are endowed with carbide teeth. The saw kerf was 2,8mm for the central boards, while the sideboards were cut off with a saw kerf of 5,0 and 5,4mm.

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Fig. 4.
VM 50 log conversion line, by Linck (Germany).

The general cutting pattern used for the conversion of the sawlogs is presented in Fig. 5. As shown in Fig. 5, five central boards with cross section 41,5 x 96mm, and two sideboards of each of the following cross section dimensions 26 x 109mm; 31,5 x 214mm and 42,5 x 149mm were envisaged to be obtained from each sawlog. The dimensions of the lumber parts considered eligible when establishing the cutting pattern followed the at-time orders of the sawmill where this conversion was performed.

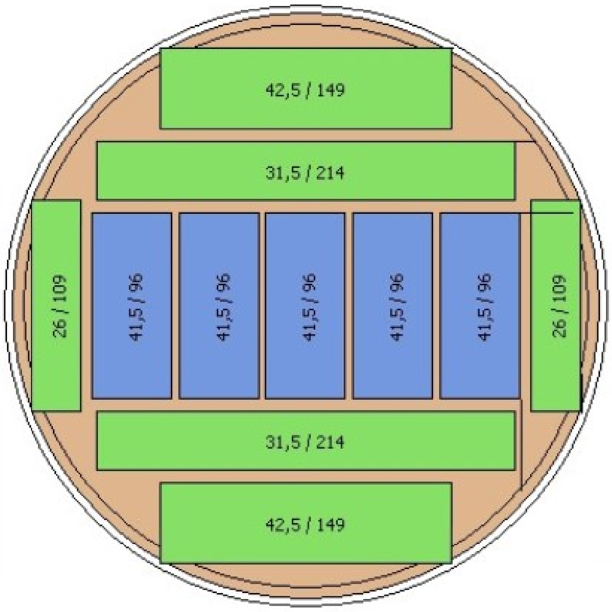


Fig. 5.
General cutting pattern for converting the resinous sawlogs into lumber.

The parameters for the lumber yield calculation were established with an accepted wane of 25% of the width and 25% of the thickness (Fig. 6).

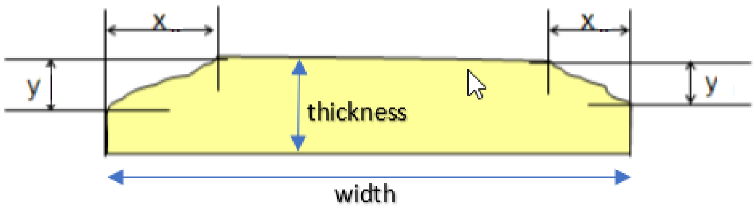


Fig. 6.
Acceptable level of wane for the converted pieces of lumber.

Based on the summed-up volumes of the resulted pieces of lumber, and the sawlog volume assessed by the Microtec scanner, the conversion efficiency (η) was calculated for each log according to Eq.(1).

RESULTS AND DISCUSSION

The exact number and dimensions of the lumber pieces resulted from each sawlog (depending on its dimensions and taper) are presented in Table 1.

Table 1

Number, dimensions and volume of the lumber pieces resulted from each sawlog

Sawlog N°	Length, m	Number of lumber pieces with cross section:			
		41,5 x 96 x mm	31,5mm x 214mm	42,5mm x 149mm	26mm x 109mm
2B	3.07	4pcs. x L=300mm + 1pcs. x L=286mm	2pcs. x L=300mm	1pcs. x L=134mm + 1pcs. x L=102mm	1pcs. x L=298mm + 1pcs. x L=267mm
3E	3.09	5pcs. x L=300mm	1pcs. x L=300mm + 1pcs. x L=287mm	2pcs. x L=297mm	2pcs. x L=300mm
4E	3.18	5pcs. x L=300mm	2pcs. x L=300mm	1pcs. x L=263mm + 1pcs. x L=226mm	1pcs. x L=295mm + 1pcs. x L=215mm
5C	3.13	5pcs. x L=300mm	1pcs. x L=300mm + 1pcs. x L=285mm	2pcs. x L=300mm	2pcs. x L=300mm
5D	3.09	5pcs. x L=300mm	1pcs. x L=300mm + 1pcs. x L=261mm	1pcs. x L=180mm + 1pcs. x L=82mm	1pcs. x L=240mm + 1pcs. x L=200mm
6B	3.19	5pcs. x L=300mm	1pcs. x L=283mm + 1pcs. x L=294mm	1pcs. x L=298mm + 1pcs. x L=293mm	1pcs. x L=283mm + 1pcs. x L=238mm
10E	3.15	5pcs. x L=300mm	1pcs. x L=300mm + 1pcs. x L=276mm	1pcs. x L=267mm + 1pcs. x L=235mm	1pcs. x L=292mm + 1pcs. x L=249mm
11C	3.16	5pcs. x L=300mm	1pcs. x L=300mm + 1pcs. x L=285mm	1pcs. x L=300mm + 1pcs. x L=285mm	2pcs. x L=300mm
12C	3.12	5pcs. x L=300mm	2pcs. x L=300mm	2pcs. x L=300mm	2pcs. x L=300mm
13B	3.21	5pcs. x L=300mm	1pcs. x L=300mm + 1pcs. x L=296mm	1pcs. x L=260mm + 1pcs. x L=200mm	1pcs. x L=200mm + 1pcs. x L=97mm
13C	3.15	3pcs. x L=300mm + 1pcs. x L=295mm + 1pcs. x L=293mm	2pcs. x L=300mm	1pcs. x L=300mm + 1pcs. x L=34mm	2pcs. x L=300mm

The data regarding the lumber volume resulted, and the conversion efficiency of each log are given in Table 2.

Table 2

Conversion efficiency of experimental fir sawlogs, as function of log dimensions and taper value

Sawlog N°, *	Top-end diameter (without bark), m	Length, m	Taper, mm/m	Wood volume of the log (without bark), m^3	Lumber volume resulted from that log, m^3	Conversion efficiency of the sawlog into lumber, %
2B	0.289	3.07	7	0.232	0.130	56.1
3E	0.328	3.09	23	0.297	0.154	51.9
4E	0.297	3.18	25	0.256	0.146	57.0
5C	0.326	3.13	12	0.284	0.154	54.2
5D	0.297	3.09	7	0.233	0.127	54.3
6B	0.326	3.19	18	0.289	0.151	52.2
10E	0.307	3.15	34	0.269	0.146	54.3
11C	0.318	3.16	16	0.287	0.153	53.3
12C	0.312	3.12	13	0.267	0.155	58.1
13B	0.298	3.21	13	0.242	0.146	60.3
13C	0.298	3.15	6	0.223	0.138	61.9
AVG	**0.308**	**3.14**	**15.8**	**0.262**	**0.145**	**55.8**

**Remark: The sawlogs with the same number originate from the same piece of roundwood.*

With an average value of 55.8%, the resulted conversion efficiency fits the upper limit of the usual range (see Fig. 1).

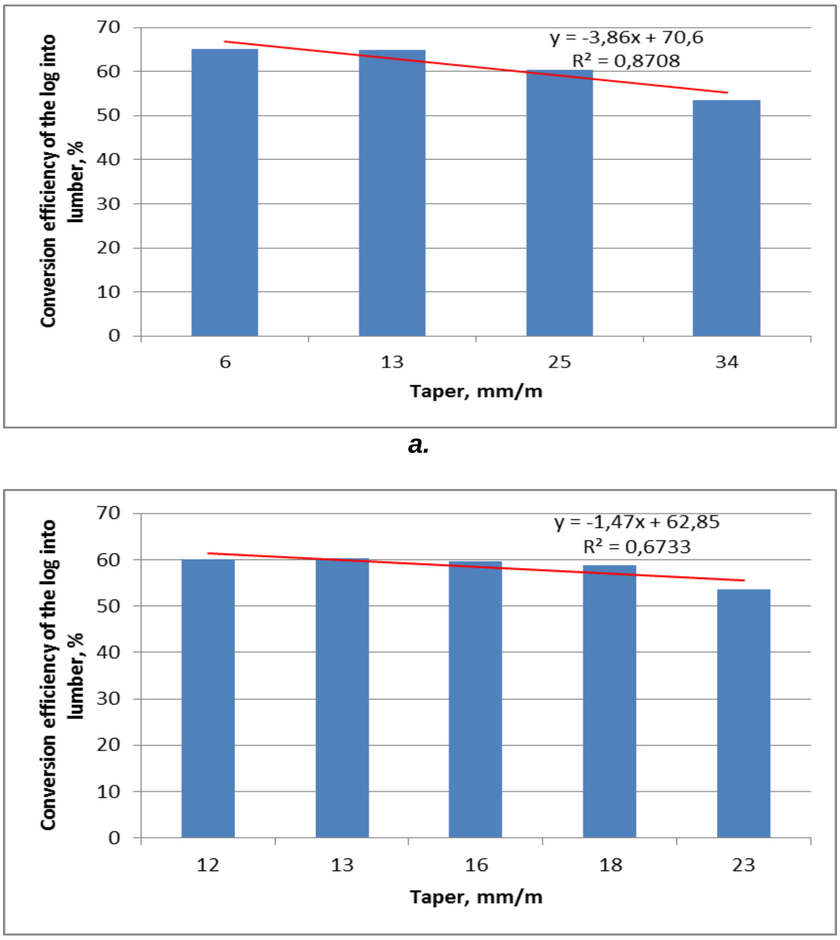
If we analyze the dependency between the conversion efficiency and the taper at similar log length and top-end diameter (*e.g.* 10E vs. 13C), we will notice that the conversion efficiency is affected by the taper, being higher with lower taper values. A correlation between the conversion efficiency and the taper is possible if we group the sawlogs into narrower diameter classes (with a maximum difference of 10mm between the highest and the lowest value). Under these circumstances, the dependency function between the conversion efficiency of the log and the taper is well described by linear descending functions (Fig. 7), with a coefficient of determination R^2=0.87 for the diameter class Φ291-299mm (sawlogs 4E, 10E, 13B and 13C) and R^2=0.67 for the diameter class Φ311-322mm (sawlogs 3E, 5C, 6B, 11C, 12C), respectively. Thus, one may state that high taper has greater impact on the conversion efficiency of the logs, the lower their diameter is.

Similar results were found by Missanjo and Magodi (2015), who stated that there is a significant negative relationship between the lumber recovery percentage and the log taper in *Pinus* conversion.

CONCLUSIONS

According to the values assessed under industrial conditions regarding the dimensions and volume of resinous sawlogs and of the lumber pieces resulted from each log, the conversion efficiency of fir sawlogs in the evaluated modern sawmill ranged between 51.9% and 61.9%, with an average of 55.8%. One of the most important factors of influence was the log taper, which ranged within the selected log batch from 6 to 34mm/m. A high taper value leads to lots of waste due to the limited range of eligible lengths of lumber, as the cutting pattern is aligned to the top diameter.

During the log sorting, all logs are measured and distributed to different assortments boxes, defined by length, top diameter and quality. The measured taper should be a part of classification, adjusted cutting patterns with narrower intervals of length for boxes with high taper will increase the output of lumber.



a.

b.

Fig. 7.
Correlation function between the conversion efficiency and the log taper for sawlogs with a –top-end diameter 291-299mm; b – top-end diameter 311-322mm.

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