

MACHINES FOR PRIMARY LOG CUTTING: PART II – COMPARATIVE ASSESSMENTS AND ANALYSIS

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ABSTRACT

In the paper a developed methodology is presented, which will be useful in a comparison between individual machines for primary cutting of logs – a vertical band saw machine with a carriage feed mechanism (*Üstünkarlı* – Turkey), circular saw machine for logs (*Kallion Konepaja Oy* – Finland) and a mobile horizontal band saw machine (*Arsov 90 Ltd.* – Bulgaria). On the basis of the obtained experimental results, which are presented in the first part of the current study and the technical parameters of the machines, the following evaluation indicators were selected: productivity, dimensional accuracy, roughness of the obtained surfaces, width of the cut, required power, cutting tools, etc. The obtained quantitative results were transformed into point scores. For each of the indicators, a weighting coefficient is also selected, depending on its importance. The advantages and disadvantages of the studied machines are indicated and an analysis of the results is carried out.

Key words: log cutting band saw, log cutting circular saw, mobile horizontal band saw, productivity, dimensional accuracy.

INTRODUCTION

The machines that can be used for primary cutting of logs are band saws, circular saws and frame saws. The first group has the greatest variety, and the band saw machines for logs can be divided into two main types – with carriage feeding, which have a vertical arrangement of the cutting mechanism, and horizontal band saws, also known as mobile band saw machines (Atanasov 2014, Atanasov *et al.* 2018). Apart from them, in some countries, machines whose cutting mechanism includes a chain saw for longitudinal cutting are also used (United States Patent No.: US 8.479,628 B2). There are also those that by means of milling heads of large sizes, simultaneously obtain the peripheral areas of the log into technological chips, after which beams are obtained and then cut into boards (Obreshkov 1996). In our country the machines with a band-cutting mechanism find the greatest application. The likely reason for this mainly lies in the smaller width of the cut, which is obtained when processing with them, the possibility of individual cutting schemes, increasing labor productivity in logs of large sizes, elimination of the need for preliminary sorting of the logs, acceptable quality of the obtained surfaces, etc. On the other hand, the shortage of wood material, as well as the relatively low consumption compared to the leading countries in the industry, turn the frame saws and to some extent circular saw into economically impractical machines for cutting logs.

In the literature, there are experimental studies that can be used to evaluate some parameters when choosing a machine for primary cutting of logs. They mainly apply to machines with a band cutting tool, and in recent years most of them are for mobile horizontal band saws but can also be found for the vertical ones (Atanasov 2013b, Atanasov 2015, Trichkov 2006). There is a lack of research on circular log sawing machines. In the first part of this study, a comparison was made regarding the quality of the resulting surfaces when sawing Scots pine, as expressed by roughness and dimensional accuracy, and the productivity of a vertical band saw machine with carriage feeding mechanism, a horizontal band saw with manual feed, and a circular

saw machine with a carriage feed (Atanasov 2024). There is another study by the author comparing a comparative analysis of beech (*Fagus sylvatica* L.) log cutting with two of the machines under study (Atanasov 2021). In general, however, there are not many papers in the literature that compare the machines used for primary cutting of logs. This also determines the purpose of the present study – on the basis of the obtained experimental results, which are presented in the first part of the current study and the technical parameters of the machines, to carry out a comparative evaluation and analysis of the machines for primary wood cutting.

METHODOLOGY

When choosing a methodology for evaluating the machines for primary cutting of logs, the following indicators were taken into account: productivity, roughness of the obtained surfaces, accuracy of dimensions (The first 3 indicators are after processing of Scots pine), width of the cut, required power, wear resistance of the cutting tools, required investment, maintenance of the machine and cost of the cutting tools, degree of mechanization. The obtained quantitative values are divided by point scales. For each of the indicators, the weighting factor is determined. Through them, a complex evaluation was calculated for each of the studied machines according to the following dependence

$$E_c = \frac{\sum I_i W_{fi}}{\sum W_{ft}}, \quad (1)$$

where E_c is the complex evaluation;

I_i – the i^{th} indicator;

W_f – the weighting factor for the i^{th} indicator;

W_{ft} – the total of the weighting factors.

The point scores are formed depending on the obtained quantitative values for the relevant indicator. The weighting factors are determined depending on the importance of the respective criterion. A similar methodology was also used in the author's previous studies (Atanasov 2013a). However, in this study, receiving a score of $I=5$ in any of the indicators, the machine will not be considered unsuitable and will not be removed from the complex score.

For the purpose of comparability of results, in addition to the three examined machines in the first part of this study, the results of a previous study by the author with a mobile horizontal band saw with mechanized feeding have been added – *Wood-Mizer LT 40* (Atanasov 2014). The general view of the machines can be seen in Figure 1.

The point scales for the criteria are:

Productivity Q_m :

- very good productivity – over $10.1 \text{ m}^2 \cdot \text{min}^{-1}$, $I=0$;
- good productivity – from 7.1 to $10 \text{ m}^2 \cdot \text{min}^{-1}$, $I=1$;
- average productivity – from 5.1 to $7 \text{ m}^2 \cdot \text{min}^{-1}$, $I=2$;
- low productivity – from 3.1 to $5 \text{ m}^2 \cdot \text{min}^{-1}$, $I=3$;
- very low productivity; – from 1.1 to $3 \text{ m}^2 \cdot \text{min}^{-1}$, $I=4$;
- unsatisfactory productivity – below $1 \text{ m}^2 \cdot \text{min}^{-1}$, $I=5$.

Surface roughness (Average value) \bar{R}_m :

- very high class of surface roughness – \bar{R}_m below $120 \text{ }\mu\text{m}$, $I=0$;
- high class of surface roughness – \bar{R}_m between 121 and $150 \text{ }\mu\text{m}$, $I=1$;

- medium class of surface roughness – \bar{R}_m between 151 and 250 μm , $I=2$;
- low class of surface roughness – \bar{R}_m between 251 and 350 μm , $I=3$;
- very low class of surface roughness – \bar{R}_m between 351 and 450 μm , $I=4$;
- unsatisfactory surface roughness class – \bar{R}_m over 451 μm , $I=5$.

Dimensional accuracy (Average value) D_a :

- with a deviation of up to 1 mm with a "+" sign and without a deviation with a "-" sign, $I=0$;
- with deviation up to 1.5 mm with the "+" sign and up to 0.5 mm with the "-" sign, $I=1$;
- with deviation up to 2.0 mm with the "+" sign and up to 0.5 mm with the "-" sign, $I=2$;
- with a deviation of up to 2.5 mm with a "+" sign and up to 1 mm with a "-" sign, $I=3$;
- with a deviation of up to 3 mm with a "+" sign and up to 1 mm with a "-" sign, $I=4$;
- with a deviation of more than 3 mm with a "+" sign and more than 1 mm with a "-" sign, $I=5$.



A)



B)



C)



D)

Figure 1: Machines used for comparison: A) Vertical band saw with carriage feed (*Üstünkarlı – Turkey*); B) Circular saw log cutting machine (*Kallion Konepaja Oy – Finland*); C) Mobile horizontal band saw with manual feed (*Arsov 90 Ltd. – Bulgaria*); D) Mobile horizontal bend saw with mechanized feed (*Wood-mizer LT 40, www.ecotechproduct.com*)

Cutting width C_w :

- width of cut up to 1 mm, $I=0$;
- width of cut from 1.01 to 2.0 mm, $I=1$;

- width of cut from 2.01 to 2.5 mm, $I=2$;
- width of cut from 2.51 to 3.50 mm, $I=3$;
- width of cut from 3.51 to 4.50 mm, $I=4$;
- width of cut over 4.51 mm, $I=5$.

Power of the main electric motor P_m (Only powers that correspond to standard electric motors are used):

- power up to 11 kW, $I=0$;
- power from 15 to 22 kW, $I=1$;
- power from 30 to 45 kW, $I=2$;
- power from 55 to 75 kW, $I=3$;
- power from 90 to 110 kW, $I=4$;
- power over 132 kW, $I=5$.

Wear resistance of cutting tools W_c :

- need for replacement when cutting more than 80.1 m², $I=0$;
- need for replacement when cutting between 50.1 and 80 m², $I=1$;
- need for replacement when cutting between 35.1 and 50 m², $I=2$;
- need for replacement when cutting between 20.1 and 35 m², $I=3$;
- need for replacement when cutting between 10.1 and 20 m², $I=4$;
- need for replacement when cutting below 10 m², $I=5$.

Required investment I_i :

- minimum investments are required, $I=0$;
- small investments are required, $I=1$;
- investments between small and medium-sized are required, $I=2$;
- medium-sized investments are required, $I=3$;
- large investments are required, $I=4$;
- very large size investments are required, $I=5$.

Maintenance of the machine and price of the cutting tools C_p :

- with low price and easy maintenance, $I=0$;
- with low price and moderately difficult maintenance, $I=1$;
- with low price and difficult maintenance, $I=2$;
- with a high price and easy maintenance, $I=3$;
- with a high price and moderately difficult maintenance, $I=4$;
- with a high price and difficult maintenance, $I=5$.

Level of mechanization M_l :

- all working movements in the machine are mechanized, $I=0$;
- a significant part of the work movements are mechanized, $I=1$;
- most of the work movements are mechanized, $I=2$;
- half of the work movements are mechanized, $I=3$;
- a small part of the work movements are mechanized, $I=4$;
- only the cutting movement is mechanized, $I=5$.

RESULTS AND DISCUSSION

1. Productivity is an important indicator that is essential when choosing a primary log cutting machine. Taking into account that in recent years there are no factories with a large volume of production in our country, as well as the fact that there is often a shortage of wood, the accepted weighting coefficient for this indicator is $W_f=3$. Accordingly, the circular machine received the highest score – $I=0$. For the band saw with carriage feed $I=2$, for both horizontal band saw machines $I=4$.

2. Since the obtained boards after processing with the studied machines will be hydrothermally treated to a moisture content of about 10÷12%, the high class of roughness is generally not a priority of the machines for primary cutting of logs. In addition, subsequent operations are almost always processed on longitudinal milling machines. For this reason, the adopted weight factor for this indicator is $W_f=1$. The obtained points are: circular machine $I=0$, band saw with carriage $I=2$, mobile horizontal band saws $I=3$. In this case, the average values of the roughness obtained with the studied machines were taken.

3. Dimensional accuracy is an important parameter for the band saw machines. The main reason is less transverse resistance that their cutting tools have. It is related to the main parameters of the wheels and the band saw blades. As known from standard BDS EN 1313–1:2010, deviations in the nominal dimensions of softwood boards with a thickness of less than 100 mm should not exceed 3 mm or be less than 1 mm. In the examined machines, when feeding at a normal speed for them, the deviations with a negative sign did not exceed 1 mm, and the closest to the lower limit were for the mobile horizontal band saws. The adopted weighting factor for this indicator is $W_f=4$, and the resulting points are: circular machine $I=2$, vertical band saw $I=3$, mobile horizontal band saws $I=4$.

4. Almost all horizontal band saws work with narrow-band saw blades with side-set teeth and around 1 mm thick. The size of their side-set varies approximately from 0.4÷0.6 mm. This means that the width of the cut when processing with them will be approximately 2 mm. On log band saw machines, the teeth are often stellite, with the blade thickness being approximately 1 000 times less than their wheel diameter. In our country, band saw machines with a carriage rarely work with wheels with a diameter of more than 1 200 mm. This means that their cutting tools will be about 1 mm thick, and hence the cut width will be just over 2 mm. One of the main disadvantages of circular machines is a wide cut, which is a consequence of the greater thickness of the saw. This results in an undesired decrease in quantitative yield. The weighting factor of this indicator is $W_f=4$. The points are: circular machine $I=5$, band saw with carriage $I=2$, mobile horizontal band saws $I=1$.

5. One of the factors on which the feed rate and hence the productivity of log machines depends is the power of the electric motor that drives the cutting mechanism. However, it also has a great impact on the consumption of electricity, and as is known, its price has increased significantly in recent years. For this reason, the weight factor of this parameter is $W_f=5$. The point evaluations of the examined machines are: circular machine $I=3$, band saw with carriage $I=1$, mobile horizontal band saw $I=0$.

6. The wear resistance of cutting tools is an indicator on which the time of performing useful work of the machine depends. This is of particular importance in factories with a high production volume. As already mentioned, the factories in our country are mostly of small

capacity. For this reason, the chosen weighting factor is $W_f=2$. The points are: circular machine $I=0$, band saw with carriage $I=1$, mobile horizontal band saws $I=3$.

7. Since the only one of the examined machines for which there is data on an actual price is the *Wood-mizel LT40* mobile bandsaw (About BGN 65 000 without VAT for a machine with a full degree of mechanization, according to *Ecotechproduct Ltd.*) the complex evaluations according to the indicator Required investment will be judged for the type of machine in general. As is known, the machines for logs, in which the feeding movement is carried out by the processed object, have significantly larger overall dimensions and price. For this reason, the accepted scoring values are: circular machine $I=5$, vertical band saw $I=5$, mobile horizontal band saw *Wood-mizer I=1* and mobile horizontal band saw *Asrov 90 I=0*, and the weight factor is $W_f=5$.

8. According to the indicator Machine maintenance and cost of cutting tools, mobile horizontal band saws that work with narrowband saws receive the best scores. They mostly have side-set teeth, the tips of which are hardened by electromagnetic induction. Their maintenance is extremely easy, and according to *Ecotechproduct Ltd.*, the price of similar cutting tools is BGN 35-40 without VAT. The weighting factor of this parameter is $W_f=5$, and the machine scores are: circular machine $I=5$, band saw with carriage $I=3$, mobile horizontal band saw machines $I=0$.

9. All machines, with the exception of mobile band saw with manual feeding, have a high degree of mechanization and with them almost every working part is driven – feeding, turning, gripping and positioning of the logs. With the *Arsov 90* band saw, these operations are performed manually. The selected weight factor is $W_f=3$, and the results are: circular machine $I=1$, vertical band saw $I=1$, mobile horizontal band saw *Wood-mizer LT 40 I=1*, and for mobile horizontal band saw *Arsov 90 I=4*.

Table 1 presents the summary results according to the relevant criteria, together with the weighting factors. Figure 2 shows a graph for the studied machines after solving formula 1. The obtained results are: circular machine – $E_c=3$, band saw with carriage – $E_c=2.44$, mobile horizontal band saw *Wood-Mizer LT 40* – $E_c=1.53$ and mobile horizontal band saw *Arsov 90* – $E_c=1.66$.

Table 1: Results by criteria

№	Machine	Indicator/Weight factor (I/W_f)									
		$Q_m/$ 3	$\bar{R}_m/$ 1	$D_a/$ 4	$C_w/$ 4	$P_m/$ 5	$W_c/$ 2	$I_f/$ 5	$C_p/$ 5	$M_l/$ 3	
1.	Circular machine (<i>Kallion Konepaja Oy</i>)	0	0	2	5	3	0	5	5	1	
2.	Vertical band saw (<i>Üstünkarli</i>)	2	2	3	2	1	1	5	3	1	
3.	Horizontal band saw (<i>Wood-Mizer LT40</i>)	4	3	4	1	0	3	1	0	1	
4.	Horizontal band saw (<i>Arsov 90</i>)	4	3	4	1	0	3	0	0	4	

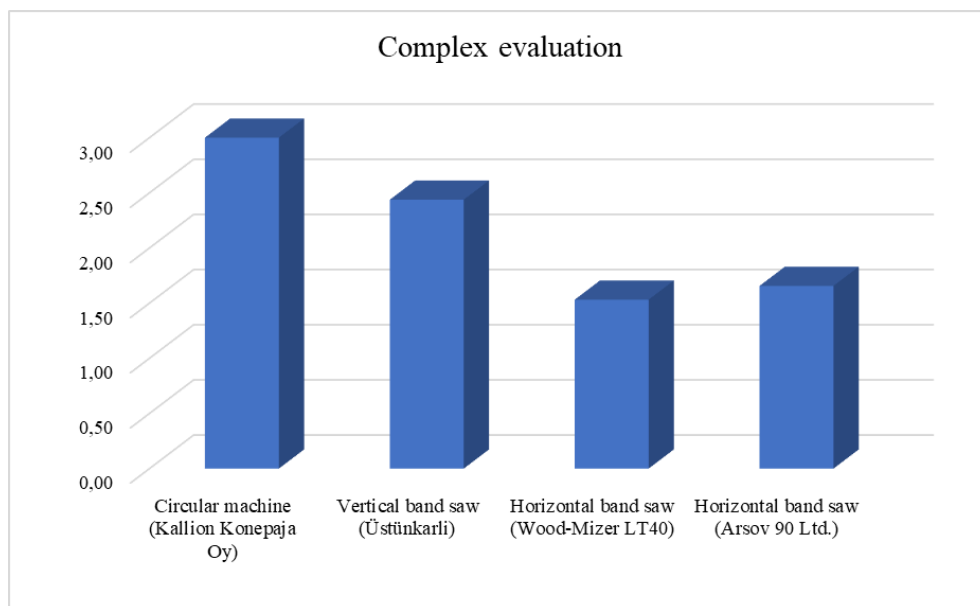


Figure 2: Complex ratings for the machines under study

CONCLUSIONS

The following more important conclusions and recommendations can be made on the basis of the obtained complex assessments:

1. Mainly due to the fact that at present there are no large factories that are engaged in the processing of logs, horizontal band saws receive the best complex grades $E_c = 1.53$ and $E_c = 1.66$. The small advantage in favor of the *LT 40* model is the high degree of mechanization that this machine has compared to the *Arsov 90* band saw. This greatly eases the work, as it is possible for only one person to work on the machine. However, its price is higher than that of a manual feed band saw.

2. The main disadvantages of the circular saw are the large power required to drive the cutting mechanism, its difficult maintenance, the expensive cutting tools and the considerable width of the cut. This makes these machines rarely used in our country, as more reliance is placed on quantitative yield rather than productivity. The resulting complex score is $E_c = 3$.

3. The vertical band saws for logs are gradually being replaced by mobile horizontal ones in our country. The main reasons are the more expensive cutting tools, the necessary investment and the shortage of raw materials in our country. The obtained complex score is $E_c = 2.44$. It should not be overlooked that the machine under study is a relatively light type of vertical band saw with a carriage.

4. It is necessary to add modern log frame saws for logs in future similar studies. The used machines in our country are old and depreciated and for that reason it would not be proper to include them in the present study.

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