

INVESTIGATION OF THE OPERATING CONDITIONS BY CUTTING OF POPLAR AND PINE LOGS THROUGH WIDE BAND SAW BLADES WITH PART-SET AND SWAGE-SET TEETH

Zhivko Gochev

University of Forestry, 10 Kliment Ohridski blvd, 1756 Sofia, Bulgaria,
e-mail: zhivkog@yahoo.com

ABSTRACT

The paper presents some experimental results concerning cutting process of poplar and pine logs through wide band saw blades with part-set and swage-set teeth. The researches were carried out in a production process of company „Fagus Ltd“, town Pernik. The influence of the feed speed and height of cutting on the productivity of the process and energy consumption were analyzed. The results are suitable to have a better knowledge and work out of the production and operating indexes and its optimization by using of wide band saw blades.

Key words: width band saw blade, part- set, swage-set, teeth, cut-out, process, pine, poplar, logs

INTRODUCTION

In recent years, band saw machines are preferred by many producers in the saw mill industry. By sawing the logs into boards are used vertical band saw machines with auto carriage and mobile horizontal band saws. Band saw machines have several advantages over other machines for logs sawing like a small width of cut, high quality board surfaces, individual log processing, do not require special sorting of logs before cutting, etc. In Bulgaria when working with wide band saw blades, the most commonly used teeth are part-set and swage-set (Obreshkov 1998).

The band saw blades wear down both in the cutting process, and the process of sharpening. The quick blunted and wearing out of the band saw blade causes greater resistance at cutting and feed, greater consumption of energy and worsens the quality of the surfaces as well (Gochev 2005).

The aim of this work is to experimentally examine the impact of feed rate on power consumption and performance of the cutting mechanism for cutting logs of

poplar and pine with wide band saws and rolled side set teeth.

METHODS

Studies were conducted in terms of production company „Fagus“ Ltd., Pernik. The logs of poplar (*Populus alba* L. and *Populus tremula* L.) and white pine (*Pinus sylvestris* L.) were cutting band saw with a trolley block – model „DURA“, (Turkey), with the following technical parameters:

- $D=1000$ mm – saw wheel diameter;
- $L_0=2470$ mm – distance between wheel axes;
- $N=30$ kW – motor power;
- $n_e=1470$ min^{-1} – revolutions per minute (RPM) of the motor;
- $D_1=140$ mm – a belt diameter of the electric motor;
- $D_2=420$ mm – a belt diameter of the leading band saw shaft;
- $V=26$ $\text{m}\cdot\text{s}^{-1}$ – cutting speed;
- $U_{\min}=3,0$ $\text{m}\cdot\text{min}^{-1}$ – minimum feed speed;
- $U_{\max}=30,0$ $\text{m}\cdot\text{min}^{-1}$ – maximum feed speed.

The logs were submitted with the trolley running on rails, the rate of which varies

continuously with a hydraulic mechanism. Feed rate is variable and is regulated by the worker - experience, depending on the height of the slot, the density of the wood, the efficiency of the saw blade and cutting power. In the process of cutting the logs, it was determined the mean value formula (1):

$$U_{\text{aver..i}} = \frac{L_{\text{log}}}{t_i}, \quad (1)$$

Where $U_{\text{aver..i}}$ is a average value of the feed speed, $\text{m}\cdot\text{min}^{-1}$;

L_{log} – the length of the logs, m;

Table 1: Linear and angular parameters of the saw blade with part-set teeth

Type of tooth profile	L, m	B, m	s, mm	s', mm	b, mm	t, mm	h', mm	r, mm	$\alpha, ^\circ$	$\beta, ^\circ$	$\gamma, ^\circ$
NV	8,1	98	1,1	0,7	2,5	20	8	3,5	24	48	18

Table 2: Linear and angular parameters of the saw blade with swage-set teeth

Type of tooth profile	L, m	B, m	s, mm	s', mm	b, mm	t, mm	h', mm	r, mm	$\alpha, ^\circ$	$\beta, ^\circ$	$\gamma, ^\circ$
NU	8,1	97	1,1	0,6	2,3	35	11	3,5	25	46	19

Table 3 shows average logs' moisture. It was measured with a hygrometer model „Lignomat Tester1“ (Germany) and average density – by weight method with the help of an electron scale RADWAG, model WLC1/A2 (Poland) with precision 0,01 g.

Table 3: Basic physical characteristics of the experimental wood

N ^o	Wood species	Moisture content, %	Density, $\text{kg}\cdot\text{m}^{-3}$
1.	Poplar	60	600
2.	White pine	80	770

Before starting of the cutting process the logs' diameter was measured in the both end – tip ($d_{\text{min1}}/d_{\text{min2}}$) and butt end ($d_{\text{max1}}/d_{\text{max2}}$). The average diameter of the logs was calculated according to formula (2) and the volume – at formula (3).

$$d_{\text{aver}} = \frac{d_{\text{min1}} + d_{\text{min2}} + d_{\text{max1}} + d_{\text{max2}}}{4}, \quad (2)$$

Where d_{aver} is the average diameter of the log, m;

d_{min} – log's diameter in the tip end, m;

t_i – the time that one cut is doing during the logs cutting, min.

The experimental investigations were carried out with band saw blades of a firm „Röntgen“ – Germany, made of a low alloy tool steel, brand CT75W3 according to DIN 544/17222 with hardness – HRC 44^{±1} with part-set and swage-set teeth.

The linear and angular parameters of the blades are showed in tables 1 and 2.

d_{max} – log's diameter in the butt end, m.

$$O_{\text{aver}} = \frac{\pi \cdot d_{\text{aver}}^2}{4} L_{\text{log}}, \quad (3)$$

Where O_{aver} is the average volume of the log, m^3 ;

L_{log} – the log's length, m.

At every one of the got lumber material (un-edged boards, rough-edged prisms and etc.) was measured it average width (h_{aver}). The input power of the cutting mechanism was performed in idle running ($N_{\text{id.run}}$) and in operating work ($N_{\text{inp.aver}}$). For that purpose was used electronic device type US301EM of a firm Unisyst Engineering Ltd. (Bulgaria). It is intended for technological measurement of single-phase or three-phase electrical energy.

Power Consumption (E) and performance of the mechanism for cutting (Q), were calculated by formula (4 and 5) (Gochev and Denev 2003).

$$E_{aver.} = \frac{N_{inp.aver.}}{60 \cdot U_{aver.} \cdot h_{aver.}}, \quad (4)$$

Where $E_{aver.}$ is the average cost of electricity, kWh.m⁻²;

$N_{inp. aver.}$ – The average input of the cutting mechanism, kW;

$h_{aver.}$ – The average height of the groove, m;

$U_{aver.}$ – Average feed rate, m.min⁻¹.

$$Q_{aver.} = U_{aver.} \cdot h_{aver.}, \quad (5)$$

Where $Q_{aver.}$ is the average productivity of the cutting mechanism, m².min⁻¹.

REZULTS

The diameter of the poplar logs during the test ranged from 180 mm to 570 mm and the number of the cuts from 3 to 9. The diameter of the white pine logs was from 140 mm to 450 mm and the number of the cuts from 1 to 8.

The saw blades were changed every two hours because of restriction on its wearing out and facilitated the recovery process of the teeth cutting capacity as well.

The working capacity of the band saw blade depended and on availability of a sand and metal objects in the logs' bark occur frequently especially in the poplar wood.

The abrasion of the saws is noticed also and on the alteration of the sawdust mode. The sawdust acquired a powdered consistence.

In addition of that along with the teeth abrasion decreased its part-set size or the size of the swage-set. Tightly press sawdust remained on the surfaces of the boards. The probability to be obtaining a curvilinear cut is bigger. An indicator for teeth blunted is the changing the saw blade sound during the cutting process. The sound got sharper. The band saw blade starts to „play”.

In table 4 are showed the generalized average values of the tested quantities by cutting of poplar and white pine logs wide through band saw blades with part-set and swage-set teeth.

Table 4: Generalized average values from the experimental test

PART-SET TOOTH, POPLAR										
Number the logs	$d_{aver.i}$ m	$L_{log.i}$ m	O_i m ³	Number of cuts	$h_{aver.}$ m	t_{aver} s	$U_{aver.}$ m.min ⁻¹	$N_{inp.aver.}$ kW	E_{aver} kWh.m ⁻²	Q_{aver} m ² .min ⁻¹
19	0,38	2,10	0,260	6	0,246	10,7	12,74	17,48	0,097	3,12
	ΣO_i		4,9				$\Sigma E_{aver}; \Sigma Q_{aver}$		1,841	59,27
SWAGE-SET TOOTH, POPLAR										
Number the logs	$d_{aver.i}$ m	$L_{log.i}$ m	O_i m ³	Number of cuts	$h_{aver.}$ m	t_{aver} s	$U_{aver.}$ m.min ⁻¹	$N_{inp.aver.}$ kW	E_{aver} kWh.m ⁻²	Q_{aver} m ² .min ⁻¹
23	0,35	2,14	0,252	5	0,227	9,8	14,48	17,2	0,094	3,33
	ΣO_i		5,8				$\Sigma E_{aver}; \Sigma Q_{aver}$		2,153	76,54
PART-SET TOOTH, WHITE PINE										
Number the logs	$d_{aver.i}$ m	$L_{log.i}$ m	O_i m ³	Number of cuts	$h_{aver.}$ m	t_{aver} s	$U_{aver.}$ m.min ⁻¹	$N_{inp.aver.}$ kW	E_{aver} kWh.m ⁻²	Q_{aver} m ² .min ⁻¹
14	0,27	2,86	0,181	4	0,179	15,2	13,8	18,6	0,141	2,23
	ΣO_i		2,53				$\Sigma E_{aver}; \Sigma Q_{aver}$		1,967	31,27
SWAGE-SET TOOTH, WHITE PINE										
Number the logs	$d_{aver.i}$ m	$L_{log.i}$ m	O_i m ³	Number of cuts	$h_{aver.}$ m	t_{aver} s	$U_{aver.}$ m.min ⁻¹	$N_{inp.aver.}$ kW	E_{aver} kWh.m ⁻²	Q_{aver} m ² .min ⁻¹
34	0,243	2,90	0,142	4	0,174	9,1	20,4	17,9	0,088	3,47
	ΣO_i		4,82				$\Sigma E_{aver}; \Sigma Q_{aver}$		2,977	118,08

Figures 1, 2, 3 and 4 show the dependencies that express to the influence of feed rate (U) on the productivity of the process

(Q) and energy consumption (E) by cutting of poplar and white pine logs with part-set and swage-set teeth.

DISCUSSION

The general trend is that with increasing the feed rate (U), the productivity of the cutting mechanism (Q) increases, and energy consumption (E) decreases, which is logical.

However, there are deviations from these relationships, as seen in the figures. They are related to peculiarities in the construction of wood, its condition and how feed the logs. Some logs have more knots and warts, curves, irregular shape, double kernel with split trunk and vegetation groves as well. The with pin logs had larger density

and content of resin. Moreover large number of knots was fixed from 6, 8 to 10 with sizes from 10 to 40 mm along the whole length of the logs.

Those defects in the wood impede the cutting process and cause limiting to feed rate. In the same time some of the logs are on a young wood with less density and others are attacked by mushrooms and become blue. This interprets and higher feed rate of the logs. Except this forces exerted on the band saw are less when the log is fed from top to the stump part that suggests as well higher feed rate.

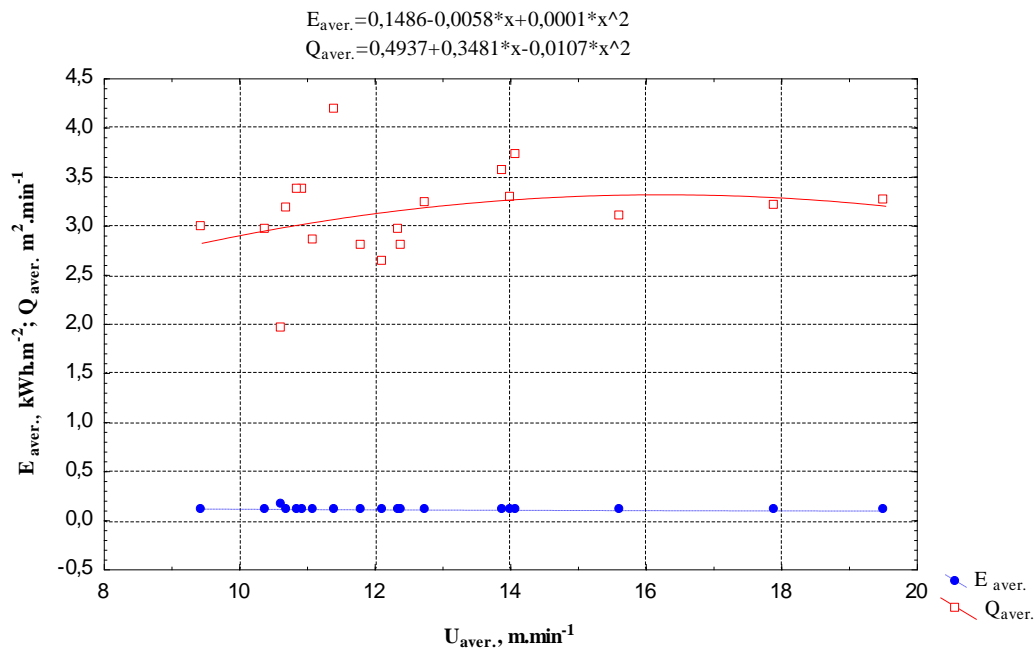


Figure 1: Influence of the feed speed (U) on the productivity of the process (Q) and energy consumption (E) by cutting of poplar logs with parted-set teeth

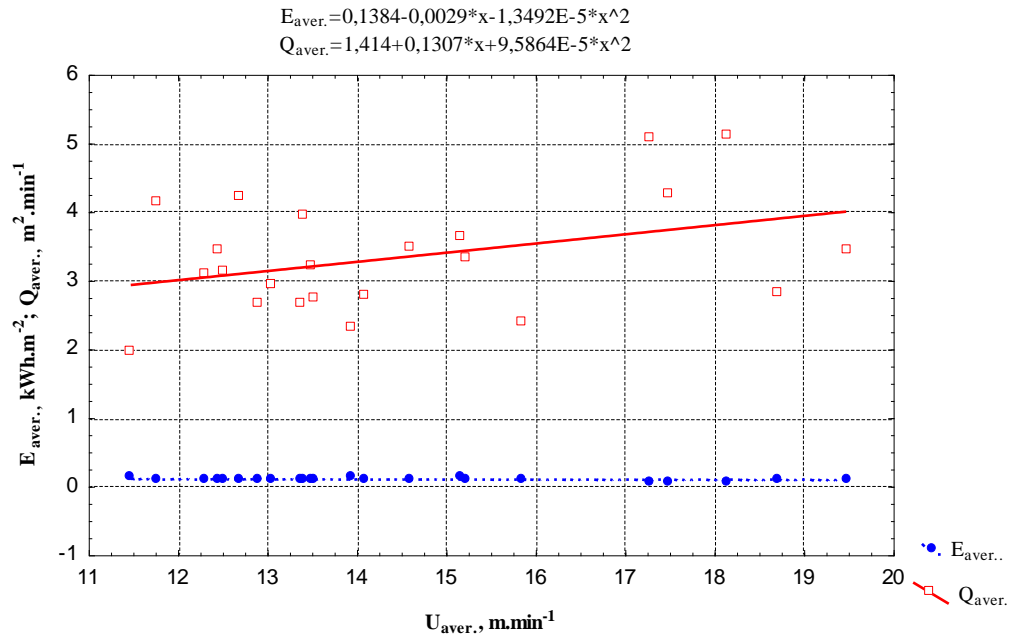


Figure 2: Influence of the feed speed (U) on the productivity of the process (Q) and energy consumption (E) by cutting of poplar logs with swage-set teeth

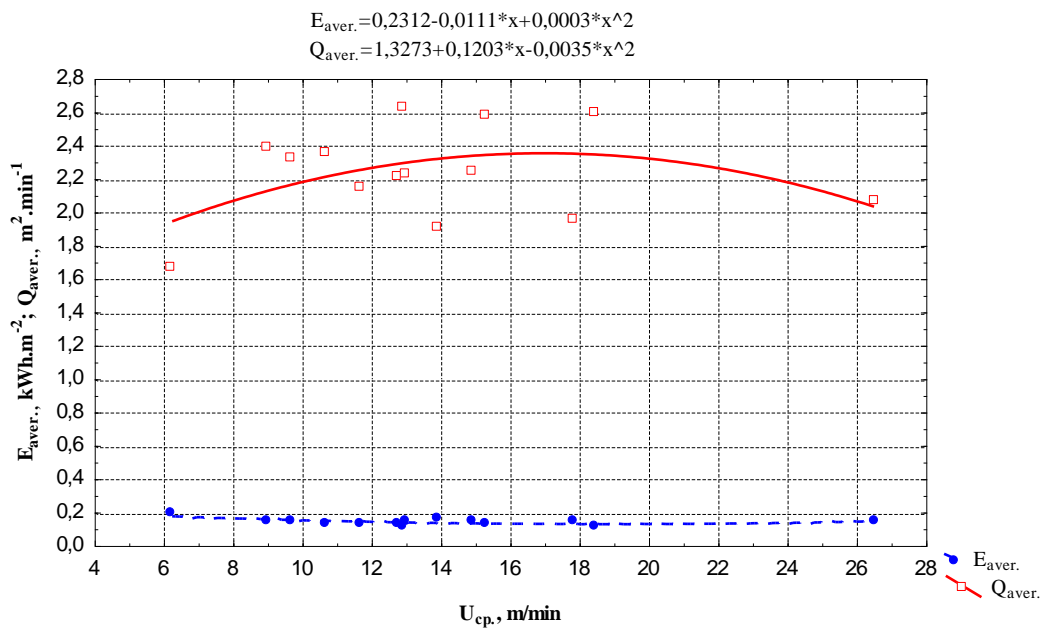


Figure 3: Influence of the feed speed (U) on the productivity of the process (Q) and energy consumption (E) by cutting of white pine logs with parted-set teeth

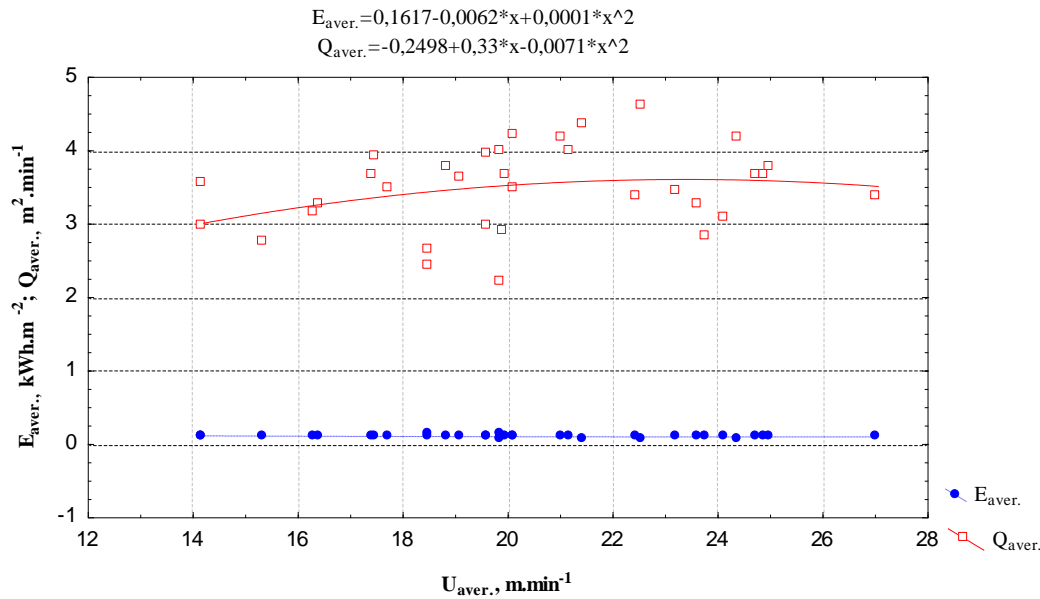


Figure 4: Influence of the feed speed (U) on the productivity of the process (Q) and energy consumption (E) by cutting of white pine logs with swage-set teeth

The human's factor does not must be ignored because to a certain extent the control of the logs cutting process depend on the operator' sense. How he feels the work on the saw blade in it interaction with the wood.

The tooth chamber's area (F_{ar}) of the parted-set and swage-set teeth was respectively 88 mm^2 and 235 mm^2 . It less capacity limited the possibility of using higher feed rates.

The average feed rate by cutting with parted-set is only with 12 % less than with swage-set teeth by cutting of poplar wood but at white pine the difference grow up to 32 %

When sawing poplar logs with part-set teeth, the energy consumption was respectively $E_{aver.min} = 0,086 \text{ kWh.m}^{-2}$ under $U_{aver.} = 15,62 \text{ m.min}^{-1}$ and $h_{aver.} = 0,198 \text{ m}$, but $E_{aver.max} = 0,144 \text{ kWh.m}^{-2}$ under $U_{aver.} = 10,62 \text{ m.min}^{-1}$ and $h_{aver.} = 0,183 \text{ m}$. The productivity of the process ($Q_{aver.}$) ranged from $1,94 \text{ m}^2.\text{min}^{-1}$ to $4,17 \text{ m}^2.\text{min}^{-1}$, which is achieved under $U_{aver.} = 10,62 \text{ m.min}^{-1}$,

$h_{ver.} = 0,183 \text{ m}$ and $U_{aver.} = 11,43 \text{ m.min}^{-1}$, $h_{aver.} = 0,265 \text{ m}$.

For the band saw blade with swage-set teeth – $E_{aver.min} = 0,060 \text{ kWh.m}^{-2}$ under $U_{aver.} = 18,5 \text{ m.min}^{-1}$ and $h_{caver.} = 0,281 \text{ m}$, but $E_{aver.max} = 0,142 \text{ kWh.m}^{-2}$ under $U_{aver.} = 11,48 \text{ m.min}^{-1}$ and $h_{aver.} = 0,170 \text{ m}$. The productivity of the process ($Q_{aver.}$) for the swage-set teeth ranged from $1,95 \text{ m}^2.\text{min}^{-1}$ to $5,10 \text{ m}^2.\text{min}^{-1}$, which is achieved under $U_{aver.} = 11,48 \text{ m.min}^{-1}$, $h_{aver.} = 0,170 \text{ m}$ and $U_{aver.} = 18,15 \text{ m.min}^{-1}$, $h_{aver.} = 0,281 \text{ m}$.

Average feed rate by sawing of wite pine logs with part-set teeth is 32 % lower than the swage-set teeth.

White pine logs have greater density and resin content. Furthermore, it was established many knots from 6, 8 to 10 in number along the log wit sizes from 10 to 40 mm. All this affects on the productivity of the process and energy consumption.

The volume of sawing white pine logs with par-set and swage-set teeth amounted respectively to $2,53 \text{ m}^3$ and $4,82 \text{ m}^3$. It is seen that wit swage-set teeth ware sawed almost double (90 %) greater than the vol-

ume of timber than part-set teeth. While the use of a saw blade part-set teeth, very quickly felt its wearing, this one with the swage-set teeth could still work.

By cutting of pine logs productivity of the process and energy consumption are largely determined by the condition of the wood - the amount and type of knots, crooks, warping and more defects of the wood.

By using the band saw blade with part-set teeth the energy consumption was respectively $E_{\text{aver.min}}=0,117 \text{ kWh/m}^2$ under $U_{\text{cp.}}=18,46 \text{ m.min}^{-1}$ and $h_{\text{aver.}}=0,14 \text{ m}$, but $E_{\text{aver.max}}=0,193 \text{ kWh.m}^{-2}$ under $U_{\text{aver.}}=6,26 \text{ m.min}^{-1}$ and $h_{\text{aver.}}=0,266 \text{ m}$. Consumption of electricity is greater than poplar logs sawing. The productivity of the process ($Q_{\text{aver.}}$) ranged from $1,67 \text{ m}^2.\text{min}^{-1}$ to $2,63 \text{ m}^2.\text{min}^{-1}$, which is achieved under $U_{\text{aver.}}=6,26 \text{ m.min}^{-1}$, $h_{\text{aver.}}=0,266 \text{ m}$ and $U_{\text{aver.}}=12,94 \text{ m.min}^{-1}$, $h_{\text{aver.}}=0,203 \text{ m}$, i.e. the productivity of the process is less.

For the band saw blade with swage-set teeth - $E_{\text{aver.min}}=0,066 \text{ kWh.m}^{-2}$ under $U_{\text{aver.}}=22,56 \text{ m.min}^{-1}$ and $h_{\text{aver.}}=0,205 \text{ m}$, but $E_{\text{aver.max}}=0,144 \text{ kWh.m}^{-2}$ under $U_{\text{aver.}}=18,48 \text{ m.min}^{-1}$ and $h_{\text{aver.}}=0,131 \text{ m}$.

The productivity of the process ($Q_{\text{aver.}}$) for swage-set teeth ranged from $2,42 \text{ m}^2.\text{min}^{-1}$ to $4,35 \text{ m}^2.\text{min}^{-1}$, which was achieved under $U_{\text{aver.}}=18,48 \text{ m.min}^{-1}$, $h_{\text{aver.}}=0,131 \text{ m}$ and $U_{\text{aver.}}=21,44 \text{ m.min}^{-1}$, $h_{\text{aver.}}=0,203 \text{ m}$.

Analysis of the results shows that the use of wide band saw blades for sawing of dense and resin content wood such as white pine, more appropriate use is swage-set teeth than part-set.

CONCLUSION

In conclusion it can be generalized from the made analyses:

1. By sawing of poplar logs it is well for wide band saw blades to be used part-set teeth, even though better results are got with swage-set teeth but the difference is not great. The poplar wood is softer and has fibrous structure. The preparation of the part-et teeth is more easily and there price is less.
2. Using wide band saw blades with swage-set teeth when sawing dense and resin content wood such white pine is really more appropriately than the use of part-set teeth.
3. The results that were received can be used for additional analyses and discounts, inclusive as well for optimizing the sawing processes for example to achieve maximum productivity of the process with minimum energy consumption and so on.

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