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Influence of qualitative and dimensional classification of Pinewood raw material as an efficiency indicator in the production of selected timber assortments

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Abstract: Wood processing plants in Poland are recipients of more than 50% of round wood, which is delivered by the State Forests National Forest Holding. Thus playing a crucial role in the technological processing of raw material for all other wood industry branches. Each group of recipients has individual needs and expectations concerning the quality of the raw material such as, its type and the size of the cross-sections of the assortment used for further production. Therefore, it is economically justified for small production plants to abandon the production of narrow groups of assortments, which usually meets the standards of timber for general purposes. The aim is to make wood processing more flexible and lower the quality of raw material to produce assortments for a specific branches of the wood industry. Wood processing experiments were conducted to produce laths for construction purposes. These materials are one of the most important elements of roof constructions. The research proved empirically that it was possible to produce quality class 1 laths (88% of all laths produced) from WC0 class pinewood used as the input raw material and that the quantitative efficiency exceeded 55%.

Keywords: round wood, pinewood, material efficiency

INTRODUCTION

Scots pine (*Pinus sylvestris* L.) is a species of the pine family (*Pinaceae*) [Forest Encyclopaedia]. It is a prevalent species in Polish forests (58.2% of the forest area in Poland). More than 6.5 million m^3 of this raw material is acquired per annum. In 2017 the State Forests National Forest Holding acquired a total of 40.2 million m^3 of wood, 60% of which was pinewood [State Forests, 2017]. Due to the high availability of raw wood in Poland, a relatively low price and very good technical properties pinewood is a species used in many branches of the wood industry, especially in the sawmill industry, the board industry, and the cellulose and paper industry.

Depending on the size and quality of raw material, wood processing plants use their stock of medium- and large-sized wood for the production of:

- construction timber – the material is used for the construction of houses and bridges. It is acquired as a result of visual or mechanical sorting of solid softwood [Kotwica et al., 2015]. It is tested for strength according to the Polish Standard PN-EN 14081-1: 2007. Once wood meets the requirements concerning mechanical properties and density, timber is assigned to the appropriate strength class C, according to the Polish Standard PN-EN 384: 2016, and it receives the CE mark. Construction material meets the highest strength requirements due to its qualitative characteristics [Kozakiewicz & Krzosek, 2013].
- fenestration joinery – there are high requirements concerning timber used for manufacturing these products. It can be divided into indoor fenestration joinery (requirements specified in the Polish Standard PN-EN 14221: 2007) and outdoor fenestration joinery (requirements specified in the Polish Standard PN-EN 14220: 2007). In order to be processed further wood must be characterised by high strength and it must be free of most defects, which need to be eliminated, e.g. by bonding with adhesives. Apart from that, wood must be characterised by good workability in

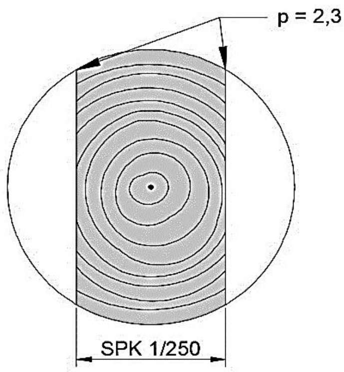
finishing processing and by dimensional stability. The light colour of the sapwood zone allows easy coating of the structure with colourless or pigmented varnish [Dubiela,2011].

- solid and layered flooring – pinewood is characterised by medium abrasion resistance, but it is relatively low-priced, has attractive appearance and it is easy to process. The requirements concerning the quality of timber are specified in the Polish Standard PN-EN 13999:2004. Pinewood (low-value assortments) is also used as a base in multilayer floorings, on which a decorative layer (e.g. hardwood/valuable wood) is placed.
- general purpose timber – it is made from medium quality raw material in wood processing plants. The dimensions of cross-sections and lengths and the quality classes of timber are diversified. The quality class of the assortment is determined by the share of defects. The high dimensional and qualitative diversity of pine timber results in a wide range of assortments meeting customers' expectations. The timber is classified according to the Polish Standard PN-75/D-96000 or PN-EN 1611-1: 2002.
- products of the garden programme – they represent the branch of the wood industry, which makes use of large-size raw materials of lower quality, in the form of medium-size timber (S2B). These products are mostly used for protection and decoration. These are mainly: shelters, privacy fences, pergolas, border edgings, log roll and many more.
- packaging products – these are mainly EUR-pallets and packaging boxes for the storage and transport of machinery and loose materials. Depending on the type of pallets produced, the standard defines permissible defects in pine timber from which the constructions of pallets are made.

Due to the wide structure of products made from pinewood, not only the qualitative and dimensional classification, but also the intended use plays a decisive role. One of the major priorities of the State Forests, which is the main supplier of raw wood in Poland, is to adjust the dimensions and quality characteristics of pinewood offered on the domestic market.

MATERIAL AND METHODS

The research was conducted in a wood processing plant situated in the south of Wielkopolska Voivodeship. About of pinewood (*Pinus sylvestris* L.) in the form of 12-metre-long logs was analysed.



where: SPK 1/250 – flitch height: 250 mm; p = 2.3 – saw kerf: 2.3 mm

Figure 1. A scheme of sawing a log into flitches

Material was handled in a technological line using an electronic log shape measurement system, which enabled the optimisation of efficiency and the selection of a technologically adequate division into logs. After the handling process, wood was sorted into groups according to its diameter at the thinner end, where the gradation was - each 2 cm. At a later stage the diameter ranges determine the height of resulting flitches. The next stage concerns sawing, i.e. the process in which raw material in the form of round wood is processed into prisms (Fig. 1). A Primultini SGF 1300 machine tool (vertical frame saw) was used for this purpose.

Flitches were processed with a Raimann KRD 430 twin-shaft multi-blade saw, where they were divided into balks. The thickness of balks was constant, i.e. 58 mm (Figure 2). The end product, i.e. construction laths, was made from this dimension. The kerf thickness (4.4 mm) was also included in the cutting process. It depended on the thickness of the circular saw blades used for cutting. The amount of balks obtained by sawing depended on the diameter of assortment. Usually four or five sharp-edged main assortments were produced from one flitch.

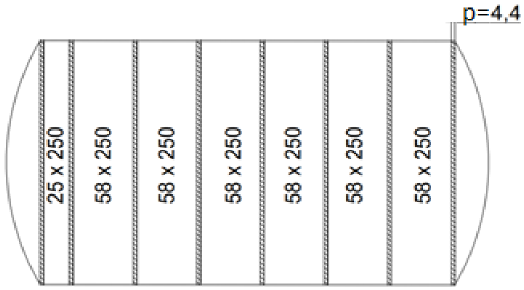


Figure 2. A scheme of sawing flitches into balks

Final stage of the technological process results in balks sawn into laths, which were the end product of this research. A multi-blade longitudinal saw was used for this operation (only the lower shaft), according to the sawing setting shown in Figure 3. Six laths were made from each flitch.

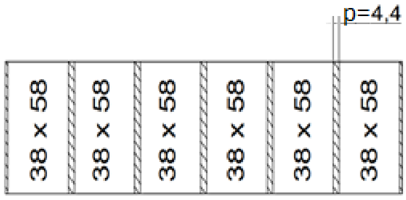


Figure 3. A scheme of sawing flitches into laths

At individual stages of the technological process side products in the form of offcuts were separated (depending on the log diameter) and they were sent for further processing. The resulting product was general purpose timber – 20- or 25-mm-thick planks, which were later offered for sale.

Each stage of the technological process included the assortments visual quality assessment, in accordance with the applicable standard, depending on the type (assortment) of the material tested. Qualified sorters determined the quality class by assessing the assortments visually according to the Polish Standard PN-75-D-9600. The balks that did not meet the quality requirements for a specific type of sawn materials were sent to be processed into planks together with side materials. The timber thickness and other measurements were made according to the Polish Standard PN-D-95000: 2002.

RESULTS AND DISCUSSION

The long logs used in the research underwent qualitative analysis (Fig. 4). The share of the logs in individual quality classes was as follows: WA0 – 0%, WB0 – 1.7%, WC0 – 64.6%, WD0 – 33.6%. Wood processing plants usually purchase long pine logs of the WC0 quality class due to the best ratio between the round wood price and the qualitative and quantitative indicators of the sawing efficiency. The long pine logs were additionally divided into classes of thickness in the middle of their length in order to make a more accurate analysis (class 1 – up to 24 cm in diameter, class 2 – 25-34 cm in diameter, class 3 – above 35 cm in diameter). Thickness class 2 was the most common of all quality classes.

Results and observations led to the conclusion that the long pine logs of the WC0 class were the most suitable material for further investigations. 37 logs (20.71 m^3) were sorted out and sent for further processing.

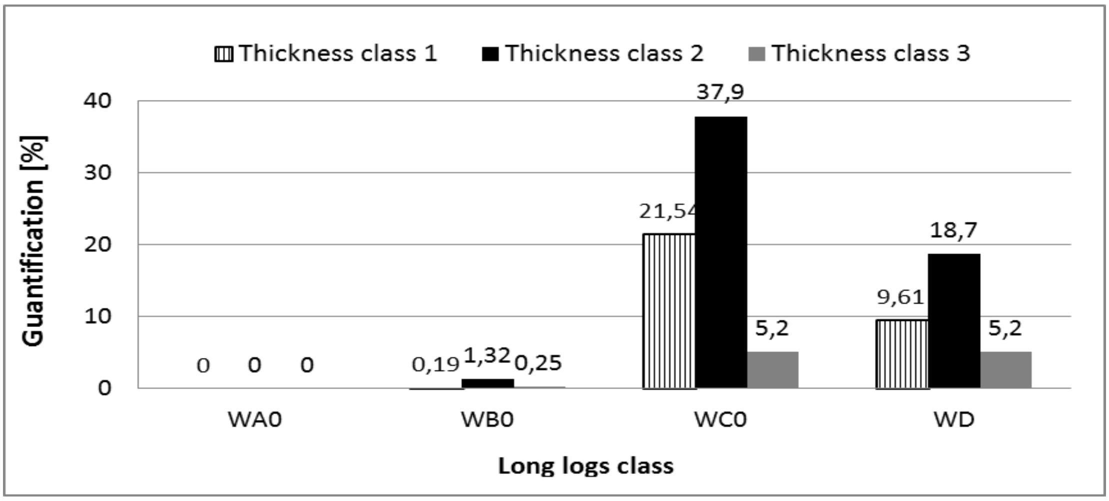


Figure 4. The percentage of pine logs in individual quality and thickness classes

The handling resulted in 56 logs with volume amounting to 21.4 m^3. The share of the logs in individual quality classes was as follows: WA0 – 0%, WB0 – 27%, WC0 – 53%, WD0 – 20%. The logs in the abovementioned quality grades were further divided according to their diameters (Fig. 5).

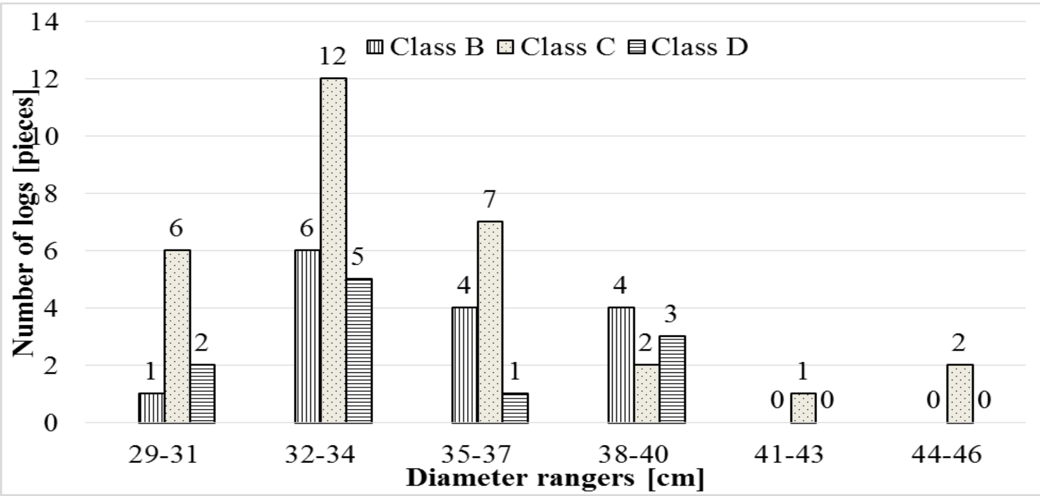
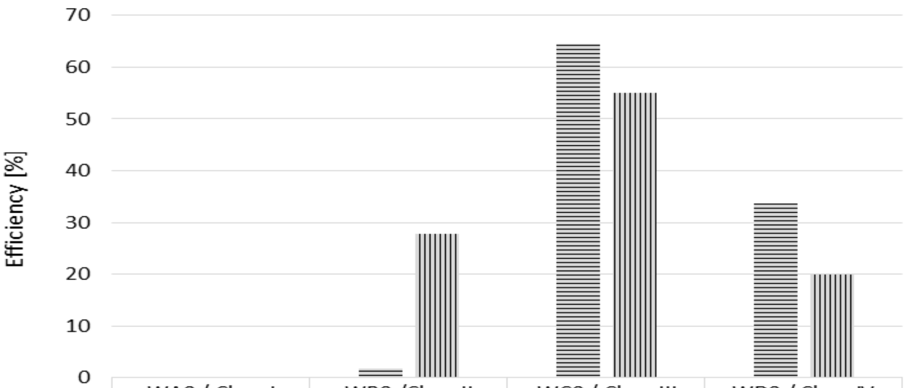


Figure 5. The dependence between the log quality class and its diameter (without bark)

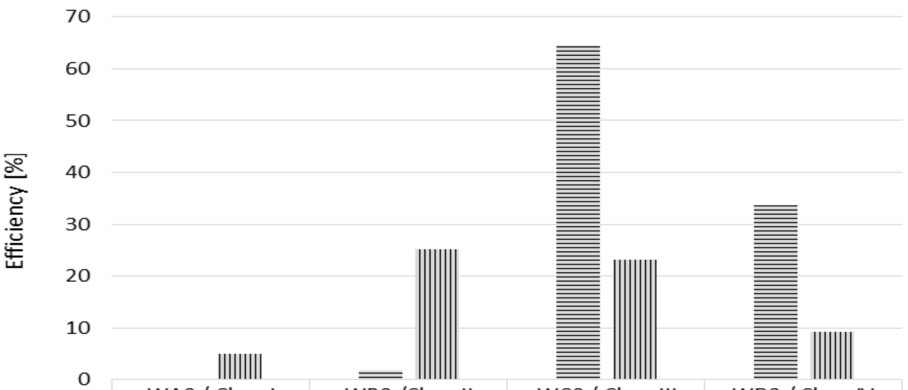
The WC0 class was predominant in each diameter range. The logs that did not exceed 40 cm in diameter had the largest share in the WB0 class. Like the WB0 class, the WD class was represented by the logs whose diameters did not exceed 40 cm. There were no logs in the WA0 class. Unfortunately, the data were not sufficient enough to find a clear correlation between the log quality class and its diameter. Figure 6 shows the results of the log qualitative efficiency, which was calculated as the ratio between the weight and volume of the long logs in individual quality classes. The low quality of the input raw material resulted in the predominance of the WC0 quality class and the lack of the WA0 class. The long logs which were included in the WD class were qualified to it mainly due to curvatures, which made it impossible to obtain large weights of log wood in higher quality classes. However, the division into logs reduced the share of the lowest quality class, i.e. WD, by nearly 14%. It is noteworthy that the share of the WC0 class dropped by nearly 10%, whereas the share of the raw material in the WB0 class increased over 15 times.



	WA0 / Class I	WB0 /Class II	WC0 / Class III	WD0 / Class IV
Long logs	0	1,8	64,6	33,6
Logs	0	27,9	55,1	20

Figure 6. The material and quality efficiency of the logs

These facts confirm the material efficiency standard in the wood processing plant. After the manipulation the total material efficiency of the logs was 103%. The xylometric paradox, which is determined by tapering and corrected by sequential measurement of the raw material, confirms the increase in the efficiency of logs, as compared with the long logs (Korczewski et al. 1970).



	WA0 / Class I	WB0 /Class II	WC0 / Class III	WD0 / Class IV
Long logs	0	1,8	64,6	33,6
Logs	5	25,2	23,2	9,2

Figure 7. The material and quality efficiency of the balks

Within the next stage of the research the quantitative and qualitative material efficiency of the balks was determined. After the logs were cut into flitches and balks, 224 pieces of main timber were obtained in total, with a total volume of 12.99 m^3. The calculations did not include offcuts and side planks produced during processing, because they were sent for further processing and production of other elements. Figure 7 shows the material efficiency, which was determined in two stages of the technological process: in the form of flitches and sawn products. 18 balks were qualified for quality class 1, which resulted in material efficiency of about 5%. It is noteworthy that only at this stage of processing the raw material of the highest quality was obtained. Assortments of quality classes 2 and 3 were the largest group of the resulting raw material. Their material efficiency in relation to the long logs amounted to 25% and 23%, respectively. The balks of the lowest quality class (class 4) made nearly 9% of the volume of the semi-finished products obtained in processing. Despite the low quality of the input raw material, i.e. long logs, the handling and sawing resulted in good quality balks, because defects in the structure of round wood were significantly reduced by sawing and further prefabrication.

Table 1. The material efficiency of construction laths

Quality class	Volume in quality class	Material efficiency in quality class in relation to long logs $W_{jpkl/d}$
1	10.21	49.2
2	1.33	6.4
Total	11.54	55.6

During the last stage of the research, results of the technological process of dividing balks into construction laths were verified. In total there were 1,309 laths produced, which amounted to 11.54 m^3 of wood. The volume difference between the balks (12.99 m^3) and the quantitative efficiency of laths amounted to about 11%. There were losses generated only by the material removed during sawing, which directly depended on the saw blade thickness (4.4 mm). Table 1 shows the material and quality efficiency in relation to the input assortment, i.e. the long logs. The assortment of quality class 1 was the dominant group of end products (about 88% of all laths made). Despite the low quality of the input raw material, the material efficiency of the end products in quality class 1 amounted to nearly 50%.

The research results suggest that it is not economically justified to produce construction laths from round wood of higher quality classes, as it is more expensive. The material efficiency of the construction laths amounted to almost 56%. This value was within the manufacturing standard for sawn products and shows that the technological process was executed well.

CONCLUSIONS

1. The analysis conducted on the selected production plant showed that WC0 was the largest quality class of available pinewood. Raw pinewood material is categorised as the WD quality class mainly due to excessive shape defects in long logs.
2. The analysis of the research results showed that the greatest decrease in efficiency occurred during the process of sawing the flitches into the balks. It was caused by the large amount of sawmill by-products generated at this stage, which did not occur at the consecutive stages of processing.
3. Proper adjustment of processing, which allows for the available base of raw materials, guarantees high quality assortments. The share of laths belonging to quality class 1 in the total volume of laths was as high as 88%.
4. The analysis of the efficiency indicators leads to the conclusion that pinewood in the WCO quality class fully meets the quality requirements for the production of construction laths. The principles of qualitative and dimensional classification, which allow for the occurrence of knots, but do not allow rotten wood, considerable discoloration or insect paths, have decisive influence.

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Streszczenie: *Wpływ doboru jakościowo wymiarowego surowca sosnowego, jako wskaźnik wydajnościowy w produkcji wybranych sortymentów tarcicy*. Zakłady pierwiastkowego przerobu drewna w Polsce są odbiorcami ponad 50% drewna w postaci okrągłej, sprzedawanego przez Państwowe Gospodarstwo Leśne „Lasy Państwowe". Tym samym odgrywają decydującą rolę na drodze technologicznego przetworzenia surowca dla pozostałych gałęzi przemysłu drzewnego. Każda z grup odbiorców posiada indywidualne potrzeby dotyczące jakości wykorzystywanego surowca, gatunku oraz wielkości przekrojów poprzecznych sortymentu wykorzystywanych do własnej dalszej produkcji. Stąd ekonomicznie uzasadnione jest, odchodzenie mały zakładów produkcyjnych od wytwarzania wąskich grup sortymentów, często zgodnych z normami tarcicy tartacznej ogólnego przeznaczenia. Dąży się do uelastycznienia przerobów i wytwarzanie sortymentów pod konkretną gałąź przemysłu z surowca niższej jakości. Dla celów badawczych przeprowadzone zostały przeroby doświadczalne uwzględniające pozyskanie łat budowlanych. Są to materiały, będące jednym z ważniejszych elementów konstrukcji dachowych. Doświadczalnie oraz empirycznie udowodnione zostało, że w odniesieniu do surowca wejściowego, jakim jest drewno sosnowe klasy WC0, możliwe jest wytwarzanie łat zaklasyfikowanych do I klasy jakości (stanowiącej 88% z wszystkich wytworzonych łat) z wydajnością ilościową przekraczającą 55%.

Słowa kluczowe: drewno okrągłe, sosna, wydajność materiałowa

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