Article citation info:
Michalec K., Wąsik R., Gach M. 2023. Impact of the presence of foreign bodies on quality and value of oak timber. *Drewno. Prace naukowe. Doniesienia. Komunikaty* 66 (211): 00005. https://doi.org/10.12841/wood.1644-3985.438.05

Łukasiewicz Poznań Institute of Technology

Drewno. Prace naukowe. Doniesienia. Komunikaty
Wood. Research papers. Reports. Announcements

Journal website: https://drewno-wood.pl/

Impact of the Presence of Foreign Bodies on Quality and Value of Oak Timber

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Article info
Received: 29 November 2022
Accepted: 28 April 2023
Published online: 02 August 2023

Keywords
wood classification
mechanical damage to wood
wood defects
metal fragments
projectiles

The paper discusses the impact of the presence of foreign bodies on the quality and value of oak timber as raw material. During the study, 109 oak bolts and logs with a total volume of 142.52 m^3 were measured and classified. The material for the study came from the Suchowice Forest District, within the Henryków Forestry Inspectorate (in the south-western part of Poland), and it was sampled from a tree stand located on the edge of the forest, where the largest concentration of rifle and artillery fire had occurred during World War II. As a result, the tree trunks contain significant amounts of shrapnel and projectiles. The length and diameter of each bolt and log were measured, and double classification was conducted: the first (I) classification took into account the presence of foreign bodies, whereas in the second (II) classification the presence of foreign bodies was disregarded. As a result of the conducted analyses, it was found that due to the presence of foreign bodies, all of the examined oak raw material was categorised as the worst quality class (D) timber. However, it was noted that during the second classification, where the presence of foreign bodies was not taken into account, a significant part of the raw material was upgraded to better quality classes, and only about 16% of wood remained in the worst, D class. Subsequently, it was calculated that the difference in the total value of the oak timber raw material classified by two methods amounted to approx. 204 thousand PLN (ca. € 43,514) – which was about 35% higher than the value calculated by the first method of classification.

DOI: 10.12841/wood.1644-3985.438.05

Introduction

Oak wood is valued for its beauty, good mechanical properties and durability. It can have many uses in carpentry, construction, furniture making, veneering, flooring, cooperage, charcoal production and fuelwood. Oak wood is greatly appreciated and widely used in many applications because of its heritage, beauty, strength and natural durability. Wood processing technologies may also have an important impact on the optimization of timber use and valuation [Santos et al. 2012]. Better wood with fewer or no

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abnormalities is utilised in more demanding applications such as veneer, while wood with more defects is selected for carpentry and rustic applications [Morosanu et al. 2011].

The main wood defects taken into account in the veneer classification are structural defects (grain slope), shape defects (curvature, tapered stem, multiple pith, ovality), chromatic indicators, destruction defects, specific defects in wood utilization, and defects due to injury (scars, bark, dead wood, cancer, pruning wounds, burnt bark) [Dumitrascu et al. 2013; Musat et al. 2017]. On the other hand, in sawmill wood, curvatures, sapwood width, ovality, eccentric pith, and multiple pith are important [Riesco Muñoz et al. 2013]. Nevertheless, during the classification roundwood, knots, sweep, heart shakes, rot and spiral grain have the greatest impact on lowering the quality class [Giefing et al. 2014; Gejdoš et al. 2021].

Other defects of wood that also affect its value are foreign bodies. Although they are rare in commercial stands, their presence can significantly reduce the quality of wood. Foreign bodies in wood typically include pieces of metal stuck within it (such as artillery shrapnel, projectiles, ingrown remnants of fences, or hammered-in nails), or ingrown stones and pieces of plastic, which are usually associated with an unnatural colour of wood, and which can lead to its rotting over time. In tannin-rich oak wood, owing to the presence of metals, characteristic inky discoloration occurs. Foreign bodies constitute a defect from the group of mechanical damage to wood – the latter is not measured, and therefore the presence of foreign bodies is only recorded incidentally when it is found [Krzysik 1974; Kubiak and Laurow 1994; Kimbar 2011; Warunki techniczne/Technical conditions 2019a]. Instances of mechanical damage, as a group of defects, downgrade the value of wood and reduce the efficiency of its processing; furthermore, they may also prevent its use for certain product ranges and applications [Barszcz and Jamrozy 2001; Szaban 2010; Michalec et al. 2011; 2015]. Processing wood with foreign bodies involves the risk of damaging the cutting parts of machines, tools, or devices used for that purpose. For this reason, the invisible presence of this kind of defect is sanctioned only in the lowest quality class (D), and the visible presence thereof may be acceptable only in class D, and only by explicit agreement of the parties to the transaction [Warunki techniczne/Technical conditions 2019b]. Therefore, this particular disadvantage is of great significance for both the quality of the wood and its value. In most cases, wood with foreign bodies comes from areas where military operations had been conducted during World War II. Even though tree stands in these areas are now reaching their felling age, the harvesting of timber, its sale as well as its subsequent processing pose a significant challenge [Kamiński 2013; Sewastynowicz 2014]. Hence, already at the stage of preparing stock estimates, it is recommended to carry out a detailed historical analysis of a given stand in order to verify the possibility of military operations in the area, and the potential presence of projectile fragments in the trees growing therein [Dardziński 2012]. The goal of the study was to determine the impact of the presence of foreign bodies on the quality and value of oak wood as raw material.

Material and methods

The study was carried out on samples of oak trunks in which the presence of foreign bodies was found. The oak wood raw material came from lot 362g, in the Suchowice Forest Subdistrict, within the Henryków Forest District (Fig. 1). The raw material came from a stand with the following features: age of the stand 142 years, species composition 100% oak, stocking index 0.7, crown cover - intermittent, average dbh 47 cm, average height 27 m, standing volume 227 m^3. The presence of foreign bodies in the form of metal fragments in this material is closely related to the location of the stand on the edge of the forest, where traces of trenches and foxholes from World War II can be found to this day, and where the largest rifle and artillery fire had been concentrated.

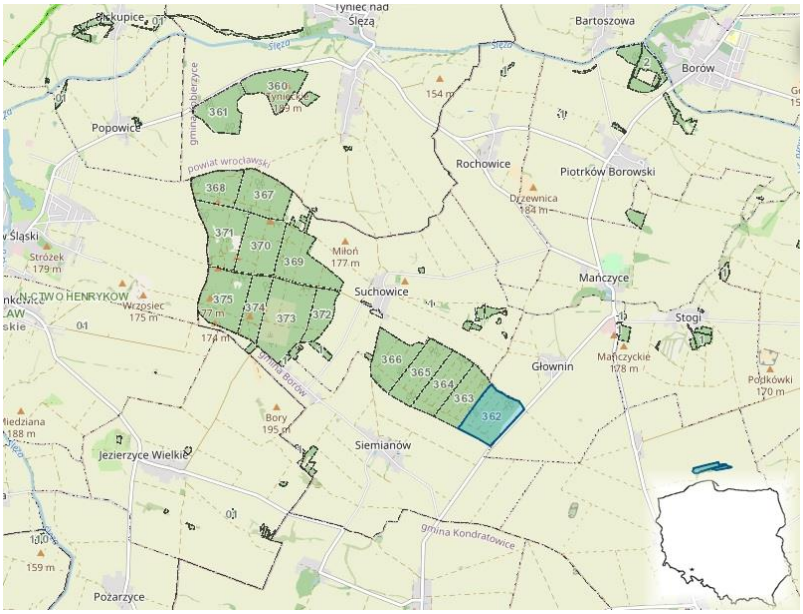

Fig. 1. Location of research area [source: www.bdl.lasy.gov.pl]

The measurement of the raw-material timber was made in accordance with the applicable Warunki techniczne/Technical conditions [2019c]. The length of each piece was measured with a tape measure, and the mid-length diameter was measured with a calliper. The timber was processed in the round shape, in the form of bolts and logs, with the bark left thereon. Then each piece was classified twice:

- The first (I) classification consisted in determining the wood quality class taking into account the presence of foreign bodies [Warunki techniczne/Technical conditions 2019b] (Table 1);

Table 1. Principles of assessing oak wood

Features		Classes			
		A	B	C	D
Minimum length [m]		2.5			
Minimum end diameter under bark [cm]		30	25	20	
Knots	sound	diameter up to:			
		2 cm	5 cm	10 cm	permitted
	unsound	not permitted	diameter up to:		
			5 cm	8 cm	15 cm
	burl	not permitted	permitted up to 1 cm in height, higher permitted in number 1/2 m	permitted	
	rose up to:	3 cm Ø	10 cm Ø	permitted	
End shake		permitted up to:		permitted	
		1/5 Ø butt	1/3 Ø butt		
Crack	edge end frost	not permitted		permitted one, up to 1/10 Ø butt	permitted
Simple sweep up to:		2 cm /1 m	3 cm /1 m	4 cm /1 m	5 cm /1 m
Spiral grain [cm/m] up to:		7	12	permitted	

Scars		one up to 6 cm wide	up to 6 cm wide	up to 12 cm wide	permitted
Multiple pith		not permitted			permitted
Rot	inner up to:	1/10 Ø butt	1/5 Ø butt	1/3 Ø butt	1/2 Ø butt
	surface	not permitted		allowed for 1/4 of circumfer-ence and up to 1/10 of diameter	allowed for 1/2 of circumfer-ence and up to 1/10 of diameter
Included sapwood		not permitted		permitted	
Wormholes		not permitted		allowed for 1/4 of circumfer-ence	permitted
Foreign bodies		not permitted			permitted by agreement of the parties

- The second (II) classification consisted in determining the quality of the wood disregarding the presence of foreign bodies. There were cases where, due to the good quality of the raw material, sectional collection was performed, and two separate sections were distinguished within one piece. In such cases, each section was measured separately (in terms of the length and diameter). The presence of foreign bodies was determined on the basis of discoloration visible on the face of the wood (Fig. 2)

Fig. 2. Visible presence of foreign bodies in wood

Volume tables for bolts and logs [Czuraj 2000] were consulted in order to calculate the volumes of logs, bolts, or sections of timber. Then, in order to determine the value of the wood, the current wood price lists in the Henryków Forestry Inspectorate were applied [Zarządzenie…/Ordinanse... 2022].
The obtained measurements were compiled utilising Excel and Statistica (version 12) software.

Results and discussion

In the study we conducted, 109 oak logs and bolts with a total volume of 142.52 m^3 were measured and classified. During the first (I) classification, which took into account the presence of foreign bodies, all the examined material was categorised as D class (Fig. 3). By contrast, after carrying out the second (II) classification, in which the presence of foreign bodies was disregarded, it was found that a significant part of the raw material was upgraded to better quality classes. A large portion of the wood was allocated to C class (104.67 m^3 – 72.59%). There were also instances of the best quality classes of wood: A 10 m^3 (6.94%), and B 5.95 m^3 (4.13%), whereas the share of the D class decreased significantly – to about 16%. In some forest districts where military operations had been conducted during World War II, more than 30% of long

timber with bullet fragments is sometimes found [Sewastynowicz 2014]. In the present study, it was also noted that after the second (II) classification, owing to the implementation of sectional collection, the total volume of wood increased by 1.67 m^3, whereas the mean and the minimum volume of individual logs decreased (Table 2).

Because of the fact that after the application of the Shapiro-Wilk test the data showed a normal distribution, the t-test was used to analyse the statistical significance of the differences [Kot et al. 2007]. The t-test revealed statistically significant differences between the volume of logs in the first (I) and the second (II) classification (Table 3).

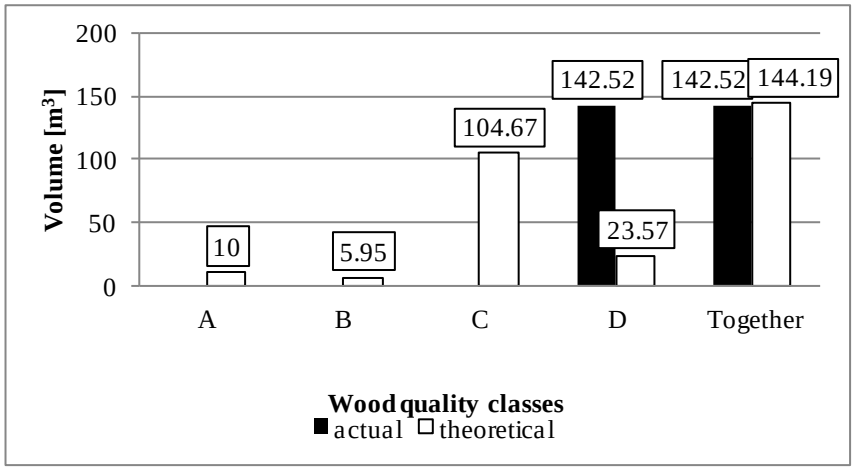

Fig. 3. Actual and theoretical volume of oak wood

Table 2. Statistical characteristics for individual logs of wood

	Classification of wood with defects		Classification of wood without defects	
	Volume [m^3]	Value [PLN]	Volume [m^3]	Value [PLN]
Average	1.31	3351.66	1.02	4008.67
Min	0.33	359.02	0.28	652.76
Max	2.38	6120.17	2.38	11051.49
Standard deviation	0.46	1188.34	0.46	2073.39
Coefficient of variation	34.83	35.46	44.85	51.72

Table 3. Results of t-test for volume and value of individual logs

	t	df	p
Volume	5.04	249	0.000
Value	-2.96	249	0.003

When analysing the value of the investigated oak timber raw material, significant differences were found in the value of logs classified by the two methods (Table 3). This was a result of the fact that during the first (I) classification, all the raw material was assigned to D class and its value amounted to approximately 365 thousand PLN (i.e. approximately 77,965 EUR at the exchange rate according to the National Bank of Poland of November 7, 2022), while during the second (II) classification, a large part of the wood was upgraded to better quality classes, which resulted in an increase in the total value of wood to approx. 570 thousand PLN (i.e. approximately 121,480 EUR) (Figs. 4 and 5). The difference, therefore, amounted to approximately 204 thousand PLN (i.e. approximately 43,514 EUR), which means that according to

the second (II) classification method the value was about 35% higher than according to the first (I) classification method. This can also be observed in the value of individual logs (Table 1). Despite the fact that the minimum and average volume of individual logs decreased, the average, minimum and maximum values for these logs increased significantly when conducting the classification of raw material using the second (II) method (i.e. the one disregarding the presence of foreign bodies).

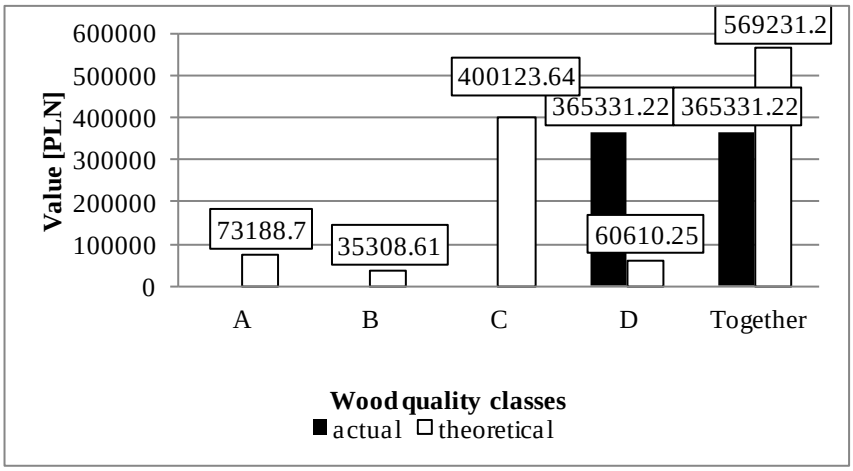

Fig. 4. Actual and theoretical value of oak wood

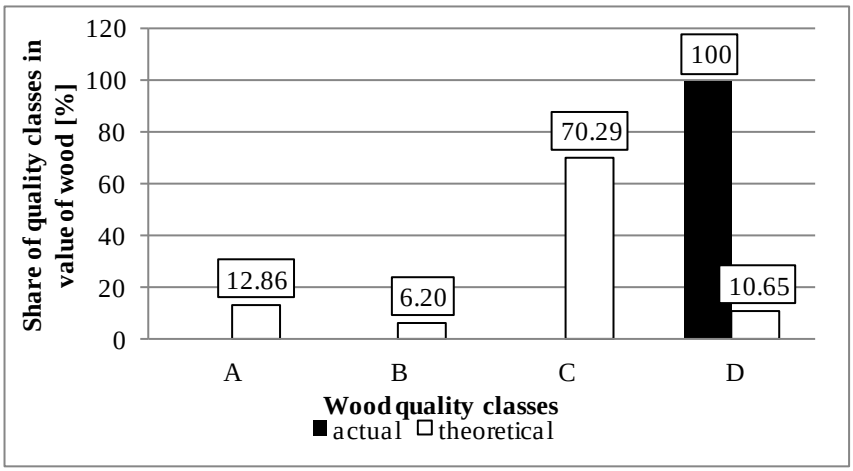

Fig. 5. Share of quality classes in actual and theoretical value of oak wood

The presence of foreign bodies according to the Warunki techniczne/Technical conditions [2019a], in force within State Forests in Poland, is classified within the group of defects caused by mechanical damage. This group also includes damage resulting from the harvesting of wood, which transforms into necrosis over time. These defects, as well as the presence of foreign bodies, have a significant impact on the quality and value of wood as raw material.

Of the forest-forming species, spruce is the most vulnerable to injuries. Research conducted by Steyrer [1992] in spruce stands in Austria showed that as a consequence of damage and the resulting rot, the income obtained from the sale of spruce wood decreased by 13%. In turn, Michalec et al. [2011], having conducted research in spruce stands, found that as a result of damage to trunks, 13.1% of the thickness of the examined material had a reduced quality. This affected the value of the raw material, which decreased by 6.5%. Another study by the same author [Michalec et al. 2015], addressing the influence of mechanical damage on the quality and value of the oak timber as raw material, demonstrated that the damaged wood was reclassified from large-sized wood to medium-sized wood of the S2 and S4 groups, and the performed calculations revealed that the decrease in the

value of wood as a consequence of damage was approximately 26%. In turn, when examining the impact of defects on the classification of beech raw material, Karaszewski et al. [2013a, b] found that about 20% of the logs had a reduced quality due to the presence of mechanical damage (necrotic scars); also, owing to the fact that the damage appeared in the lower parts of the trunks, the average volume of such logs amounted to 0.58 m^3.

The quality and value of the raw material are also influenced by the damage caused by wild animals, which usually tends to turn into necrosis over time. Having examined the impact of spruce bark stripping by animals on the development of trunk rot, Szaban [2010] stated that with the increasing age of the stands and the age of the studied trees, the rot volume also increases, which in turn reduces the quality and the value of the raw material. Barszcz and Jamrozy [2001], who analysed fir and ash tree damage caused by bark stripping by deer, noticed that as a result of game damage, about 40% of the thickness of the fir raw material was downgraded to worse timber quality classes, while in the case of ash material, the corresponding share was about 25%. The decrease in the quality of the raw material also resulted in a loss in the value of the timber, which amounted to 18.3% for fir, and 20.5% for ash.

Upon analysing the impact of wood defects on the value of the large-size timber of various tree species, Szramka et al. [2017] found that knots, burls and foreign bodies had the greatest impact on the reduction in the value of wood as they reduced the overall value of the wood by about 7% of the volume of the examined raw material. In the case of oak timber, foreign bodies reduced the quality by approximately 6.5% of the volume of oak wood, and its value decreased by approximately PLN 118/m^3. On the other hand, studies on the classification of oak veneer wood carried out in Romania [Dumitrascu et al. 2013; Musat et al. 2017] show that the main defects affecting the classification result were knots, curvatures and wormholes. Research by Riesco Muñoz et al. [2013] on sawn timber productivity reveal that wanes and insect galleries had the greatest impact. Other defects that commonly affect the structural quality of beams (knots, general slope of the grain, cracks, distortions, etc.) have rarely been the cause of eliminating boards for structural use. It is worth noting that out of the 109 timber logs analysed in the present study, 12 were put on submission sales of precious timber, where they generated high prices, much higher than would result from the value of the D class in which they were originally categorised.

Conclusions

1. The analyses conducted for the purpose of this study indicate that due to the presence of foreign bodies, all of the studied oak timber was categorised in the worst quality class (D). However, it was noted that during the second (II) classification, where the presence of foreign bodies was disregarded, a significant portion of the raw material was upgraded to better quality classes, and only about 16% of the wood remained in D class.
2. As a result of implementing two classification methods, it was found that the difference in the total value of oak wood, classified by the use of two methods, amounted to ca. 204 thousand PLN (approximately 43,514 EUR), which translated to an approximate 35% increase in the value with respect to the first (I) method of classification.
3. In commercial stands, foreign bodies in wood are very rare, which is also confirmed by the omission of this defect in the European standard for the classification of oak wood (EN 1316-1:2012). Nonetheless, there are cases of forest stands in Poland where intensive warfare was carried out and the presence of foreign bodies in the wood is very common. Thus, the classification of raw material suspected of including foreign bodies should be performed with utmost care. Downgrading the quality class of raw material causes measurable financial losses to the forest district, while upgrading may result in complaints by the recipient of the raw material. In extreme cases, if the recipient has not been informed about the defect, additional costs may be incurred, such as transport of the returned raw material from the recipient at the sender's expense, or paying compensation for equipment damaged during wood processing. The presence of foreign bodies, about which the recipient has not been informed, and which is revealed during handling or processing, is subject to a warranty claim in Poland as a hidden defect.
4. In practice, the presence of foreign bodies in wood is determined by visible marks or discoloration of the wood. Because of the high labour intensity, it is impossible to use devices for detecting foreign bodies in wood in the field. If the presence of foreign bodies in the wood is found, a log of a minimum length (2.5 m) is separated for the use of sawn timber of the worst quality (class D). If such a length cannot be separated, the wood is used for firewood.

Acknowledgements

This Research was financed by the Ministry of Science and Higher Education of the Republic of Poland.

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