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Comparison results of visual and machine strength grading of Scots pine sawn timber from the Greater Poland-Pomerania Forestry Region in Poland

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Abstract: *Comparison results of visual and machine strength grading of Scots pine sawn timber from the Greater Poland-Pomerania Forestry Region in Poland.* The paper presents an analysis of the strength grading results performed by two methods – visual (appearance) and machine, carried out for sawn timber obtained from the Greater Poland-Pomerania Forestry Region in Poland. Visual strength grading was performed in accordance with PN-D-94021:2013, while the machine strength grading with the use of MTG device (Brookhuis Electronics BV). As a result of the tests, it was confirmed that a large part of timber batch (39%) was classified as a reject while visual grading, when the machine grading resulted in a very small share of sawn timber classified as rejects (only one piece). At the same time, during machine strength grading there was only one sawn timber piece that was not classified for any class or a reject. Based on its visual appearance, this timber element should be graded as reject.

Keywords: strength grade, Scots pine sawn timber, Polish structural timber, visual grading, mechanical grading

INTRODUCTION

Wood industry, is a natural, ecological and renewable material that is increasingly used in various fields. The constantly growing demand for wood, with the simultaneous systematical declining harvesting of roundwood in recent years, forces its rational management. It consists in the best possible adjustment of parameters and mechanical properties of sawn timber to its intended use. This can be noticed on example of the use of wood in construction works. A characteristic feature of wood, limiting its use as load-bearing construction element, is not only the diversity of properties within different types of wood, but also the variability of mechanical properties and density within the same species (Obede et al. 2012, Christoforo et al. 2015). It is caused by many factors, but one of the most important are tree growth conditions (Zobel 1989, Mederski et al. 2015, Zeidler et al. 2018, Krzosek et al. 2019, 2020). Despite these difficulties the importance of timber used in construction increases year by year. From the material fulfilling auxiliary functions in traditional construction and used mainly on roof trusses and for interior finishing, wood has become a construction material. In modern timber structures several main techniques can be distinguished: classic frame buildings, assembled from scratch at the building site or made in prefabrication technology.

Cross-linked structural slabs (CLT) are getting more and more popular. Buildings with 14 storeys were built in the world using these modern materials, e.g. in Norway (Abrahamsen and Malo 2014), 18 storeys in Canada (Fast 2016) and in Norway (Abrahamsen 2017) and 24 storeys in Vienna (Woshitz 2015, Palfy and Woschitz 2016). In Winterthur, Switzerland until 2026 the tallest timber residential building named Rocket&Tigerli will be built, consisting in the 100 meter tall timber tower (www.shl.dk/rockettigerli/). Currently in Poland prefabrication technology is used to build timber structures with 4 floors (Beśka 2018).

One of the necessary conditions for safe building with timber is the use of wood with adequate strength parameters. Sawn timber used in construction for structural purposes must be subjected to strength grading. There are two methods for strength grading of structural sawn timber: visual and machine.

Strength grading by visual methods consists of a thorough examination of each piece of sawn timber and its qualification into specific grade classes on the basis of noticed wood structure defects, and shape and processing defects. In visual grading, the following wood features and defects are taken into account: knots, grain deviation, cracks and fissures, resin pockets, bark pockets, rot and insect tunnels, shape deviations, etc. Shape and processing defects are wanes, longitudinal (sides and planes) curvatures, transversal curvatures, twists and other cutting defects, such as mechanical damage or exceeding dimensional tolerances. As a result of visual grading, timber is sorted into specific sorting classes. Each of the EU countries has its own national regulations regarding strength grading of sawn timber by the visual method, for example: Germany (DIN 4074-1:2012), UK (BS 4978:2007), France (NF B 52-001-1:2011), Slovakia (STN 49 1531:2001), Italy (UNI11035-2:2010). Following this, there are distinct sorting classes in different countries and there are different methods of assessing timber features, e.g. knottiness. These standards are historically conditioned, they differ in terms of grading criteria and the number of grade classes. Strength grading by visual method in Poland is carried out on the basis of PN/D-94021:2013. As a result of grading, sawn timber is qualified into KW – high, KS – medium and KG – low quality. Sawn timber that does not meet the requirements of KG grade class is not suitable for structural applications and call a reject.

Machines for the strength grading of timber are based on the measurement of certain characteristics of wood, which can be determined in a non-destructive manner and which are known to correlate with the bending strength. The higher the correlation between the wood characteristic tested by the machine and its bending strength, the more reliable sorting results of this machine. Mechanical strength sorting has already been in use for over 50 years. In Europe, many different designs have been developed and applied on an industrial scale over the past years, some of them have already been the subject of publications by various authors (Denzler et al. 2005, Glos 1982, Krzosek 1995, Krzosek 2009, Krzosek and Bacher 2011). The most important advantage of strength grading by machine method is classifying of sawn timber directly to grades C, according to EN 338:2016This standard introduced the following classes for coniferous timber: C14, C16, C18, C20, C22, C24, C27, C30, C35, C40, C45 and C50, and for hardwood: D30, D35, D40, D50, D60 and D70. Poplar wood is treated as coniferous, thus, it is placed into the C classes. It can be noticed that the number at the C letter in a given strength class corresponds to the bending strength of sawn timber. In practice, in order to qualify the sawn timber for a given C class using sorting machines, its modulus of elasticity and density should be determined. Other characteristic values can be calculated on the basis of mathematical relations and correlations between these parameters. Therefore, modulus of elasticity and density are the key parameters when sorting sawn timber using the machine method. Additionally, they can be determined non-destructively on a full-size sawn timber when using a grading machine. Scaling such a machine, i.e. its release for use, is carried out according to strictly defined procedures and involves examining a certain amount of sawn timber first on a tested machine and then checking the results on the strength testing machine. The results obtained from non-destructive testing are verified by results obtained in traditional, destructive manner of timber testing. After obtaining satisfactory consistency of results, it is assumed that the grading machine is calibrated and can be approved for use (under many additional conditions – see EN 14081-4:2009). Currently, manufacturers of sawn timber can choose from a number of machines and devices dedicated for strength grading, approved for use in Europe. Table 1 presents a list of machines and devices available on the European market for the strength grading of sawn timber, along with their basic principles of operation.

Table 1. Strength grading machines available on the European market [https://blogs.napier.ac.uk/cwst/grading-machines-speeds/]

Nr	Machine	Principle of operation	Manufacturer	Country
1	Cook Bolinder	Mechanical bending	Tecmach	UK
2	Computermatic/ Micromatic	Mechanical bending	Tecmach	UK
3	Raute Timgader	Mechanical bending	Raute	Finland
4	EuroGreComat-702	X-ray	Microtec	Italy
5	GoldenEye-702	X-ray	Microtec	Italy
6	EuroGreComat-704	X-ray + mechanical bending	Microtec	Italy
7	Dynagrade	Acoustic type machine	Dynalyse	Sweden
8	VISCAN	Acoustic type machine	Microtec	Italy
9	EuroGreComat-706	X-ray + Acoustic type machine	Microtec	Italy
10	GoldenEye-706	X-ray + Acoustic type machine	Microtec	Italy
11	MTG 960 with balance	Acoustic type machine + balance	Brookhuis	Netherlands
12	Precigrader	Acoustic type machine + balance	Dynalyse	Sweden
13	Grademaster	Acoustic type machine + balance + optical scanner	Dimter	Germany
14.	E-Scan FMW/FW	Acoustic type machine + balance	Luxscan	Luxembourg
15	Triomatic	Acoustic type machine	CBS-CBT	France
16	CRP 360 L MSR	Mechanical bending	J.R.T. Inc.	Canada
17	Xyloclass T	Acoustic type machine	Xsylomeca	France
18	Noesys	Acoustic type machine	SARL Esteves	France
19	MTG 920 (without balance)	Acoustic type machine without balance	Brookhuis	Netherlands
20	VISCAN-PLUS	Acoustic type machine	Microtec	Italy
21	Xyloclass F	Acoustic type machine	Xsylomeca	France
22.	VISCAN-COMPACT	Acoustic type machine	Microtec	Italy
23	MTG Batch 962/966 (with balance)	Acoustic type machine + balance	Brookhuis	Netherlands
24	MTG Batch 922/926 (without balance)	Acoustic type machine	Brookhuis	Netherlands
25	Rosegrade	Acoustic type machine	Rosens	Sweden
26	EScan FM/F	Acoustic type machine	Luxscan	Luxembourg
27	E-CONTROL model AC	Acoustic type machine	Innodura	France
28	Rosegrade plus	Acoustic type machine	Rosens	Sweden
29	Viscan portable (with balance)	Acoustic type machine + balance	Microtec	Italy
30	Viscan portable (without balance)	Acoustic type machine	Microtec	Italy
31	WoodEye Strength Grader	Acoustic type machine + laser tracheid effect measurement	Woodeye	Sweden
32	RS Strength Grader	Laser tracheid effect measurement	Rema Sawco	Sweden
33	LuxScan OptiStrength XE	X-ray + acoustic type machine	Luxscan technologies	Luksembourg
34	LuxScan OptiStrength X	X-ray	Luxscan technologies	Luksembourg
35	STIG	Acoustic type machine	ILKON	Slovenia
36	Finscan Nova	Camera scanning	Microtec Innovating	Finland

			Wood	
37	Finscan HD	Camera scanning	Microtec Innovating Wood	Finland
38	MODULO	Mechanical bending	M. Manfred Hudel	France
39	RS Strength Grader Density	Laser tracheid effect measurement	RemaSawco	Sweden

Because of the use of grading machines, the obtained results are objective; moreover, modern automated machines sort with efficiency much higher than human. Automatic, computer-controlled, very efficient machines (e.g. feed speed of up to 200 m/min) can be integrated into automatic technological lines for the production of, for example, laminated timber (German: BSH – Brettschichtholz, English glulam), solid timber construction glued to length (German: KVH – Konstruktionsvollholz) or CLT (Cross Laminated Timber). In such automatic lines grading machines are joined with the following circular saws, which cut out fragments of boards with unacceptable wood defects.

In Polish sawmills, the method of visual grading is used almost exclusively. The first strength grading device was installed in polish sawmill in 2015 – in Polish sawmill, Tartak Janina i Wacław Witkowscy (Bekas 2016, Krzosek et. al 2015). Another sawmill – Tartak Abramczyk – purchased a machine for the sawn timber strength grading in 2018. Currently, the following companies are using machine strength grading of timber -Wiązary Burkietowicz, Odnova and KPPD.

According to the research carried out so far, a large share of rejects is obtained during grading sawn timber when using the visual method, and only a small amount of timber of high strength grade is obtained. With the applying of strength grading by machine method, much more sawn timber of high strength grades is obtained and far less rejects (Diebold 2009, Karlsson 2009). According to research conducted at Faculty of Wood Technology (WULS-SGGW), as a result of visual strength grading up to 52.9% of sawn timber in the tested batch was classified as reject, and only 4.4% to the highest strength grade KW. When sorting the same batch of sawn timber using the MTG device, only 17.5% of the tested batch was classified as a reject (Krzosek 2009). Further studies on pine sawn timber from selected natural forest regions of Poland are currently ongoing within the Biostrateg 3 research project.

RESEARCH MATERIAL

The research material consisted of sawn Scots pine (Pinus *sylvestris* L.) timber from the Greater Poland-Pomerania Forestry Region in Poland. The sawn timber was cut of raw materials with age classes IV and V, obtained from the young, mixed forest within the Regional Directorate of State Forests in Zielona Gora (Forest Inspectorate Wymiarki, Forest District Lutynka, divisions 23c and 23d, geographic coordinates: 51°55’35.7”N, 15°06’04.9”E). The timber was dried in industrial conditions in a chamber drier, up to the humidity of ca. 12%, and planed. The nominal dimensions of timber after drying and planing were: 40 x 138 x 3000mm. There were 150 pieces of timber in the batch under research.

RESEARCH AIM AND SCOPE

The aim of research was to verify what are the differences between results of visual (appearance) and machine strength grading. The scope of research included strength grading of sawn timber with both methods.

MATERIAL AND METHODS

Strength grading by visual method was carried out in accordance with PN-D-94021:2013. As a result of the grading, the sawn timber was assigned to sorting classes KW, KS, KG or classified as reject. Strength grading by the machine method was carried out with the use of MTG (Mobile Timber Grader) device from Brookhuis Electronics BV. The dynamic modulus of elasticity is measured by the vibration method. The MTG device has already been used in previous studies conducted at the Faculty of Wood Technology (Krzosek and Grześkiewicz 2008; Krzosek 2009, Krzosek et al. 2019, 2020).

RESULTS AND ANALYSIS

The results of strength grading by visual and machine method are presented in table 2 and 3.

Table 2. Results of sawn timber strength grading by visual method in accordance with PN-D-94021:2013

Visual strength grade acc. to PN-D-94021:2013							
KW		KS		KG		Reject	
[number]	[%]	[number]	[%]	[number]	[%]	[number]	[%]
6	4.0	17	11.3	68	45.3	59	39.4

As a result of sawn timber grading by the visual method, only 6 pieces (out of 150) were assigned to the KW strength grade (4.0 % of the whole batch), 17 pieces to KS grade (11.3% of the whole batch), 68 pieces to KG grade (45,3% of the whole batch), whereas 59 pieces (39.4%) were classified as rejects. The obtained results of strength grading by visual method were comparable to the results relating to the same amount of sawn timber but originating from Baltic Forestry Region in Poland (Krzosek et al. 2020), where the following was obtained: KW - 5 pcs (3. %), KS - 12 pcs (8.0%), KG - 57 pcs (38.0%), reject - 76 pcs (50.7%). Comparing the presented results of the visual sorting of sawn timber from Greater Poland-Pomerania Forestry Region with the results relating to sawn timber coming from Silesian Forestry Region (Krzosek et al. 2019), a significant difference in the efficiency of sawn timber in the KW class and the KG class can be noticed. In case of sawn timber originating from Greater Poland-Pomerania Forestry Region, the efficiency of the KW class was only 4.0%, and for sawn timber from Silesian Forestry Region, the efficiency of the KW class was as much as 19.5%. The inverse relationship was observed for the KG class. The efficiency of this class of sawn timber from Greater Poland-Pomerania Forestry Region amounted to 45.3%, while the same efficiency for sawn timber from Silesian Forestry Region was clearly lower and amounted to 29.5%. The grading efficiency for the remaining classes: KS and reject for both compared forest regions was almost identical: KS about 11% and reject about 39%. On the basis of the obtained results, it can be concluded that the timber from the Greater Poland-Pomerania Forestry Region has significantly lower quality compared to the timber obtained from the Silesian Forestry Region and the quality of timber was comparable to that of the Baltic Forestry Region (Krzosek et al. 2020).

Table 3. Results of strength grading of sawn timber by machine method with the use of MTG device

Strength grade acc. to EN 338											
C40		C35		C30		C24		C18		Reject	
[number]	[%]	[number]	[%]	[number]	[%]	[number]	[%]	[number]	[%]	[number]	[%]
6	4.0	34	22.7	41	27.3	61	40.7	6	4.0	2	1.3

As a result of sawn timber grading by the machine method (MTG), 4.0% (6 pieces) of the batch was in C40 strength class, 22.7% (34 pieces) in C35 class, 27.3% (41 pieces) in C30 class, 40.7% (61 pieces) in C24 class, 4.0% (6 pieces) in C18 class and only 1.3% (2 pieces) rejects were noticed. It is worth noting that a large number of sawn timber – 26.7% in total – was assigned to classes that are unachievable at visual strength grading (i.e. C40 and C35).

It is also worth noting that as a result of machine strength grading, in addition to sawn timber of high strength grades, high C24 class efficiency was obtained (40.7% of the tested batch), with low C18 class efficiency (only 4.0%) and negligible amount of rejects (only 1, 3.0%). Comparing the results of machine grading of sawn timber from Greater Poland-Pomerania Forestry Region with the results related to two previously studied regions: Silesian (Krzosek et al. 2019) and Baltic Forestry Region (Krzosek et al. 2020), it can be noticed that the sawn timber from the Greater Poland-Pomerania Forestry Region has clearly lower quality than timber from Silesian Forestry Region, but at the same time significantly higher quality than timber originating from Baltic Forestry Region.

A practical flaw of the MTG device is the inability to grade sawn timber with knots occurring on its face side, in cases where an extremely large twist of fibres is present and when planks faces are not precisely cut. In such situations, according to authors' assumptions, a wave caused by an impact to the board forehead does not reach the other side because of the mentioned defects, neither is it reflected from it nor returns to the vibration detector. In such cases, the MTG device displays the message: ERROR. During the tests described, 1 of a total number of 150 sawn timber boards was not classified into strength grades (0.7% of the batch). Practice indicates that such boards should be described as rejects. Finally then, in the presented research a total number of 2 pieces of sawn timber was qualified as a rejects – one as an actual grading result (Reject) and the other described by the MTG device as an ERROR.

CONCLUSIONS

1. The sawn pine timber under research was of significantly lower quality that timber originating from Silesian Forestry Region and at the same time of slightly better quality than that coming from Baltic Forestry Region.
2. It was confirmed that the higher efficiency of sawn timber of an excellent quality (C30 and better) as well as lower quality (C18) are obtained when grading by machine method in comparison to the results of strength grading by means of visual method (with the assumption that C24 is equivalent to KS class and C18 class is equivalent to the KG class).
3. The assumption that the machine strength grading results in definitely low share of sawn timber considered as rejects has been confirmed.
4. There are sawn timber elements which were not assigned to any class or marked as rejects during the machine strength grading. Such timber should be classified as rejects based on its visual appearance.

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Streszczenie: *Porównanie wyników wizualnego i maszynowego sortowania wytrzymałościowego tarcicy sosnowej z Wielkopolsko-Pomorskiej Krainy Przyrodniczo Leśnej.* Praca dotyczy analizy wyników sortowania wytrzymałościowego drewna sosny zwyczajnej dwoma metodami – wizualną oraz maszynową, przeprowadzonego dla surowca pozyskanego z Wielkopolsko-Pomorskiej Krainy Przyrodniczo Leśnej. Sortowanie wytrzymałościowe metodą wizualną przeprowadzono zgodnie z PN-D-94021:2013, natomiast sortowanie metodą maszynową przy użyciu urządzenia MTG holenderskiej firmy Brookhuis Electronics BV. W wyniku przeprowadzonych badań potwierdzono prawidłowość, że przy

sortowaniu maszynowym otrzymuje się bardzo małą liczbę sztuk tarcicy zaliczoną do odrzutów oraz niewielką ilość tarcicy przyporządkowanej do najniższej klasy: C18. Jednocześnie w trakcie badań zdarzyły się sztuki tarcicy, które przy sortowaniu maszynowym nie zostały zaliczone do żadnej klasy ani do odrzutów. Taką tarcicę na podstawie jej wyglądu należy zakwalifikować jako odrzut.

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