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Theses of the doctoral (PhD) dissertation

Determination of the stack volume of spruce industrial timber using individual and electronically 3D – measurement

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1. Introduction

The measurement of roundwood is probably the most important aspect of the business connections between the forestry and the timber industry. In addition to the timber quality, the timber volume is the most important parameter and of key relevance for the price formation.

Given the great importance of timber measurement, various measurement methods for industrial timber have become established in the practice over the past decades. They allow to generate the necessary results relevant for calculation of the prices at different locations and independently of the time of measurement. These methods range from simple manual measurements of the stack using a measuring tape to photo-optical measurement systems with special cameras.

In contrast to the sawmilling industry, paper, pulp, and wood-based panel industries process timber assortments of lower quality (referred to as industrial timber). Due to the condition of the logs, their low value compared to sawmill wood, and the absence of technical facilities, electronic measurement of these assortments on an individual log basis in the factories of the three above mentioned industries is not possible. Therefore, other measurement methods must be used, which are capable of representing the volume as accurately and efficiently as possible.

2. Aim of the research

This study deals with the measurement of spruce industrial stacked timber. To this end, an extensive series of tests was conducted in which the accuracy of the measurement processes currently used in practice for industrial timber was investigated. In the process, first and foremost, the differences between the measurement values determined by the respective measurement processes and the actual solid volumes were analysed. Furthermore, the range of variation in the results for numerous individual tests is presented statistically. In particular, the accuracy ranges in which the differences are located should be illustrated.

This accuracy testing can be realised with the help of a fully automated, calibrated and certified JORO – 3D type roundwood measurement system. This system, working electronically and contactless, makes it possible to establish exact measurements for comparison. Measurement data which corresponds to that from an individual and manual full measurement can be generated.

A second series of tests should illustrate the dependency of the solid volume for a stack of wood of industrial timber on the top and mid diameters of the individual logs. To this end, individual logs of spruce presorted into defined size classes are stacked and the total volume is determined after using the sectional volumetric measurement method on the roundwood measurement plant. Through statistical analysis, conclusions can be drawn concerning the conversion factor per size class from cubic to solid measure.

The research project is characterised in particular by the fact that individual and electronic determination of the solid volume of multiple stacks of industrial timber had not been

scientifically performed to date. Consequently, there is no comparable study in the literature in the field and may therefore be of interest both for the forestry industry and for the purchasers of industrial timber.

3. Research method

First, the series of tests 1 were conducted in which the accuracy of the measurement methods currently used in practice for industrial timber were investigated. Here, the sectional volumetric measurement method, photo-optical measurement, sample method, truck measurement, weight acceptance and Swedish indexing method were included as the measurement methods.

The series of tests 1 comprised a total of 2,006 m³ pb of mechanically stacked spruce/fir industrial timber of the quality N in a log length of 3 metres. In the process 28,248 individual logs were measured electronically at the plant after the data determination in the forest and at the plant. A total of 33 individual stacks of various sizes between 22.50 – 138.80 m³ pb were studied. The timber removal by truck comprised 38 full loads and 23 partial loads. The stacks tested were selected specifically from different forest districts in Baden-Wurttemberg and Bavaria, i.e. only one test was carried out for each forest district. This is to ensure that any dependence of the results on the harvesting company is ruled out.

Based on the knowledge from the series of tests 1, in which the mid diameter of the individual logs demonstrated a significant impact on the solid volumes of stacked industrial timber, this observation was followed up in an additional test. The series of tests 2 was carried out on site at a sawmill in Baden-Wurttemberg and involved a total volume of 870.35 m³ ub. In order to analyse the effect of the mid diameter on the solid volume of stacked industrial timber, 12,701 individual logs without bark were presorted into 10 defined size classes according to the top diameter and were then measured again.

The initial situation described the framework conditions for the most comprehensive study of volume calculation for industrial timber to date under controlled conditions and in strict compliance with the appropriate guidelines.

4. Results

The statistical analysis of the series of tests 1 proves that the percentage difference in relation to the total amount of the stack volumes in the six measurement methods for industrial timber tested, with the exception of truck measurement, is below 5 %. In particular, the sectional volumetric measurement method impressed with a different of just 0.44 % and thus reflected the actual measurement volumes from the 3D - plant most precisely.

The graphical representations of the results of the respective individual tests show that, particularly for weight acceptance and the sample method, significant fluctuations occur with regard to measurement accuracy. The standard deviation value for weight acceptance of SD = 10.22 % indicates a significant spread of the individual values around the average. Consequently, it is difficult to reproduce the correct stack volumes with a statistically high probability using this method. This hypothesis is supported by the frequency distribution of the absolute percentage deviation. It was only possible to achieve a measurement accuracy of +/- 5 % using weight acceptance in 11 of the 33 individual tests.

The results from the series of tests 2 showed that an increase in the diameter of the individual logs was associated with an increase in the solid volume and the conversion factor from cubic to solid measure of between 0.580 in tests with the smallest mid diameters (10.30 cm) and 0.671 in tests with the largest mid diameters (21.60 cm). The increase of this factor was visualised in a diagram and demonstrates non-linear progression.

5. Conclusions

The presentation of the resulting conversion factors and solid content percentages makes it clear what ranges and differences should be expected in the estimation of the actual stack volumes for the individual tests. The conversion factor from cubic measure inclusive bark to solid measure exclusive bark of 0.70 used and valid in Germany until 01/01/2015 was not even nearly reached using any of the measurement methods studied, meaning that the actual stack volume of industrial timber has evidently been over-estimated for decades.

This study also indicates that the measurement methods currently used do not always succeed in representing the actual stack volume of industrial timber. The statistical analysis proves that the correct measurement result depends on multiple factors, the influence of which on the respective methods is not sufficiently quantified or is not taken into account at all. Further development and optimisation of the measurement processes for stacked industrial timber would therefore undoubtedly be in the interests of all actors involved in the sale of timber.

6. Theses of the dissertation

I. The percentage difference in relation to the total amount of the stack volumes in the six measurement methods for industrial timber tested, with the exception of truck measurement (+ 7 %) is less than 5 %. In particular, the sectional volumetric measurement method impressed with a different of just 0.44 % and thus reflected the actual measurement volumes from the 3D - plant most precisely.

II. The constant additional volume in truck measurement results in a deduction value (5 %) which is too low. If the gross cubic measure of a load was reduced by 11 % then it is possible to represent the volumes determined by the 3D – plant.

III. The graphical representations of the results of the respective individual tests show that, particularly for weight acceptance and the sample method, significant fluctuations occur with regard to measurement accuracy. The standard deviations for weight acceptance of SD = 10.22 % and for the sample method of SD = 9.28 % indicate a significant spread of the individual values around the average.

IV. If you are aiming for a measurement accuracy of +/- 5 % in the individual tests, then this can be achieved with a probability of 76 % for the sectional volumetric measurement method, 64% for photo-optical measurement, 46 % for the sample and Swedish indexing methods, 34 % for weight acceptance and just 27 % for truck measurement.

V. The taper, ovality and crook parameters have a negative effect on the pack density of a stack, and consequently on the solid volume. An increase in the taper, ovality and crook values therefore results in a reduction of the solid volume. In addition, an effect of the mid diameter can be observed. Accordingly, the solid volume of a stack increases significantly with an increase in the diameter of the individual logs. Regression analysis confirms that the four parameters as a whole have a highly significant effect on the solid volume of a stack of wood.

VI. An increase in the diameter of the individual logs was associated with an increase in the solid volume and the conversion factor from cubic to solid measure between 0.580 in tests with the smallest mid diameters (10.30 cm) and 0.671 in tests with the largest mid diameters (21.60 cm). This factor increase demonstrates non-linear progression and is primarily a result of the fact that it is more difficult to achieve the maximum pack density at small diameters with a higher number of pieces per cubic metre.

7. Publications and presentations related to the topics of the dissertation

HEINZMANN, B. & BARBU, M. (2016). Genauigkeit der fotooptischen Poltervermessung von Industrieholz am Beispiel von FOVEA. Forstarchiv, Jg./Heft: 87/6, Deutscher Landwirtschaftsverlag, München , S. 194-197.

HEINZMANN, B. & BARBU, M. (2017). Maßermittlungsvergleiche von Raummaßverfahren und Gewichtsübernahme für Industrieholz mit einzelstammweiser Werksvermessung. Austrian Journal of Forest Science - Centralblatt für das gesamte Forstwesen, Jg./Heft: 134/1, Wien , S.37-52.

HEINZMANN, B. & BARBU, M. (2017). Effect of mid-diameter and log-parameters on the conversion factor of cubic measure to solid measure concerning industrial timber. Pro Ligno - An international Journal in the Field of Wood Engineering, Volume 13, Number 1, Brasov , S.39-44.

HEINZMANN, B. & BARBU, M. (2017). Mit dem Durchmesser steigt das Poltervolumen - Einfluss des Mittendurchmessers auf den Umrechnungsfaktor von Raummaß auf Festmaß bei Industrieschichtholz. Holz-Zentralblatt, Jg./Heft: 143/18, DRW-Verlag, Leinfelden-Echterdingen , S. 414-415.