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EFFECT OF MID-DIAMETER AND LOG-PARAMETERS ON THE CONVERSION FACTOR OF CUBIC MEASURE TO SOLID MEASURE CONCERNING INDUSTRIAL TIMBER

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Abstract:
Concerning industrial timber, the measure of stacked logs with equal wood length is cubic meter with bark (FVA 1997). It is consequently a volumetric measure including the non wood-containing spaces. The following work determines by extensive tests the solid measure of several stacks of wood by the means of an electronically measuring system, and calculates the resulting conversion factor. It was possible to make a statement about how the mid-diameter of logs from a stack and particularly log-parameters influences the conversion factor. The measurements in 3D, the mid-diameter, the crook, the taper and the ovality are considered and their influence on the factor were analysed. The results are illustrated and evaluated by using a correlation and regression analysis. The greater influence had the mid-diameter and the crook, which show strong correlations on the factor.

Key words*: conversion factor; cubic measure; industrial timber; log properties; solid measure; 3D-measurement.*

INTRODUCTION

Stem wood is calculated based on its dimension in cubic meter solid volume excluding bark (m^3f ub), and charged to the buyer in this measurement unit. One solid cubic meter is equated to the volume of one cubic meter of pure wood (RVR 2015).

However, for industrial timber, i.e. logs which are broken down by chemical or mechanical processes at a later point (FORST-HKS 1969), it is not possible to determine the dimensions on an individual log basis, so that in practice the two methods of the volumetric measurement and the weight control are used almost exclusively for determining the sales volume (Staudenmaier 2015).

Whereas with the weight control the wood mass is calculated in a water-free state, with the volumetric measurement method, the volume derived from a stack of wood is used for determining the volume to be charged (Frommhold 2013). In this case, the cubic meter including bark (m^3 pb), in addition to the pure wood substance, also includes the bark and the air spaces, resulting from stacking the logs.

OBJECTIVES

The literature recommends conversion factors from the cubic measure to the solid measure, which are based on scientifically derived or field-proven values. According to the „Rahmenvereinbarung für den Rohholzhandel“ (German framework agreement for the trade with raw timber, RVR) of 2015, these conversions to the pure wood volume must not be applied as a measure for sale, as, due to fluctuations, they are merely average values.

In the context for this study, the author currently investigates the measurement of industrial timber. An extensive series of tests with several individual tests is used to identify the areas, in which the fluctuations of the respective conversion factors between the cubic measure and the solid measure occur. In addition, it is to be shown whether the average mid-diameter of a stack of wood and individual log parameters, such as taper, crook, and ovality, affect the conversion factors.

MATERIAL AND METHOD

Testing scope and procedure

The series of tests comprised a total of 2,006m³ pb of stacked industrial spruce with quality N/F (“normal”/”faulty”) and log length of 3.00 meters. 33 stacks of wood with 28,248 individual logs were electronically measured with a 3D – system in the factory after collecting the cubic measure in the forest by using the sectional volumetric measurement method. Thereby, the stack length, stack height, and stack depth measures are used to determine the gross volume. The stacks of wood were selected specifically from

33 different forest districts in Baden-Wurttemberg and Bavaria, i.e. only one test was carried out for each district. This is to ensure that any dependence of the results on the harvesting company is ruled out.

As already mentioned, an electronic and automated measurement system was used for measuring and classifying the test logs. This is a certified and calibrated roundwood measurement system of the type JORO–3D. Regarding the calculation of the log volume and the determination of individual quality parameters, the fully electronic measurement unit captured the following relevant data:

- log length (m);
- butt-, mid- and top-diameter (cm);
- taper (cm/m);
- crook (%);
- ovality (%).

The collection of data was enabled by means of three specifically arranged laser camera units, which scan the log at the speed of light (Jörg Elektronik 2006). For determination of the log diameter, the measured values are processed by means of cross-measurement, i.e. in two measurement planes using pairs of diameters perpendicular to each other.

Data collection

The diameter values used for calculation of the *mid - diameter* are the measured values of the measurement section including the log-centre. The log-centre is at a distance of half the nominal length from the thicker log end (VDS 2005). The mid-diameter is specified in centimeter as a whole number.

For determination of the *taper*, the diameter values over the entire length of the log, starting at the log-centre in steps of 50cm to the log ends, are collected (Jörg Elektronik 2005). The now cumulated local diameter differences with respect to the nominal length reveal an average taper of the log in centimeters per meter.

The *crook* of a log is determined by considering several measurement areas over the entire length of the log. Similar to the method for taper determination, the measured values for crook determination are collected starting from the log-centre at a distance of 50cm. At each of these measurement points, the deviations of the log axis from the ideal centre line of a cylinder are measured (VDS 2005). This reveals the average crook of the log in percent.

The *ovality* is the ratio between the usable volume of a log (based on the smallest mid-diameter) and the volume resulting from the average value of the diameter pairs of the cross- measurement in the log-centre. The ovality data are collected again based on the diameter measurements in steps of 50cm from the log-centre to the log ends. The relative ovality in percent thus evaluates the loss of the yield during sawing the timber (Jörg Elektronik 2016).

Data evaluation

The values for the mid-diameter, taper, crook and ovality determined by the 3D measurement system were collected for each stack of wood and the relevant average values of the individual logs were summarised (see Table 1). This summary also lists the evaluated cubic and solid measures for all 33 individual stacks of wood. The conversion factor resulting from the quotient of these two measures was evaluated for each test.

RESULTS

The collected and evaluated data of all tested stacks of wood is summarised in Table 1. Each row indicates the mid-diameter, taper, ovality and crook of logs as well as the cubic and solid measures for each individual test.

Table 1

General view on the individual results of the 33 tested stacks of logs

test (Nr)	mid-diameter (cm)	taper (cm/m)	ovality (%)	crook (%)	cubic measure m³ pb	solid measure m³f ub	factor
1	14,50	0,95	6,35	0,75	103,29	62,801	0,608
2	13,30	0,84	7,09	0,74	138,80	81,250	0,585
3	14,88	1,20	7,00	0,80	39,23	23,135	0,590
4	13,82	0,90	9,30	0,70	39,57	24,556	0,621
5	12,14	1,00	7,78	0,60	53,29	29,567	0,555

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6	11,63	0,80	7,35	1,00	54,90	28,579	0,521
7	13,98	0,90	7,15	0,70	68,67	41,399	0,603
8	12,83	0,60	6,90	0,50	40,91	25,536	0,624
9	13,73	0,90	8,10	0,70	37,66	20,636	0,548
10	13,06	0,60	7,90	0,60	25,09	14,801	0,590
11	13,81	0,90	7,38	0,89	46,80	27,014	0,577
12	12,04	0,80	6,87	0,60	49,43	28,864	0,584
13	13,24	0,92	6,76	0,70	52,32	29,211	0,558
14	13,90	0,60	8,03	0,59	49,26	31,824	0,646
15	11,39	0,80	9,10	0,85	85,66	48,488	0,566
16	11,02	0,60	7,35	0,80	49,71	27,274	0,549
17	13,64	0,90	6,54	0,57	60,41	36,220	0,600
18	13,52	1,00	7,00	0,60	22,50	13,216	0,587
19	12,78	0,70	6,30	0,70	30,25	18,498	0,612
20	13,59	0,70	9,54	1,04	50,36	30,205	0,600
21	12,44	0,76	7,90	0,96	84,03	49,151	0,585
22	12,96	0,70	6,73	0,67	135,10	81,957	0,607
23	11,22	0,60	7,60	0,75	82,73	47,616	0,576
24	12,40	0,90	6,30	0,50	69,77	43,528	0,624
25	13,23	0,90	8,00	0,80	29,91	17,356	0,580
26	13,17	0,70	7,50	0,70	27,55	16,905	0,614
27	14,76	0,67	7,01	0,60	67,91	44,548	0,656
28	13,87	0,70	6,20	0,60	38,81	23,944	0,617
29	13,34	0,87	6,96	0,57	69,08	43,027	0,623
30	15,76	0,76	7,00	0,60	86,28	54,404	0,631
31	13,12	0,62	6,33	0,62	56,49	34,521	0,611
32	13,58	0,70	5,67	0,60	131,49	80,696	0,614
33	12,80	0,90	7,30	0,60	28,75	17,443	0,607

Table 2 gives a summary of the minimum, maximum and average values of the test series. This facilitates the assessment and estimate of the respective individual values.

Table 2

Minimum, maximum and average values of the test series

	mid-diameter (cm)	**taper (cm/m)**	**ovality (%)**	**crook (%)**	**factor**
minimum	11,02	0,60	5,67	0,50	0,513
maximum	15,76	1,20	9,54	1,04	0,656
average	13,20	0,80	7,28	0,70	0,595

In order to represent how the conversion factor (in the following referred to as factor) depends on the individual parameters, the correlations per pair between the factor and the individual collected measured values for the mid-diameter, taper, ovality and crook are calculated. For this purpose, the correlation coefficient according to Pearson is used, as all variables have a metric measurement level.

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Table 3

Correlation of the parameters with the factor

	correlation (r) with factor
mid-diameter	0.568
taper	-0.256
ovality	-0.238
crook	-0.542

Strong correlations between the factor and the mid-diameter as well as between the factor and the crook are revealed (Table 3). The correlation with the mid-diameter is positive (r = 0.568) and the correlation with the crook negative (r = -0.542). The correlation with the taper and the ovality are significantly less strong and are both negative (Table 3). These linear correlations of the factor with the four parameters are also illustrated by Fig. 1 in an x-y diagram. Each diagram shows the 33 values of the individual tests.

For simultaneous examination of the effect of all four parameters on the factor, a linear regression analysis was performed where the factor acts as a dependent variable and the four parameters mid-diameter, taper, ovality and crook act as independent variables.

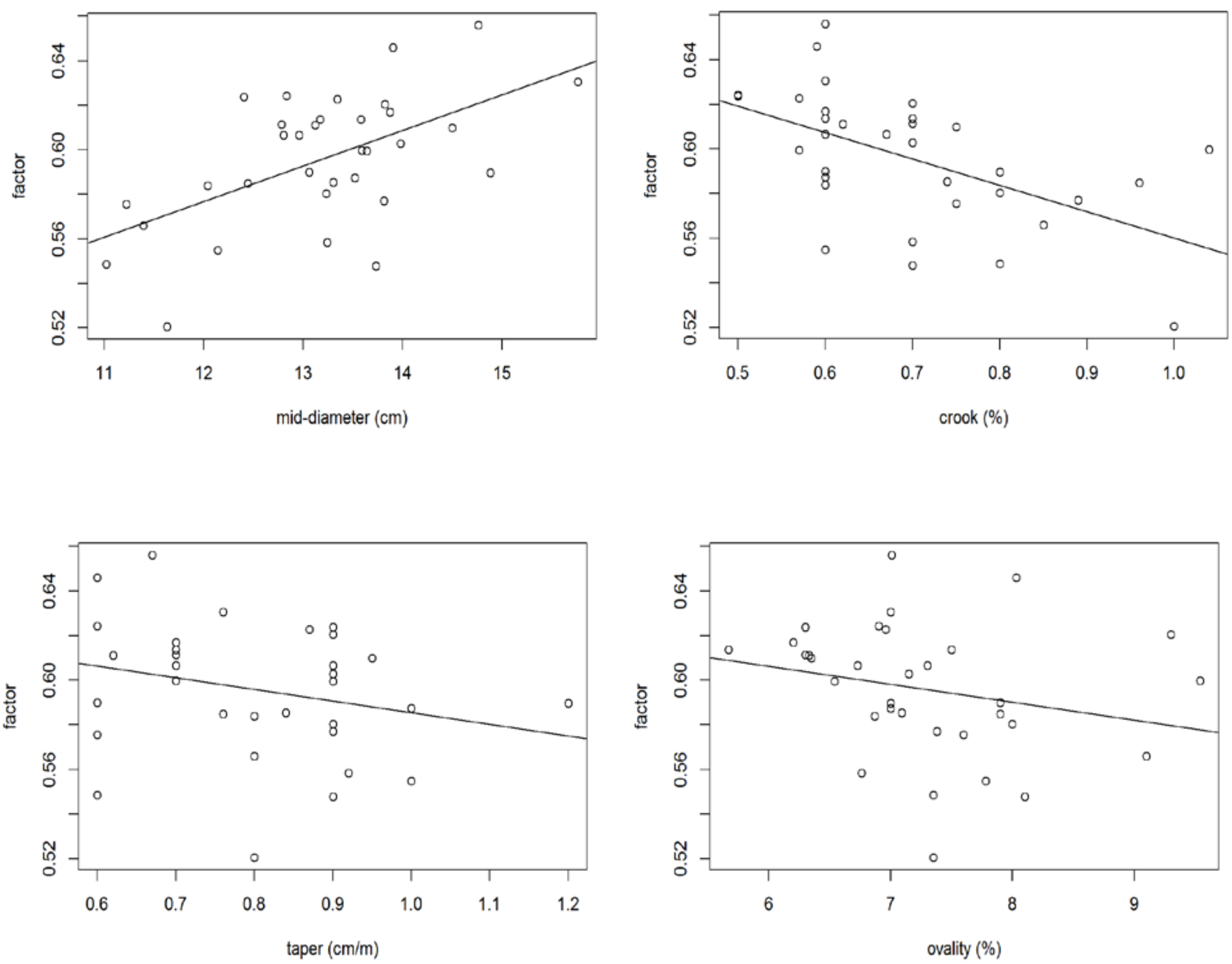

Fig. 1.
The factor correlation with mid-diameter, crook, ovality and taper.

This results in the following regression result (Table 4): The F-value is revealed with F(4;28) = 13.364 with a p-value of $p<0.001$, and the four independent variables in their entirety thus reveal a highly significant effect on the factor. The adjusted R^2 of the regression is revealed with $R^2 = 0.607$. Therefore, approx. 61% of the variance of the factor can be explained by the independent variables used here.

Table 4

Regression analysis with the conversion factor as dependent variable

	dependent variable: factor
mid-diameter	0.017***
taper	-0.008**
ovality	0.003
crook	-0.009**
observations	33
adjusted R^2	0.607
F-Statistic	13.364*** (df = 4; 28)
Note:	*$^*p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$*

Regarding the four independent variables, the three variables mid-diameter, taper and crook reveal a statistically significant effect on the factor, whereas the ovality does not reveal a significant effect. In this context, a positive coefficient is revealed for the mid-diameter with B = 0.017, p<0.001, i.e. an increase of the mid-diameter results in an increase of the factor. In contrast, the taper with B = -0.008, p<0.01 and the crook with B = -0.009, p<0.01 each reveal negative coefficients. Thus, an increase of the values of these characteristics results in a decrease of the factor.

In order to be able to rule out that a multicollinearity exists between the independent variables, the VIF-values (VIF = variance inflation factor) of the regression model were calculated (Table 5). As a general requirement, each of the VIF-values has to be smaller than 10, which clearly is the case here.

Table 5

VIF – values of the regression model

	VIF - Wert
mid-diameter	1,155
taper	1,110
ovality	1,361
crook	1,410

DISCUSSION

As already mentioned above, the literature and regulations recommend values for the conversion factor from the cubic measure to the solid measure for industrial timber based on the log length. For stacks of wood with a log length of 3.00 meters, the factor is 0.600 (RVR 2015). The average value of the conversion factor of the test series completed with all 33 individual stacks of logs is 0.595. Accordingly, this result can be interpreted as realistic.

The tests performed show further (Table 2) that the conversion factor is subject to significant fluctuations (0.513 – 0.656). The reason for this is the varying structure of the logs. As proven by these statistical results, the crook, taper, and ovality affect the packaging density of the stacked wood and as a consequence the solid measure. In particular, an increase of the crook values results in a decrease of the factor (Fig. 1, diagram at the top right). Although the correlations with the parameters taper and ovality are less significant, an increase of these two parameter values still results in a reduction of the conversion factor (Fig. 1, diagrams at the bottom).

Therefore, the average mid-diameter of stack of wood affects the result of conversion to the solid measure. Fig. 1 (diagram at the top left) illustrates the increase of the factor with an increase of the mid-diameter. Accordingly, the solid measure of stacked logs increases significantly with an increase of the diameter of the individual logs.

Finally, it remains to be said that there are other influencing factors which can affect the conversion from the cubic measure to the solid measure. Especially the stacking and the delimbing quality, the bark condition and the aspect, that logging waste may be between the logs may affect the result (Wilwerding 1995). It is, however, not possible to measure these influences in an objective manner and it is thus difficult to assess their effects on the conversion factor.

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