POSSIBILITIES AND BENEFITS OF THE MORE ACCURATE GRADING OF LOGS

Karel Janák

Abstract

The yield of sawn-timber is one of the most important indicators of sawmill production. One of parameters affecting it is the accuracy of measurement and grading the logs according to their top diameter in the course of their preparation on the yard. The paper derives the accuracy of measurement and grading the logs attainable by current devices and evaluates the dependence of theoretically achievable yield of sawn-timber from the centre of the log middle on the accuracy of grading. The actual economic benefit of log grading accurate to 0.5 cm is calculated under conditions of two real sawmills with the different volume of production, technological equipment and production programme.

Key words: *log grading, sawn-timber yield, log dimension measurement, round wood yards, log yards, top diameter*

INTRODUCTION

Raw material represents about 65 to 77% total production costs at the production of sawn timber. Thus, the yield of sawn timber is one of the most monitored parameters.

The yield is affected by many factors, namely dimensions of the processed raw material and the produced assortment of timber, technological equipment of the mill, its technical conditions, qualification and carefulness of the sawmill staff as well as suitably prepared sawing pattern. The carefulness and accuracy at the compilation of sawing schedules and their conformity with the accuracy of preparation and grading logs according to top diameters are, however, of fundamental importance. At the same time, it refers to parameters, which can be affected by the organization of production contrary to, for example, dimensions of produced sawn-timber.

Dimensions of logs were determined traditionally by measurement using a tape and calliper and were given in cm. At present, electronic measurements predominate at medium-sized and large sawmills. Commonly achieved accuracy of present measuring systems is given in units of millimetres and technically attainable accuracy of measurements ranges in tenths of millimetres. Nevertheless, the diameter of logs is always given in cm and logs are graded and prepared for sawing with the same accuracy. However, the higher accuracy of log grading offers generally also higher yield. There is a question what accuracy of measurement and grading the logs is efficient from the aspect of the raw material character, what increasing the sawn-timber yield is offered and what

economic benefits can be achieved under actual conditions of sawmills in the Czech Republic.

MATERIAL AND METHODS

The volume yield of sawn-timber consists of the yield of sawn-timber from the centre of the log middle and sideboards. From the production and economic aspects the yield of sawn-timber from the centre of the log middle (main boards) is fundamental. Slash grain wood (sideboards) are virtually a supplement of the main production. Effects of the diameter grading will be, therefore, calculated for the main board yield.

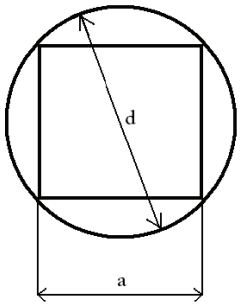
Determination of theoretical yield

The yield is affected by many factors. It is necessary to eliminate effects of other factors at the calculation of the effect of one factor.

Factors resulting from dimensional non-uniformities of logs (flattening, stem curvature, crook and shape anomalies) are not usually taken into account at the ordinary determination of yield. If their effect is more substantial, for example at processing raw material of lower quality classes, the rate of effect is evaluated by statistical methods as the decline of yield under given conditions as compared to ideal conditions. Thus, elimination of these effects is simple. Similarly, it is possible only "not to take into account" effects of the technical condition of machinery or the operator qualification.

Dimensions of logs (diameter, length), dimensions of the produced sawn timber, allowances for trimming and saw kerf are, on the contrary, factors creating input data at the calculation of any real yield of sawn timber. Effects of each of the factors are sizable. It is not possible not to take these factors into account. To include these factors represents marked increasing the labour input but mainly immoderate decreasing the labour results lucidity. Therefore, our work was aimed at the determination of the effect of the log grading accuracy according to top diameter to achieve the highest theoretically attainable yield of main boards (yield of sawn-timber from the centre of the log middle).

The theoretically attainable yield of main boards is defined as the yield of one piece of sawn-timber from the centre of the log middle of square cross section, which is exactly inscribed in the log top end cross-section. Allowances for timber shrinkage and machining are not taken into account.



$$a = \sqrt{\frac{d^2}{2}} = 0{,}707d$$

d –top diameter of a log
a - thickness/width of sawn timber

Fig. 1: Conditions for the determination of the theoretical yield of main boards

Determination of the extent of parameters

The extent of top diameters of logs included to the evaluated set corresponds to the most often processed diameters of logs in the Czech Republic, namely 18 to 35 cm. The mean top diameter of coniferous logs processed ranges from 25 to 27 cm.

The ordinary step of the top diameter grading of logs used at large sawmills processing hundreds of thousands m^3 logs per year is 1 cm at present. At medium-sized sawmills processing tens of thousands m^3 logs per year, the step is 2 cm. At small sawmills, we often meet a step 3 cm, which can be considered to be the limiting value of grading according to the top diameter. Grading is not usually uniform within the whole extent of processed logs and the ordinary step of grading represents a mean value. Broad grading or no grading according to the top diameter at all can be admitted at small sawmills equipped with bent saws. These saws make possible to adapt sawing to the dimensions of currently processed logs. Thus, the dependence of yield on grading the logs according to their diameter is not decisive at using a band saw. This group of sawmills is not, therefore, included into our research.

Values of the log diameter are taken by electronic systems and evaluated accurate to millimetres. However, the uneven surface of logs (debarked but mainly in the bark) causes that taken values of diameter vary within units of mm. Therefore, their filtration (levelling) is necessary and so the actual accuracy of evaluated data is lower. At the evaluation of a diameter in two directions perpendicular at each other separately, an error ranges at a level of ±2-3 mm (at taking the diameter of barked logs). This value can be considered to be a limit value also for the accuracy of log grading according to top diameter. Positioning the logs into the feeding equipment of main sawmill machines is affected at least by the same error. If we take into account also irregularities of the log cross section and its difference from a circle the value of a step for accurate grading the logs reaching 5 mm appears to be a reasonable maximum from material and technological aspects as well as the accuracy of measurement.

On the basis of carried out analyses attainable values of the accuracy of log grading according to the top diameter were determined within the limits 0.5 to 3 cm being graduated at 0.5 cm. For the purpose of research, the wider zone (theoretically attainable) of values is selected: 0.3 cm; 0.5 cm; 1 cm; 1.5 cm; 2 cm; 2.5 cm; 3 cm; 3.5 cm; 4 cm; 4.5 cm; 5 cm. Values of the accuracy of grading 0.3 cm (under reasonable minimum) and >3 cm (above reasonable maximum) are included due to comparative and check reasons.

Procedure

At grading the logs according to top diameter the given box is characterized by the smallest log diameter. It is decisive for the largest dimension of a sawn timber, which can be produced from logs in the box and at the same time, the volume of logs is determined according to the dimension. Logs of higher diameters in the box are present (according to the accuracy of grading), however, they cannot be used for the production of main boards (sawn timber from the centre of the log middle) and, thus, they decrease their yield. The logs can increase the yield of sideboards, however, their production is not profitable from economic aspects being considered to be additional.

To evaluate yields attainable at the various grading of logs according to top diameters, the zone of top diameters of logs included into the evaluated set was divided at 1 mm. Ideal dimensions of a square cross section of the main board figure accurate to 0.1 mm were determined to each of the top diameter values. Dimensions obtained in this way represent a relatively wide assortment of produced sawn timber.

In the presented case, the accuracy of grading corresponds to details in the number of nominal diameters of logs. Thus, a box includes only one nominal log diameter. Based on this diameter, the volume of a log 5 m long and with 1 cm/m taper is calculated. Sawn timer from the centre of the log middle (main boards) produced from this box can have dimensions corresponding most highly to the top diameter. The smallest dimension of sawn timber is the first higher dimension which is not possible to produce from one lower diameter degree logs. For example, at an interval of 1 cm grading, from the 18 cm box, it is possible to produce main boards of the square profile corresponds to diameters 17.1 – 18.0 cm. Within one box, sawn timber of lower dimensions is produced with lower yield, see Tab. 1.

Tab. 1: The method of calculating the yield
(range of top diameters 18.1 to 20.0 cm, grading at an interval of 0.5 cm and 1 cm)

Square side [cm]	***Necessary top diameter [cm]***	***Grading at 0.5 cm***		***Grading at 1 cm***	
		Nominal top diameter in the box [cm]	***Yield***	***Nominal top diameter in the box [cm]***	***Yield***
12.79	18.10	18.50	47.37	19.00	45.06
12.86	18.20		47.89		45.56
12.94	18.30		48.48		46.12
13.01	18.40		49.01		46.62
13.08	18.50		49.54		47.13
13.15	18.60	19.00	47.63		47.63
13.22	18.70		48.14		48.14
13.29	18.80		48.65		48.65
13.36	18.90		49.17		49.17
13.43	19.00		49.68		49.68
13.50	19.10	19.50	47.82	20.00	45.60
13.57	19.20		48.31		46.07
13.64	19.30		48.81		46.55
13.71	19.40		49.32		47.03
13.78	19.50		49.82		47.51
13.85	19.60	20.00	47.99		47.99
13.93	19.70		48.55		48.55
14.00	19.80		49.04		49.04
14.07	19.90		49.53		49.53
14.14	20.00		50.02		50.02

RESULTS

Theoretical values

The dependence of yield on the accuracy of log grading is nearly linear. An increment rises slightly towards lower values. Values of the yield are heavily affected by the top diameter of logs. The total dependence of the theoretically attainable yield of main boards

on the accuracy of log measurement (particular curves) and on the top diameter is demonstrated in Fig. 2.

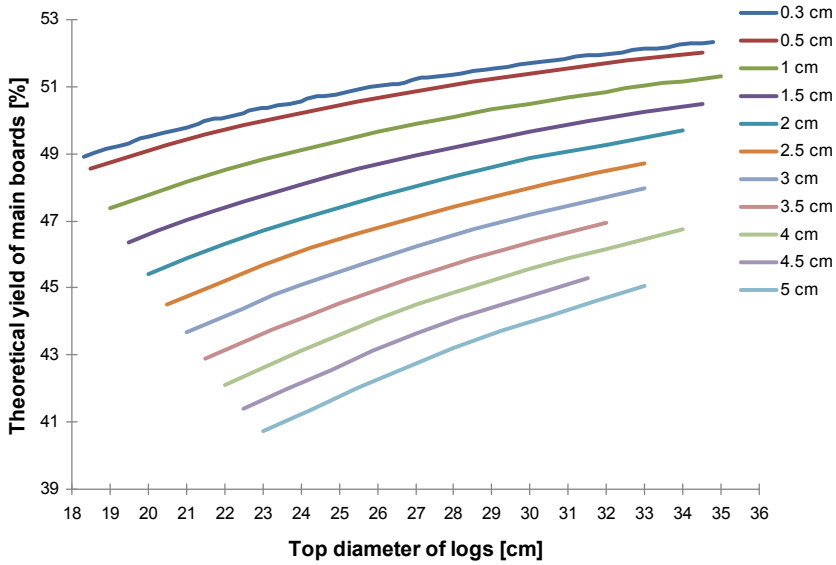


Fig. 2: The dependence of theoretically attainable yield of main boards on the accuracy of log grading according to the top diameter

Numerical values of yield, which can be read from the diagram, apply to the ideal prism of square cross-section without allowances taking into account affects of shrinkage, accuracy of machining or requirements of the timber customer. Approximately and on average, it is possible to expect that these losses will cause the decline of the yield by 3 - 4%. Under operational conditions, another decline will be caused by the non-square shape of the actual main board figure and the number of saw kerfs (both given by the timber assortment produced) and the thickness of kerfs given the technological equipment of the mill. Nevertheless, increased yield due to the increased accuracy of log grading, i.e. a difference between particular courses, is not fundamentally affected. At the increased accuracy of grading by 0.5 cm it is possible to expect increasing the yield of main boards (sawn-timber from the centre of the log middle) at an interval from 0.8 to 1%.

Values attainable in practice

The theoretical yield of sawn timber free of all affects with the exception of top diameter was defined in the methodology. To create a view on the effect of a change in the accuracy of log grading on yield under conditions of an actual sawmill, particular effects could be expressed by means of factors. However, the number of factors and accuracy of their determination cannot be sufficiently confidential. Thus, a result, which can serve for the calculation of benefits of log grading changes in an actual sawmill can be obtained only by the general analysis of production, through re-counting the sawing schedules of all actually manufactured dimensions of sawn-timber and comparing particular yields achieved according to the original and newly proposed method of log grading.

To check benefits achievable in practice two sawmills were selected processing only conifers, however, with the markedly different volume of production and technological equipment:

a) A sawmill processing 520 000 m^3 logs per year equipped with two production lines. The first one, aimed at logs from 15 (top end) to 45 cm (bottom end) in diameter is compiled of aggregates with circular saws, the second one aimed at logs up to a diameter of 56 cm is equipped with aggregates with band saws. The mean top diameter of logs ranges between 24 and 26 cm, the range of products is nearly the continuous series of cross dimensions of sawn timber (many hundreds of dimensions) in lengths only 4 and 5 m. The existing diameter grading of logs takes place within the range 15 to 40 cm at an interval of 1 cm, within the range 41 to 56 cm at an interval of 3 cm.

b) A sawmill processing 40 000 m^3 logs per year equipped with a couple of frame saws. The extent of processed diameters of logs is 14 (top end) to 60 cm (bottom end), mean top diameter of logs is 25 to 28 cm. The range of products consists (on average) in 20 to 35 cross dimensions in lengths from 3 to 6 m. The existing grading of logs ranges from 150 to 240 mm at an interval of 3 cm, from 240 to 320 mm at an interval of 2 cm and from 320 to 420 mm again at an interval of 3 cm. This method of grading is, from time to time, modified according to needs of the actually produced assortment of sawn timber.

A detailed description of the analysis exceeds possibilities of the paper and, thus, it would not be even efficient and suitable (as for theoretical aspects). An idea on the extent of the analysis can create following results:

a) The sawmill processing 520 000 m^3 logs per year

At a line equipped with an aggregate with circular saws, 1 448 orders of the total volume of 280 487 m^3 logs were processed. Out of the number, for 286 orders of the total volume of 58 997 m^3, logs with 0.5 cm lower top diameter could be used. At a line equipped with aggregates with band saws, 1 068 orders of the total volume of 170 599 m^3 logs were processed in the course of the monitored period. Logs with 0.5 cm lower top diameter could be used at 177 orders of the total volume of 27 910 m^3. A mean yield at this group of orders with 1 cm grading is 51.07 and 52.49% at a line with circular saws and band saws, respectively. At grading using a 0.5 cm interval of the top diameter, mean yield would reach 54.96% at a line with circular saws, i.e. higher by 3.90%, at a line with band saws 55.38%, i.e. higher by 2.89%. Thus, total mean yield at both lines in the course of the monitored period is increased by 0.62%. For the monitored period (January – November 2009), the benefit of grading logs at a 0.5 cm interval would represent 3 090.5 m^3 main boards. After the deduction of about 2 750 m^3 sideboards (decline in its yield), the total benefit would exceed CZK 5.5 million in the CR in the 2nd half-year of 2009.

b) The sawmill processing 40 000 m^3 logs per year

The mean yield of main boards ranges about 47.79% at the present method of grading logs. In case of increasing the accuracy of grading there is a possibility to achieve about 50.24% yield of main boards. Thus, the difference would reach 2.41%. At 40 000 m^3, it amounts to 964 m^3 per year. At the calculation according to mean actual prices of main boards (sawn-timber from the center of the log middle) financial savings reach about CZK 4 400 000. After the deduction of sideboard prices, savings will decrease to about CZK 1 750 000. Nevertheless, at sawmills of this size, it is necessary to take into account that the sufficient

number of logs of optimum top diameter will not be available for every order in a given time. Therefore, it will affect unfavourably the actual yield.

DISCUSSION

Values of yields reached in production differ from theoretical values thanks to different properties of raw material, assortments of produced timber and types or technical equipment of a sawmill. Moreover, theoretical and practical values are also subject to administrative affects. A method of the raw material measurement, ways and accuracy of determining dimensions and a method of the log volume calculation are most marked.

Differences between manual and electronic measurements and electronic methods of measurement affect substantially the value of the measured volume of raw material. If the different method of measurement is not used to evaluate the log volume and grading differences in evaluated yields do not occur. However, this case comes into question only at lines, which handle the raw material (unbarked logs) and grading is carried out on the basis of measuring the logs after their barking before a sorter.

The method of rounding values of diameters read in mm and given in cm can substantially affect differences in yields theoretically calculated and virtually attained between grading at an interval of 1 cm and 0.5 cm. At the arithmetical rounding, the administratively recorded volume of raw material (recorded usually in whole cm) does not differ from values of volume recorded at an interval of 0.5 cm (on average). For yields, values given in the presented paper are applied. The same situation would occur if nominal values of the raw material diameter are graded according to the accuracy of log grading (at 0.5 cm, 1 cm, 2 cm etc.). The most usual method of the conversion of log diameters from mm values to cm values used for its sale is the removal of mm. In that case, all log diameters between two whole cm values have a nominal value of the lower whole cm (20.2cm → 20cm; 20.8cm → 20cm). Thus, at the calculation of yield, we start administratively (at all "0.5 cm" values) from the lower volume of logs (20.8 cm are not 20.5 cm but 20.0 cm) and values of the increased yield come out higher than in reality. Thus, the sawmiller is much ahead. On the contrary, if the step of grading is broader than the step of nominal diameters of logs (e.g. grading at an interval of 2 cm, delivered raw material at 1 cm), the volume of raw material is higher and yield is lower than is given in the paper. Thus, the sawmiller is disadvantaged. Effects mentioned above can be combined.

CONCLUSION

At large sawmills in the Czech Republic, grading of logs according to their top diameter at 1 cm step is standard at present while at medium-sized sawmills, the grading is carried out at a step of 2 cm.

At these sawmills, the measurement of raw material is nearly always electronic making possible the accuracy of measurement and grading at an interval of 0.5 cm. This accuracy is achievable from the aspect of raw material properties being also utilizable from the point of view of the technological equipment of mills. Nevertheless, the number of boxes of a sorter or the area of the raw material yard is a limiting factor for the majority of medium-sized sawmills.

The accuracy of log grading according to their top diameter has a fundamental effect on the achieved yield of main boards (yield of sawn-timber from the centre of the log middle). Increasing the accuracy of grading by 0.5 cm it is possible to expect increased yield of main boards on average by 0.8 - 1% at the simultaneous decrease of sideboard yield roughly by 0.4 – 0.8%. With respect to the value of sideboards at a level of 60% of main boards, the economic benefit of the increased accuracy of log grading is on average higher by 40%.

With regard to the number of factors affecting the yield of sawn timber (the assortment of processed raw material and produced sawn timber, technological equipment of the sawmill, technical conditions, carefulness of the sawmill operators, etc.) it is possible to obtain a detailed image on benefits of the more accurate grading of logs under operational conditions only through the total analysis of production. A detailed analysis carried out under conditions of a modern sawmill processing about 500 000 m^3 raw material per year came to a benefit about CZK 5.5 million (about € 200 000) per year (by means of changing the accuracy of grading from 1 cm step to 0.5 cm step). Under conditions of a sawmill with a standard equipment processing about 40 000 m^3 logs per year the benefit amounted to CZK 1.75 million (about € 70 000).

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