The Influence of Sawlog Top End Diameter, Length and Taper on Volume Yield

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In Lithuanian sawmills the volume yield of sawn timber is still calculated and planned on the basis of the standards worked out according to generalized mean form and dimension indices of sawlogs. This paper presents the initial data on the impact of diameter, length and taper of sawlogs on the volume yield and practical possibilities to use obtained data for more accurate assessment of these indices in production process.

Distribution of sawlogs according to the diameter classes for coniferous and broadleaved species in Lithuanian sawmills have been specified. This enables more effective log sorting before log intake and sawing. A mathematical model of sawn timber volume yield disclosed significant linear diminishing influence of log taper, considerably less reduction give log length. Increasing of top end diameter influences volume yield positively, however, more intensively with the growth of log taper. All these influences have been exactly evaluated numerically.

Key words: sawn timber, volume yield, sawing kerf, log length, top end diameter, taper

Introduction

Traditional technological and economical sawn timber production efficiency indices – productivity, production quality, complex utilization of raw material, energy consumption and other remain actual at all production stages (Pranckevičienė, Baltrušaitis, 1998). Still, some of them are affected by rapid implementation of new technologies and equipment. Along with already common conceptions of volume, specification and qualitative sawn timber yield has started existing a conception of value yield which is very sensitive to market demands and changes. Profitability of today's sawmilling becomes problematic without automated production management systems and modern computer programs (Cassens et al., 1993, Garin et al., 1998, Eldeshtein et al., 1999). Work based on experience and intuition only means a loss in the competition with new production planning and optimization methods.

Modern sawn timber production conception covers the following chain: forest – processing - end user. In Lithuania prevailing production and transportation of sawlogs is in assortments, thus, a decision on optimal dimensions of logs and their quality should be precisely and efficiently taken at the logging stage. As it is known, pine and spruce have different typical zones of distribution of branches. Quality grading systems of sawlogs of pine and spruce in different countries are also different; nevertheless, most of them are directly related to the position of the single log in the tree stem (Nordic Timber. Grading rules, 1995). Paying no attention to tree stem quality zones, results in production of sawlogs with the different quality features. For example, log with the overgrown knots includes a certain length zone of loose or unsound knots or a log with loose knots possess some part with sound knots from the top part of the log. It is very important to eliminate this, for it influences further production of sawn timber. Such a drastic quality inadequacy of different assortment zones reduces both the value of logs and the value of sawn timber produced from them. Therefore, to improve the quality of sawn timber assortments, sometimes they have to be shortened on the account of volume output taking into consideration contract requirements. In Lithuania still small profit is gained by obtained in this way residual pieces of wood, sawdust, bark or chips. There being no cellulose industry, they are best utilized for fuel and partially in board production. Thus, the need of optimal crosscutting of stems is obvious, seeking to produce suitable sawlogs, avoid greater labour consumption and volume output reduction, improve the quality of sawn timber assortments when sorting them out. At present it is difficult to say, what the average lengths of various sawlogs should be in Lithuania which are obtained by optimal crosscutting. Before it will be figured out by specific experimental studies it is interesting to explore theoretically the influence of sawlog length on the volume yield of sawn timber.

The effect of log length on the volume yield is not precisely defined at present. It was only stated, that yield increases with decreasing log lengths. Most standards were set for 6,0 - 6,5 m long logs. Stems were cut into such lengths independently of the quality of sawlogs and sawn timber. This is essentially wrong and unacceptable practice. By producing shorter assortments a twofold benefit is gained: logs of better quality are produced, taking into account distribution zones of sound and unsound knots, log sweep and other defects, while at the same time greater sawn timber yield is obtained. Thus it is very important to analyse and try to optimize volume yield of sawlogs of different lengths.

There is no reliable data either on complex interrelationship of different combinations among log top end diameter – length – taper as volume yield function.

Optimal crosscutting of tree stems influences also the distribution of the sawlogs into the top end diameter classes. Different sawmills apply various ranges of the log sorting according to the top end diameter, but 1 – 2 centimeter increment from one diameter class to another prevails. Effective log sorting ensures high volume yield of sawn timber. In Lithuania no verified data exist about the distribution of sawlogs into different top end diameter classes, which thus eliminates the possibility of the accurate prognosis of the sawn timber production at a separate sawmill or throughout the country. Having such data these prognoses could be easily defined and calculated. Length and diameter of the sawlogs together with the taper make the main impact on the volume yield of sawn timber. Such data are necessary to specify various standard indices applied in sawmills, for in Lithuania it is common, that taper for spruce and pine logs on average is 1 cm/m. However, in practice this index changes from 0,7 cm/m, when log top end diameter is 12 cm up to 1,6 cm, when its diameter is 40 cm, and even up to 1,8 cm/m, when the diameter is 60 cm and more. The taper itself may also differ within the same tree stem. Generalized (average) tapers in practice are held constant for a certain diameter class, for instance, 12-13 cm diameters are considered to have 0,75 cm/m taper, 19-22 cm diameters – 0,9 cm/m, 23 - 26 cm diameters – 1 cm/m, 31-34 cm diameters – 1,15 cm/m and so on (Aksenov et al., 1976). This assumption is false, causing errors, because logs of different diameters may have the same taper. As mentioned above, still greater confusion and error are caused by accepted in our geographical latitude (earlier for the whole European USSR part) relative 1 cm/m taper. It is worth thinking over a possibility to use available timber volume tables (Medienos tūrio lentelės, 1999) and other accumulated forest inventory data attempting to model and optimize them mathematically for finding out optimal parameters of sawlogs.

Therefore, one of the aims of this paper is also to have a look at what impact the taper may really have on calculating volume yield.

Materials and methods

The calculations of the influence of log top end diameter, length and taper were done according to the theory that was developed by many scientists (Aksenov et al., 1976, Graschov, 1981, Kaliteevskij, 1996). Ch. Feldman (Feldman, 1932) for the first time has defined maximum volume yield of edged assortments sawing by cant method. Afterwards he adjusted it for the log through sawing. The theory is based on the fact that mathematically is given such a sawing pattern, when the thickness and width of boards, i.e. total crosscut area, falling within top end circle, is greatest. Maximum possible volume yield is convenient for analysing various factors, such as log diameter, length, taper, sweep, width of sawing kerf, allowable wane and many others, affecting the volume yield of sawn wood. Such a sawing pattern is presented in Figure 1 and written as follows:

$$0,1D\text{-}0,135D\text{-}0,43D\text{-}0,135D\text{-}0,1D \quad (1)$$

where D – log top end diameter.

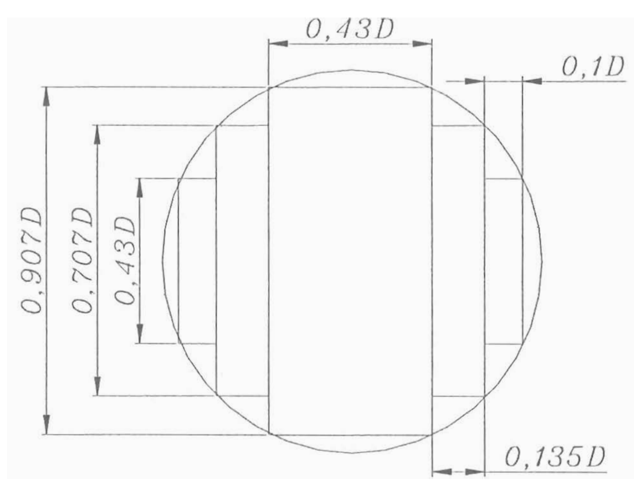

Figure 1. Log cutting scheme according to the theory of maximum possible volume yield

Calculations for accepted log top end diameters D_{top}=14, 16, 18, 22, 24, 26, 28, 30 and 32 cm were based on corresponding thickness and widths of boards, which is derived by formula.

When the log taper is equal zero, i.e. it is of a cylinder or close to it form, theoretical volume yield, paying no attention to shrinkage and sawing kerf, is calculated according to formula:

$$Y = \frac{L\sum F}{V_l} \quad (2)$$

where $\sum F$ –the sum of board cross-sectional areas falling into top end circle, m²; L – length of the log and boards, m; V_l – log volume, m³ ($V_l = \pi R^2 L$); R – radius of log top end circle, cm.

$\sum F$ is calculated:

$$\sum F = (0{,}2R \times 0{,}86R) \times 4 + (R\sqrt{2})^2 = 2{,}69R^2 \quad (3)$$

Then

$$K_l = \frac{2{,}69R^2}{\pi R^2} = 85{,}7\%$$

When sawing kerf width is equal zero, volumetric shrinkage of produced assortments is 8%, and then volume yield approximately constitutes 78%. After calculating volume yield according to CAS 3.75A program, volume yield comprised 78,8%. This index was accepted as basic for further calculations estimating the impact of log diameter, taper and length on volume yield.

A more precise and imitational ("computer") sawing of logs abroad has specially designed and widely applied programmed equipment (Labeda, 1993). The Department of Mechanical Wood Technology of Kaunas University of Technology has implemented one of the most modern systems – CAS 3.75A and CAS 3.75B, designed in Sweden (CAS – Computer Aided Sawing). These programs help optimize volume and value yield of sawn timber, taking into account the form and dimensions of logs, sawing schemes and patterns, allowable wane, sawing kerf, prices of raw material and produced assortments, etc.

CAS 3.75A program was applied to calculate volume yield according to the theory of maximum sawing patterns. Log top end diameters applied were *Dtop*=14, 16, 18, 20, 22, 24, 26, 28, 30 and 32 cm, their lengths (*L*) 3,5; 4,0; 4,5; 5,0; 5,5; 6,0 and 6,5 m and tapers (*T*) 0, 0,2; 0,4; 0,6; 0,8; 1,0; 1,2 and 1,4 cm/m. As to the diameter, length and average taper affect the volume yield complexly, registering several of these parameters and changing the third have to be studied.

Results

Insufficiently is studied sawlogs percentage distribution according to top diameter classes, falling within them by the amount of logs and volume. The data are necessary when calculating optimal sawmill capacities, choosing equipment, drying kilns, etc. Some of the mentioned indices are known from foreign countries. However, their direct implementation is unacceptable due to differences in growth conditions, felling age, logging technologies and so on. We conducted studies in several sawmills and enterprises and obtained log distribution by diameters, calculating the volume and quantity of coniferous logs. It is given in Figure 2.

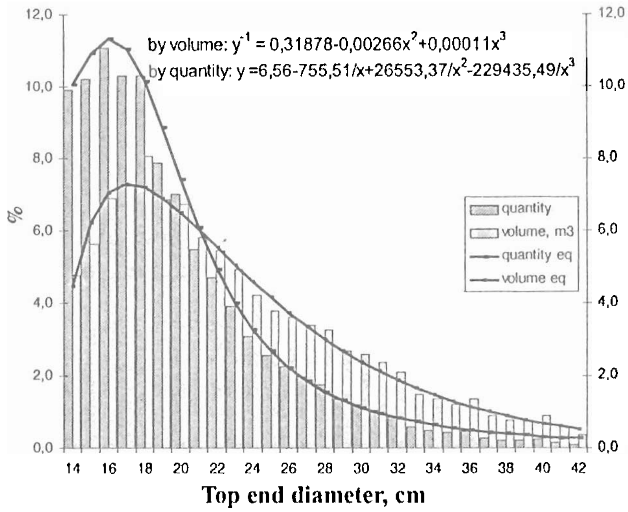

Figure 2. Distribution by top end diameters, calculating the volume and quantity of logs

Sawlogs with the top end diameter up to 20 cm make up 66,7 % by quantity and 46,2 % by volume from the total amount of tested sawlogs (number of sawlogs in the sample exceeded 87 thou. pieces).

The data processed by program CAS 3.75 are graphically depicted in Figures 3 and 4.

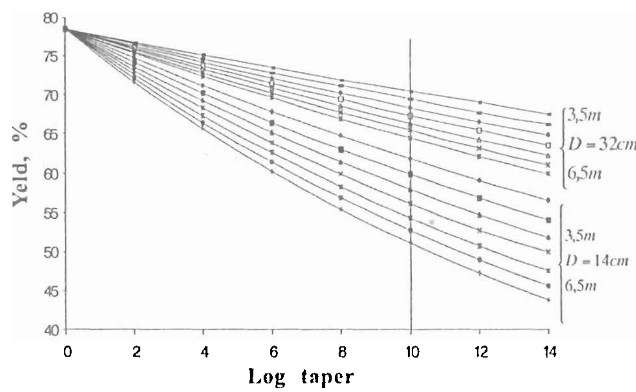

Figure 3. The impact of log taper on sawn timber yield

Figure 3 presents the effect of log taper on sawn timber yield by fixing log top end diameter (*L*=3,5; 4,0; 4,5; 5,0; 5,5; 6,0 and 6,5 m). For the sake of figurativeness, dependence curves of the same diameter (32 cm and 14 cm) are presented in one scheme. Vertical line represents 1,0 cm/m taper applied in Lithuania. Initial point of all curves is 78,8%. It can be seen that volume yield decreases with increasing taper; besides, it is decreasing more intensively with less log top end diameter. E.g., under log length 3,5 m, taper 1,0 cm/m and top end diameter D=32 cm, the yield of sawn timber comprises 70,8%, while under D=14 cm the yield makes up 62,0%. Under log length 6,5 m, taper 1,0 cm/m and D=32 cm, the yield is 64,8% while under D=14 cm, the yield constitutes 51,3%. It is obvious, that with increasing length and taper the yield diminishes, however, it increases with greater top end diameter.

Log length impact on sawn timber yield is also almost linear; however, with greater diameter the curves come closer.

Figure 4 represents the effect of log top end diameter on sawn timber yield by fixing taper (schemes show tapers 0,2 and 1,0 cm/m).

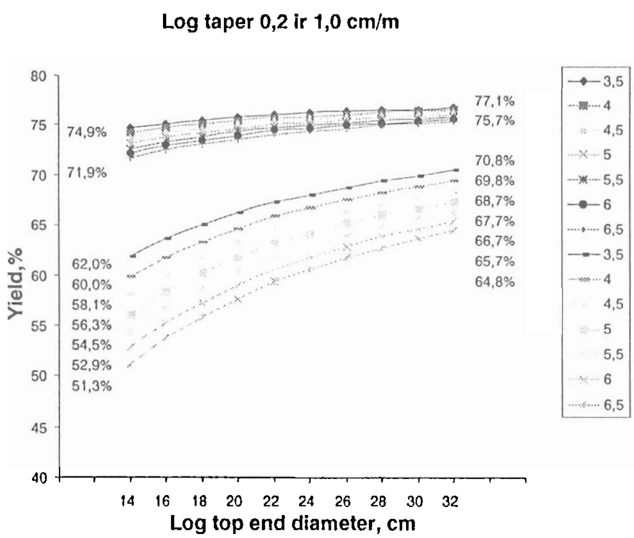

Figure 4. The impact of log top end diameter on sawn timber yield

Here the curves are non linear. With log top end increment the volume yield increases. The longer the log, the more scattered volume yield curves are. E.g., under 1,0 cm/m taper, D=14 cm, log length 3,5 m, the volume yield will comprise 62,0%, under D=32 cm, the volume yield will be 70,8%.

With increasing log length the volume yield decreases, however, less, when the top end diameter is less.

While analysing the impact of top end diameter it is obvious, that the intensity of changes in volume yield increases with greater log length and taper.

Mathematical model of the dependence of 3 factors (log taper T, top end diameter D and length L):

$$Y=78,96+0,51D-2,22L-18,41T-0,02D^2+2,36T^2+0,06L^2+0,06DL+0,53DT-2,35LT \quad (5)$$

where T – log taper, cm/m (*0...1,4 cm/m*); D – log top end diameter, cm (*14...32 cm*); L – log length, m (*3,5...6,5 m*).

Correlation coefficient of regression curve is 0,9984, the coefficient of determination 0,9968. It can be seen that the equation adequately describes the impact of top end diameter and taper on maximal volume yield of sawn timber.

After simplifying the formulae and recalculating regression coefficients, it may be written for practical use as a linear model:

$$Y=77,79+0,42D-1,88L-14,63T \quad (6)$$

Correlation coefficient of regression curve is 0,9664, the coefficient of determination 0,9339.

Instead of taper, formulae, used to calculate the taper of a group of diameters of individual logs, may be applied (Graschov, 1981):

$$T = \frac{19+D}{50-L} \quad (7)$$

It is obvious, that taper has the greatest influence on sawn timber yield, then top end diameter and length has the least influence.

Conclusions

Mathematical model for calculation and optimization of volume yield of sawn timber could be used for easy practical planning of target-oriented volumes of the production in each sawmill. Groups with the certain log top end diameters being processed could be assessed as a targeted volume yields separately thus helping sawmill manager control and follow up the production. Models could be used effectively on a larger scale for the calculations of the maximum achievable production of sawn timber even throughout the country. Having figures of the volumes of sawlogs produced for example per year and their distribution according to the diameter classes (see Figure 2) it is possible to make prognoses of the volumes of the sawn timber to be produced.

Further studies are now conducted on the impact of log sweep, accuracy of focusing into the center of saw set, width of kerf, allowable wane and other parameters on sawn timber yield. As sawn assortments according to the theory of optimal sawing pattern cannot satisfy the needs of users, assortments of certain dimensions are allowed by the theory of optimal patterns to have some deviations to one or another side. Such sawing patterns are called relatively optimal. Thus, optimal sawing patterns will be ascertained with respect to concrete dimensions, sawing kerfs, etc.

At present sawn timber yield standards are too generalized and it makes impossible to access more accurately the parameters of logs: sweep, sawing kerf, positioning errors, etc. In Lithuania log scanning means, adequately showing log form and its position towards saw set in computer monitor, are already applied in some places and in the nearest future will be used more widely. In this case log position and its changes can be easily regulated, therefore, the studies and results become especially important for our further investigations.

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ВЛИЯНИЕ ВЕРШИННОГО ДИАМЕТРА, ДЛИНЫ И СБЕГА БРЕВЕН НА ОБЪЕМНЫЙ ВЫХОД ПИЛОМАТЕРИАЛОВ

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Резюме

В Литовском лесопилении выход лесопильной продукции до сих пор планируется и расчитывается на базе стандартных средних характеристик бревен. В статье представлены результаты исследования комплексного влияния вершинного диаметра, длины и сбега бревен на величину максимально возможного объемного выхода пиломатериалов. Полученные математические модели позволяют прогнозировать и контролировать производственный процесс на уровне каждого отдельного лесопильного предприятия, а также использовать их для стратегического планирования объемов пилопродукции на уровне региона или страны. Также было исследовано расспределение поступающих на лесопильные предприятия Литвы вершинных диаметров бревен на отдельные размерные классы. Эта информация полезна для оптимальной сортировки бревен на предприятиях. Математическая модель, связывающия максимально возможный объемный выход пиломатериалов с вершинным диаметром, длиной и сбегом бревна позволила определить численную значимость влияния данных факторов. Наибольшее снижение объемного выхода по линеному закону приводит увеличение сбега бревен, тогда как влияние длины менее значимо. Увеличение диаметра повышает максимально возможный выход пиломатериалов, причем более интенсивный прирост выхода наблюдается при большем сбеге бревна.

Ключевые слова: пиломатериалы, объемный выход, пропил, длина, вершинный диаметр, сбег бревна