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MEASUREMENT OF ROUND TIMBER USING ELECTRONIC MEASUREMENT SYSTEMS

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Abstract - In many countries logging is a very important sector of economy, a factor, which led to an extensive industrialization in the field of wood processing within the last three decades. In particular electronic measurement systems are used to optimise the commercial utilization of the resource “timber” and also for data acquisition in trade and commerce.
Modern measuring assemblies for round timber enable not only to acquire the volume of round timber but also to record – self-acting - taper, sweep and ovality. More and more efforts are undertaken to use data - primarily attained for internal purposes only and for pricing, respectively. Therefore, the measurement methods presently used should be analyzed and several criteria for measurement of round timber in the future should be discussed and - last but not least - basic requirements on measurement systems as far as the valuation of features of wood is concerned should be identified.

1. MEASURING PRINCIPLES

General - Measuring assemblies for round timber determine the mid log diameter in two axes oriented perpendicular to each other: the averages of such pairs of diameters in the same plane will be generated on at least two measuring points close to the middle of the log length; the minimum of these averages will be called the mid log diameter; where the log volume is determined as the product of the area of a circle with the same diameter as the mid log diameter and the log length.

Typical measurement systems in use - Conventional measuring assemblies for round timber determine the log diameter using a system of light grids consisting of two opposite measuring units for each axis. Either one of them is equipped with infrared transmitters in a line and the other one with infrared receivers on the opposite side (principle of the sheaf of parallel lines) or each measurement unit is equipped with infrared transmitters in a line on each side and with a single infrared receiver on the side opposite to the transmitters (principle of central projection). The device to determine the log diameter is mounted so that the log laying centremost on the conveyer passes transmitter and receiver beam lengthwise. When the log disrupts the light grid, it reflects a shade which will be evaluated by the receiver electronics. If the measuring assembly uses the principle of the sheaf of parallel lines, the size of the shadow corresponds to the log diameter at this position. (Fig. 1,2);

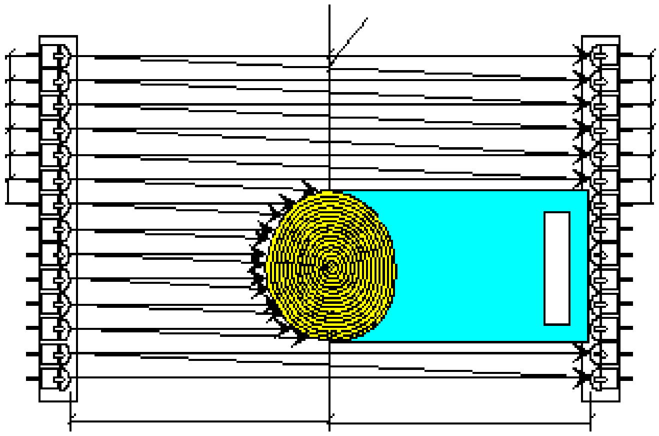

Fig.1 Principle of the sheaf of parallel lines

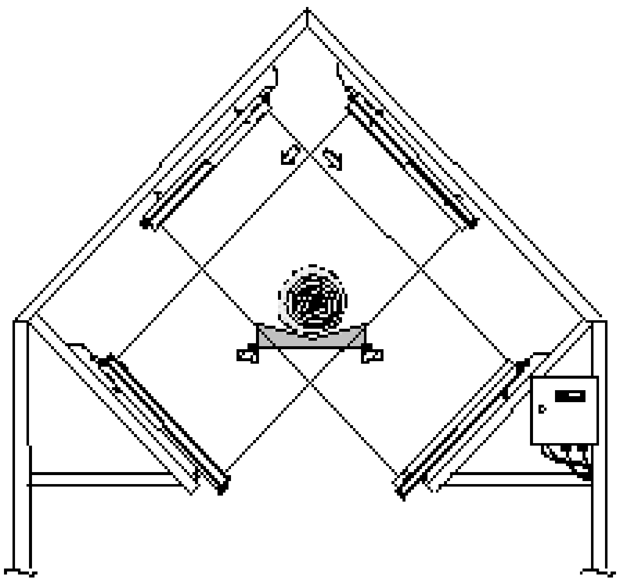

Fig.2 Twin axis measurement, mounting 45°

However for measuring assemblies with central projection (Fig. 3) the two shadows comply with the angular fields whose boundary straight lines can be interpreted as tangents of the two circles. The centres of these two circles are the intersection point of the two bisectors. Two times the normal distance of the centres of these circles from the tangents correspond to the diameter of the log at this point.

Fig.3 Principle of central projection

The length measurement is made by one or more light barriers, in fixed distances – which is the most advisable arrangement - and a shaft encoder, which is mounted at the chain wheel of the longitudinal conveyor.
If the length measurement is made by one light barrier, the measuring assembly measures the log length in that kind: When it is recognizing the top end of the log, it starts counting pulses. At the butt end, it finishes counting. The exact log length is calculated from the sum of the counted pulses multiplied by the way per pulse.
If the length measurement is made by two or more light barriers, there are two kinds of measurement possible: if the log length is smaller than the distance of the second barrier from the first one, the measuring assembly starts counting pulses, when the first barrier is recognizing the butt end and finishes counting, when the second barrier is recognizing the top end of the log. The exact log length is calculated as the difference of the distance of the second barrier from the first one and the sum of the counted pulses multiplied by the way per pulse. In the other case the measuring assembly starts counting pulses, when the last barrier is recognizing the top end of the log and finishes counting, when the first barrier is recognizing the butt end. The exact log length is calculated as the sum of the distance of the last barrier from the first one and the sum of the counted pulses multiplied by the way per pulse.
During the length scanning pairs of diameters are gradually evaluated; the acquired values of these pairs of diameters are stored. When the length scanning is finished, from the stored values this pair will be selected, which is to consult for the determination of the log diameter.

In most cases, chain conveyors with lugs are used. Here it is necessary to transport the log lengthwise through the measuring system in such a way that its contours are visible and not covered by chains, schutes or similar parts of the conveyor. If it is impossible to interrupt the conveyor at the measuring position the chains will cover the measuring range. In this case a suitable appliance has to be provided for blanking out the conveyor chains (fig.2).
For measuring the crook and sweep of the log, the log must not move on the conveyor while it is measured. Therefore, conveyors which are interrupted at the measuring position are normally not suitable for crook and sweep measurement.

"3D-Method" - Nowadays, measuring assemblies for round timber based on the so called "3D-Method" come more and more into operation. The notation "3D-Method" is deduced from the ability of these assemblies to acquire the topology of a log and to provide a three dimensional log presentation. This is an advantage and a valuable help for acquiring taper, sweep or ovality of a log.
The measuring principle can be described as follows: a closed light trace around the log is produced by a proper photometric device (generating multiple laser beams) and is recorded by various digital cameras (fig.4). Since these cameras have to be positioned in a certain angle to this line of light, the resulting image has to undergo distortion correction. Doing so for the first time 3D-information on the log can be received. This leads to the generation of a 3D-projection of the log and, furthermore, to the determination of the mid log diameter. Calculating the diameters relevant for the determination of the mid log diameter you have to use two pairs of parallel tangents which are placed in perpendicular position to each other in the resulting image of the light trace. These tangents have to be rotated step by step by an angle φ. In this way you will get pairs of diameters (as mentioned above already) which are the normal distance of each two parallel tangents. Analysing all pairs of diameters the pair with the minimum average is chosen.

Fig.4: Projected laser beam on log for the 3D-method

Basically such a 3D-projection could also be achieved by conventional methods, too. But the step by step determined pairs of diameters have to be transformed by a calculation into elliptic areas of cross section which do not represent the real log very well. An optimal 3D-projection requires the best possible recording of areas of cross section giving rise to the development of this method for determining mid log diameters.

2. MEASUREMENT UNCERTAINTY

The values determined by an electronic measuring assembly for round timber vary from the values of the measured log; these deviations are usually unknown to the user of the measuring assembly and therefore have to be regarded as uncertainty of measurement. As far as measurement uncertainty is concerned the influences of the determination of diameters and of the length of the log and also the influence of the measuring software have to be taken into account. This also includes shortcomings because of sensitivity to environmental influences.

The value of the uncertainty of measurement depends on several parameters and generally cannot be estimated. If an electronic measuring assembly for round timber is operated in transactions liable to verification in Austria, its deviations must not exceed the maximum permissible errors stipulated by the legislator. If mpe_D denotes the maximum permissible error for the diameter and mpe_L the maximum permissible error for length then

$$\left|d_k - D_k\right| \le mpe_D \text{ und } \left|l - L\right| \le mpe_L$$

is valid for k=1,2, where the capital letters stand for the effective values of the measured log and the small letters for the values determined by the measuring assembly. The values for the maximum permissible error mpe_D apply for an individual measurement; a maximum deviation of a quarter of the maximum permissible error mpe_D for the diameter is allowed for the average of at least ten diameters measurements of an identical measured log; for the average of at least three such averages a maximum deviation of one tenth of the maximum permissible error mpe_D for the diameter is allowed; for the average of at least ten length measurements a maximum deviation of one fifth of the maximum permissible error mpe_L for length is allowed.

The reference diameter D of the measured log is determined by the average of the log diameters D_1 and D_2. Considering that the measured diameter d is determined as the average rounded down to the rounding value rv_D of the two diameters d_1 and d_2 also rounded down to the rounding value rv_D, and adhering to the maximum permissible error mpe_D mentioned above the following interval boundaries d_{min}, d_{max} are obtained

$$d_{min} = D - (mpe_D + 3/2\, rv_D),\ d_{max} = D + mpe_D$$

for the individual reference diameter resp.

$$d_{min} = D - (1/4\, mpe_D + 3/2\, rv_D),\ d_{max} = D + 1/4\, mpe_D$$

for the average of 10 individual reference diameters determined on an identical measured log as well as

$$d_{min} = D - (1/10\, mpe_D + 3/2\, rv_D),\ d_{max} = D + 1/10\, mpe_D$$

for the average of a sufficient charge of logs (at least 30 logs with diameters spread evenly over the hole measuring range)

Considering further that the measured length l is rounded down to defined length-steps with the rounding value rv_L, the following interval boundaries l_{min}, l_{max} for the maximum permissible deviations are obtained

$$l_{min} = L - (mpe_L + rv_L),\ l_{max} = L + mpe_L$$

for the length of a single log as well as

$$l_{min} = L - (2/5\, mpe_L + rv_L),\ l_{max} = L + 2/5\, mpe_L$$

for the average of at least 10 individual measurements.

Customarily round timber is traded by the volume; therefore it is interesting to know how the differences in the dimensions of diameter D and length L affect the volume. To answer this question it should be clarified how the volume V of round timber has to be determined. It is standard practice in timber industry to equate the volume of a log to the volume of a cylinder, to equate its area to $D^2 \times \pi/4$ and its height to L . Consequently

$$V = D^2 \times \pi/4 \times L$$

applies for the reference volume resp.

$$v = d^2 \times \pi/4 \times l$$

for the volume of the measured log. This results in the following interval boundaries v_{min}, v_{max} relevant to the compliance with the maximum permissible volume deviations

$$v_{min} = [D - (mpe_D + 3/2\, rv_D)]^2 \times \pi/4 \times [L - (mpe_L + rv_L)]$$

$$v_{max} = [D + mpe_D]^2 \times \pi/4 \times [L - mpe_L]$$

for a single log resp.

$$v_{min} = [D - (1/10\, mpe_D + 3/2\, rv_D)]^2 \times \pi/4 \times [L - (2/5\, mpe_L + rv_L)]$$

$$v_{max} = [D + 1/10\, mpe_D]^2 \times \pi/4 \times [L - 2/5\, mpe_L]$$

for the average of a charge of at least 30 logs with diameters spread evenly over the hole measuring range.

$$v_{min} = [D_{media} - (1/10\, mpe_D + 3/2\, rv_D)]^2 \times \pi/4 \times \times [L_{media} - (2/5\, mpe_L + rv_L)]$$

$$v_{max} = [D_{media} + 1/10\, mpe_D]^2 \times \pi/4 \times [L_{media} - 2/5\, mpe_L]$$

for the average of a charge of at least 30 logs with diameters spread evenly over the hole measuring range, where applies:

$$D_{media} = \frac{\sum D_i^2 \times L_i}{\sum D_i \times L_i} \text{ and } L_{media} = \frac{\sum D_i^2 \times L_i}{\sum D_i^2}$$

Neglecting the terms that contain deviances of the second order as factors one obtains

$$v_{min} = V - D_a^2 \times \pi/4 \times (mpe_L + rv_L) - - 2D \times L \times \pi/4 \times (mpe_D + 3/2\, rv_D)$$

$$v_{max} = V + D^2 \times \pi/4 \times mpe_L + 2D \times L \times \pi/4 \times mpe_D$$

for a single log resp.

$$v_{\min} = V - D_{\text{media}}^2 \times \tfrac{\pi}{4} \times \left(\tfrac{2}{5}\, mpe_{\text{L}} + rv_{\text{L}}\right) - 2D_{\text{media}} \times L_{\text{media}} \times \tfrac{\pi}{4} \times \left(\tfrac{1}{10}\, mpe_{\text{D}} + \tfrac{3}{2}\, rv_{\text{D}}\right)$$

$$v_{\max} = V - D_{\text{media}}^2 \times \tfrac{\pi}{4} \times \tfrac{2}{5}\, mpe_{\text{L}} - 2D_{\text{media}} \times L_{\text{media}} \times \tfrac{\pi}{4} \times \tfrac{1}{10}\, mpe_{\text{D}}$$

for the average of a charge of at least 30 logs with diameters spread evenly over the hole measuring range.

For the relative deviation Δv of the volume from the reference volume V applies

$$\Delta v = \frac{v - V}{V}$$

Hence ensue the following interval boundaries $\Delta v_{\min}$, $\Delta v_{\max}$, relevant to the compliance with the relative maximum permissible deviations for the volume:

$$\Delta v_{\min} = -\left(\frac{2 \times mpe_D + \tfrac{3}{2} rv_D}{D} + \frac{mpe_L + rv_L}{L} \right)$$

$$\Delta v_{\max} = +\left(\frac{2 \times mpe_D}{D} + \frac{mpe_L}{L} \right)$$

for a single log, resp.

$$\Delta v_{\min} = -\left(\frac{\tfrac{1}{5} mpe_D + \tfrac{3}{2} ru_D}{D_{\text{media}}} + \frac{\tfrac{2}{5} mpe_L + ru_L}{L_{\text{media}}} \right)$$

$$\Delta v_{\max} = +\left(\frac{\tfrac{1}{5} mpe_D}{D_{\text{media}}} + \frac{\tfrac{2}{5} mpe_L}{L_{\text{media}}} \right)$$

for the average of a charge of at least 30 logs with diameters spread evenly over the hole measuring range

The reference volume V is based on the volume of a cylinder with a circular slice plane. Since the two diameters D_1 and D_2 usually differ, it may be more correct to adopt the slice plane of the cylinder as an ellipse with the axes D_1 and D_2. In this case the reference volume V_{E} result as

$$V_{\text{E}} = D_1 \times D_2 \times \pi/4 \times L$$

If ΔD denotes the deviations of the log diameters D_1 nd D_2 from the reference diameter D the reference volume V can be calculated as follows

$$V_{\text{E}} = (D^2 - \Delta D^2) \times \pi/4 \times L$$

Consequently applies

$$V - V_{\text{E}} = \Delta D^2 \times \pi/4 \times L$$

For the relative volume deviation ΔV it follows:

$$\Delta V = \frac{V - V_E}{V_E} = \frac{\Delta D^2}{D^2 - \Delta D^2}$$

This equation only holds true if D is determined as the average of the log diameters D_1 und D_2 that are collateral to the principal and the secondary axis of the ellipse (Fig.5)

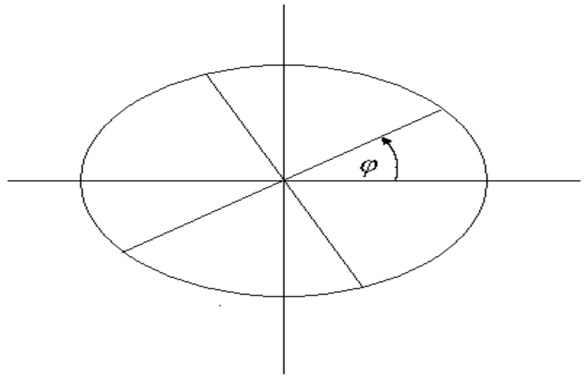

Fig.5 Pairs of diameters (in normal position and rotated by an angle φ).

For any pair of normal to another arranged diameters φD_1 and φD_2 rotated from the normal position by an angle φ generally applies:

$$\varphi D_1 = [(D + \Delta D)^2 \times \cos^2 \varphi + (D - \Delta D)^2 \times \sin^2 \varphi]^{1/2}$$
$$\varphi D_2 = [(D + \Delta D)^2 \times \sin^2 \varphi + (D - \Delta D)^2 \times \cos^2 \varphi]^{1/2}$$

If $\varphi = 0$ then applies: $\varphi D_1 = D_1$ and $\varphi D_2 = D_2$;
If $\varphi = \pi/4$ then applies: $\varphi D_1 = (D^2 + \Delta D^2)^{1/2} = \varphi D_2$;
If $\varphi = \pi/2$ then applies: $\varphi D_1 = D_2$ and $\varphi D_2 = D_1$.

For the relative deviation $\Delta\varphi V$ of the volume of a measured log from the reference volume V_{E}: applies

$$\Delta\varphi V = \frac{\varphi V - V_E}{V_E} = \frac{\Delta D^2}{D^2 - \Delta D^2} \times (2 - \cos^2 2\varphi)$$

where $\Delta\varphi V_{\min} = \Delta V$ and $\Delta\varphi V_{\max} = 2 \times \Delta V$.

3. CONCLUSIONS

Choosing a cylinder of elliptical slice plane with the principal axes D_1 and D_2 as the reference volume leads to a shift of the interval boundaries $v_{\min}$ by ΔV resp. $v_{\max}$ by $2 \times \Delta V$ relevant for the compliance with the maximum permissible volume deviations of a single log. The same is true for the compliance with the maximum permissible volume deviations for the average of a charge of at least 30 logs with diameters spread evenly over the hole measuring range - but in this case it cannot be indicated how big the shift exactly is; in any case it is at least $\Delta V_{\min}$ und $2 \times \Delta V_{\max}$ for a single log. They lay between $\Delta V_{\min}$ and $\Delta V_{\max}$ for measuring assemblies using the 3D-Method.
Altogether this results in a fictive advantage for the seller of round timber, whereas diameter rounding and length grading yield to a fictive advantage for the buyer, which however is much bigger than the seller's advantage. A particular risk is the backgrading of the length of individual logs when round timber with excess length of more than the maximum permissible error mpe_{L} for length is delivered. This risk increases the more the log length L approximates to the nominal length for this log prearranged between buyer and seller.

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