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Wedge prism as a tool for diameter and distance measurement

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ABSTRACT: The wedge prism, which is generally used for the measurement of basal area in diameter at breast height, is also a tool for the measurement of distance as well as for the measurement of diameters at a certain height of the stem, in the upper stem. Measurements using the wedge prism are based on the same principle as measurements using Bitterlich mirror relascope. This method is appropriate for non-destructive determination of stem volume. Moreover, the wedge prism can be used for the sorting of logs in standing trees when the small end of expectant assortment has to be known. As the wedge prism is a common tool for foresters, its usage seems to be larger than only the measurement of basal area.

Keywords: wedge prism; upper stem diameter measurement; distance measurement; log sorting

The wedge prism is a widely used small tool for the measurement of basal area, mainly in diameter at breast height (dbh). It is one of the tools based on the method invented by the Austrian forester Bitterlich (Korf et al. 1972). The principle is an angle counting of stems using the ratio of the diameter to the distance between the measured stem and the observer (the centre of the sample plot). There are two ways of projecting the angle:

– By prolonging two lines of sight from the eye through two points whose lateral separation is fixed, both of which are in the same horizontal plane and both of which are at the same fixed distance from the eye (Husc et al. 2003),
– By deviating the light rays from the tree through a fixed angle (wedge prism).

The principle is that the given ratio between widths at a certain distance from the eye. The ratio is determined with an angle gauge according to the trigonometric function (see Fig. 1).

$$\alpha = 2\text{arctg}\frac{a}{2b} = 2\text{arctg}\frac{(a)}{2(b)}$$

To calculate the basal area of trees per hectare the following formula is used:

$$G = 2{,}500\left(\frac{a}{b}\right)^2 M = cM$$

where: c – quotient,
M – number of countable trees whose angle is wider than α or that lie precisely on the borderline (Korf et al. 1972; Šmelko 2000).

The quotient is equal to 1 for the ratio 1:50 between the segment a and the segment b (Bitterlich 1958 in Korf et al. 1972; Bitterlich 1984). This quotient is very convenient because the ratio enables to measure distances or diameters easily using the wedge prism. The ratio means that the tree is in the borderline if the distance in meters is a half of the diameter in centimetres. If an observer is 23 meters from the tree and the tree is in the borderline, so its diameter is 46 etc. The fact enables to measure the diameters at certain heights of standing trees commonly inaccessible for other measuring devices. The use of the wedge prism is based on the same principle as the use of the Bitterlich mirror relascope (Wide Scale) for measuring diameters on upper stems (Salas 2002, 2005).

The measures using the quotient 1 is only one of more possibilities. For instance if we use the wedge

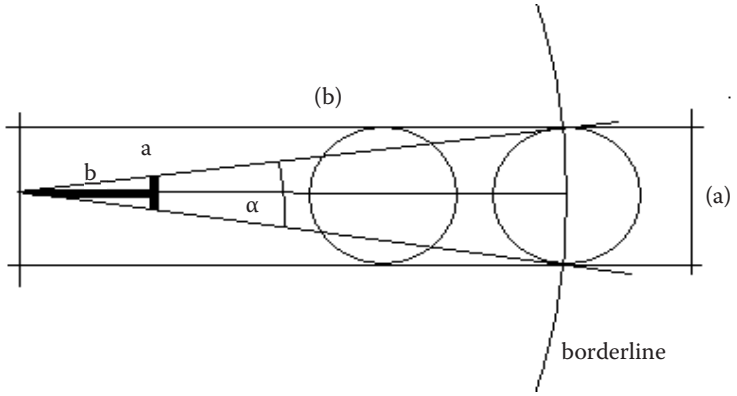

Fig. 1. Geometry of the angle gauge

Table 1. Average values and their differences

	Diameter measured optically with wedge prism	Diameter measured with calliper	Difference	Standard deviation of differences
In "laboratory"	33.95	34.24	–0.29	0.88
In forest	38.80	38.62	0.18	0.92
Total	36.38	36.43	–0.05	0.93

prism with the quotient (basal area factor) 4, the diameter in centimetres is equal to the distance from the tree in meters times 25.

Hypothesis and method

If the distance between the diameter at a certain height and the observer is known and the diameter is shown through the wedge prism on the borderline, the diameter is easily countable with the quotient equalling 1. The distance is measured with a telemeter, the height with a hypsometer. It is possible to measure the horizontal distance from the tree and the angle to a certain height when the diameter lies on the borderline. The method was also described for determining the tree diameter at breast height (Bitterlich 1996).

For testing the accuracy of the method the laser telemeter was used and then the measured diameter was measured using the calliper with one-centimetre scale. Firstly, the test was realized in "laboratory" conditions when the individual blocks of stems were placed to windows of a building (height from 5 to12 m) then finding the distance when the blocks were on the borderline. The distance was measured using the laser telemeter with half-a-meter scale. The diameter was calculated and compared with the control measure using a calliper. Secondly, the test was realized in natural conditions on sharp slopes (more than 30°). The slopes enabled the control using the calliper. The diameters were measured at the stem height of 1.50 m, the observer stood in the lower part of the slope so the slope alternated the inaccessible height of the stem. Complete results are shown in Table 1.

RESULTS

55 diameters were measured in "laboratory" conditions, 55 diameters in forests.

Differences between diameters measured with a wedge prism and diameters measured with a calliper were tested using the paired *t*-test. We tested a hypothesis that the mean difference between the used measuring methods is equal to zero. Results are shown in Table 2.

There are statistically significant differences for laboratory conditions. We can also compute confidence intervals for the mean difference. Denote by $\bar{d}$ average difference, s standard deviation of differences, n number of observations and $t_{n-1}(\alpha)$ critical value of Student's distribution with $n - 1$ degrees of freedom. Under assumption of the normal distribution of differences, the interval

$$\bar{d} \pm \frac{st_{n-1}(\alpha)}{\sqrt{n}}$$

Table 2. Paired *t*-test for differences

	Test statistic	Significance level
In "laboratory"	–2.47	0.017
In forest	1.46	0.151
Total	–0.62	0.540

covers the value of mean difference with probability of 1 – α. Thus, we have a 95% confidence interval (–0.53; –0.05) for differences in laboratory conditions.

CONCLUSION

The optical measuring of the diameter at various heights of stem using the wedge prism as a tool for measurement is a sufficiently accurate method for measurement and can be used for measuring the diameters in the upper stem.

Use of the method

Using the wedge prism is easier than using the mirror relascope because one checks only one vertical plain while the mirror relascope needs two vertical plains to be checked. The method gives a possibility of calculating the volume of the tree without its destruction. The non-destructive method is essential for calculating the volume in forests (virgin forests) where the yield tables do not exist or for the revision of the existing tables. The stem is divided into parts and they are calculated using the common method of calculating the logs such as Huber's or Smalian's formula for log volume (Korf et al. 1972; Šmelko 2000). The sum of log volumes gives the volume of the stem. The form height is a ratio between the stem volume and the diameter at breast height.

The method of measuring the diameter at a certain height of the tree is also appropriate for the sorting in standing trees. For sorting one needs to know the diameter in the small end of logs. According to the Recommended Rules for Log Measuring and Sorting in the Czech Republic (Kolektiv 2002) the border diameter of small end for sliced veneer assortments is 45 (48) cm. 45 (48) cm mean the distance 22.5 (24) m when the diameter lies on the borderline. Thus if the diameter measured from this distance lies on the borderline at a certain height or is even larger, the log fulfils the criterion to be sorted to the sliced veneer log. If the wedge prism is completed with the hypsometer, which can measure the distance as well, for instance by laser, the method of sorting is sufficiently precise and cheap.

In addition, the method can be used for the measuring of distances in forests (from 1 to 50 m). If the tree is marked by two points or two lines whose distance is according to the rule listed above, i.e. distance we want to measure in meters twice in centimetres and the lower point (line) optically appears in the position of the upper point, our position is at a given distance. The wedge prism in this situation is held vertically (rotated through an angle of 90° from the normal position for basal area measurement).

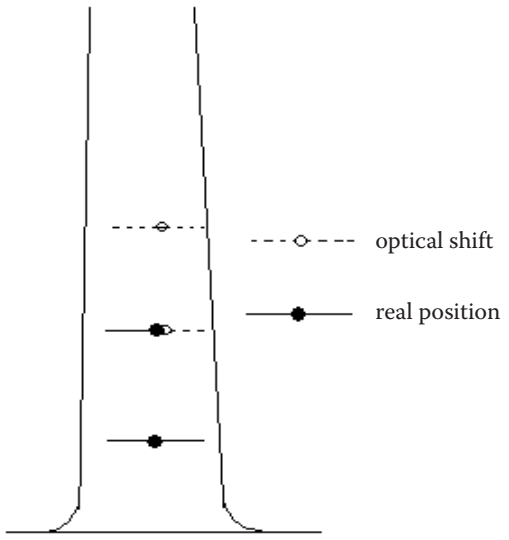

Fig. 2. Marking the tree and optical shift of the image visible in the wedge prism

The same principle is used for the alignment of circular sample plots (Hale 1994). If the plot centre is fixed by the pole marked with circlets at a given distance, the distance from the centre to the plot border is measured using the same principle as mentioned above.

The wedge prism seems to have more chances to be used than only for the measurement of basal area. However, its use is influenced by the ability of the observer to determine precisely the border tree, in our cases the borderlines. Any error in measurement leads to a bigger error in calculated results. From this aspect the proposed methods for larger usage of the wedge prism should be proved experimentally in various types of stands and on various tree species.

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Optický klín jako nástroj pro měření průměrů a vzdáleností

ABSTRAKT: Optický klín, který se obvykle používá pro měření kruhové základny v prsní výšce, je také nástroj pro měření vzdáleností nebo pro měření průměrů v různých výškách stromů. Měření s použitím optického klínu je realizováno na základě stejného principu jako měření s použitím Bitterlichova zrcadlového relaskopu. Tato metoda je vhodná pro nedestruktivní určení objemu kmene. Navíc je možné optický klín použít pro sortimentaci ve stojících porostech, kdy musíme znát průměr čepu na očekávaných sortimentech. Protože optický klín je pro lesníky obvyklým nástrojem, jeho použití může být širší než pouze pro měření kruhové základny.

Klíčová slova: optický klín; měření průměrů v nedostupných výškách; měření vzdáleností; sortimentace

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