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GEOMETRICAL ANALYSES OF PLANTATION LOGS: TAPER, BOW, CROOK, PITH ECCENTRICITY, AND OVALITY

Mohd-Jamil AW, Zairul AR & Nor Marzuina FKN

INTRODUCTION

In plantation forestry, quantitative analyses of the outputs are essential to precisely evaluate the productivity and economic potential of the industry. Likewise, the needs for quantifiable properties of the sawlogs such as taper, bow, crook, pith eccentricity, and ovality are no exception. The yields of the plantation programme can only be evaluated if the parameters of the logs are measurable.

For instance, the boles of 16-year-old *Acacia mangium* were found tapered especially from the height of 6 meters and above (Lim et al. 2011). Likewise, logs of locally grown *Eucalyptus* hybrid (*E. grandis* × *E. urophylla*) were also reported with taper (Zairul et al. 2021). But how similar were the tapering conditions? Since both studies reported taper as a qualitative value, further analyses with respect to other variables such as age and site, or future comparisons with other species, will not be feasible. Thus, for a better understanding of the geometrical properties and more helpful records, the degree of the taper must be quantified.

In general, the geometrical shape of a log depends on various factors such as tree species, age, trunk positioning, environment, topography, and silviculture treatment. Deviation from the nominal cylindrical shape may cause significant errors in calculating stem volume and lead to economic losses in the sawmilling industry. In exploratory research and laboratorial tests of timber material, disregarding the importance of geometrical precision of the log could result in discrepancies in the derivation of timber properties. For instance, a study demonstrated that heart checks decrease the bending strength by approximately 15 percent. Heart checks are due to poor seasoning or due to the difference in the tangential and radial shrinkage around the pith (Green et al. 2001). Thus, the preparation of timber specimens for mechanical assessments by ignoring the position of the pith within a log might affect the resultant properties (Figure 1).

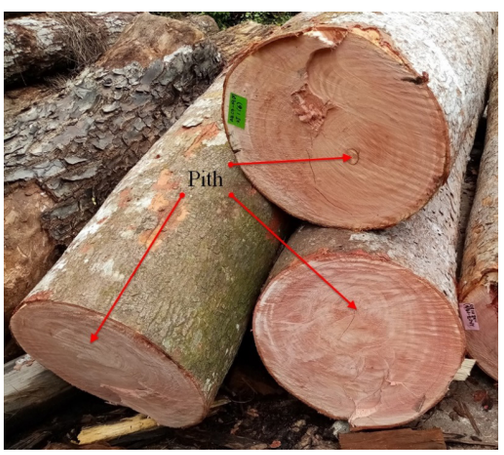

Figure 1 The profile of these logs seem fairly round, but the piths are indistinctly eccentric

Previously, the analyses of the diameter, cross-sectional area, and volumetric calculation of plantation logs were described by Mohd-Jamil & Nor Marzuina (2020). Also, the measurements and analyses of bark and sapwood/heartwood proportion of logs have been explained by Mohd-Jamil et al. (2021). This article is a quick reference for the recommended analyses and quantification with regards to the taper, bow, crook, pith eccentricity, and ovality of plantation logs. The measurements and formulae presented herein are based on standard methods and supported by various research outputs.

TAPER

Taper refers to a progressive reduction in the diameter along the length of a log (Figure 2). Logs with lower taper are more consistent in diameter. This diameter-height ratio significantly influences volumetric recovery. Sawing of logs with high taper is more complicated and produces relatively more waste than logs with low taper. Generally, tapered logs produce more offcuts and wane in sawn timbers. Excessive tapering could also result in uneven sapwood-heartwood proportion in sawn timbers which ultimately affects the drying and grading quality. In practice, the initial sawing is always made on the smaller end to minimise the occurrence of wane.

Figure 2 A sawlog with taper profile

Evaluation of taper

The taper of a log is measured as the difference of the two end diameters per each meter long. Taper, T (cm m^{-1}) is evaluated based on the over-bark diameters, using the formula (Maraseni et al. 2007):

$$T = \left[\left(\frac{d_1 + d_2}{2}\right) - \left(\frac{d_3 + d_4}{2}\right)\right] / L$$

where d_1 is the largest diameter (cm) across the geometric centre of the bottom end, d_2 is the diameter (cm) across the geometric centre perpendicular to d_1, d_3 is the largest diameter (cm) across the geometric centre of the top end, and d_4 is the diameter (cm) across the geometric centre perpendicular to d_3 while L is the axial length (m) of the log (Figure 3). On odd occasion, T could be a negative value indicating that the diameter of the bottom end is smaller than the diameter of the top end. Richter (2015) classified a log as heavily tapered if the diameter of the stem deviates more than 1.0 cm per meter.

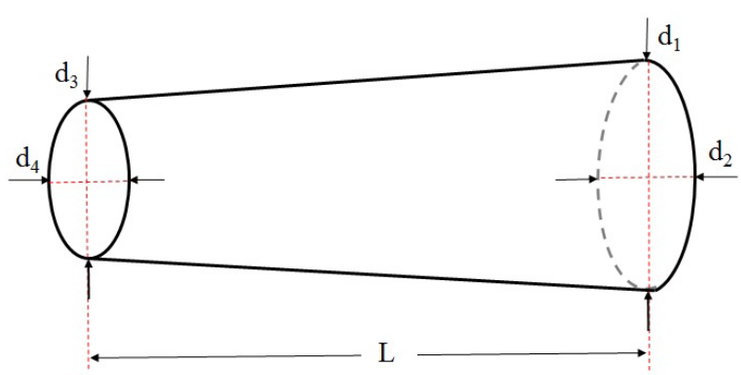

Figure 3 Measurements of taper

BOW AND CROOK

Bow refers to log deviation from a straight plane, curving to one side along the longitudinal axis (Figure 4). A curving of a log to multiple sides at different trunk heights is called crook (Richter 2015). Bowed trunks are commonly found in leaning trees, grown on hillsides or riverbanks, as well as in trees frequently exposed to strong wind. Leaning trees form reaction wood as a self-adaptive biomechanics response to the bending conditions. In softwoods, the reaction wood is formed underside of the leaning trunk, known as compression wood. In hardwoods, the reaction wood is formed upperside of the leaning trunk, known as tension wood. Compression wood generates compression stress which pushes the trunk back to the upright position. On the contrary, tension wood generates tensile stress that pulls the trunk to the upright position (Gardiner et al. 2014).

Sawing of a log with a bow produces a relatively lower recovery rate. For a log with a considerable bow, the initial sawing is normally done on the concave and convex sections to eliminate the curved sections. Crooked logs are commonly separated into two portions to increase the sawing recovery. In terms of the timber mechanical properties, bow contributes to the amount of cross-grained planks which are significantly lower in strength compared to straight-grained planks. Sawn timbers with cross grain are susceptible to warping during the process of drying. Bow could also result in inconsistent sapwood-heartwood proportion in sawn timbers. Also, heavily bowed and crooked logs are not suitable for veneer peeling.

Figure 4 A bowed sawlog

Evaluation of bow and crook

The bow of a log is measured based on the maximum deflection within the concave profile (Figure 5). The deflection is measured using a ruler with the assistance of an extended string that forms the chord of the curvature. Bow, B (cm m^{-1}) of a log is calculated using the formula (Richter 2015):

$$B = \frac{D}{L}$$

where, D is the maximum deflection (cm), and L is the length (m) of the bowed section.

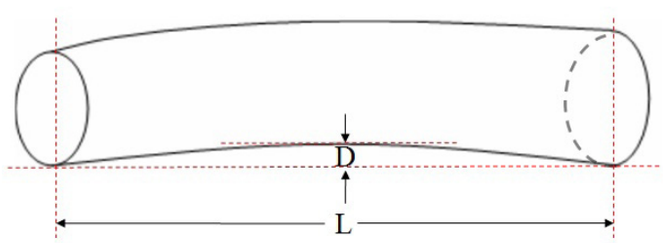

Figure 5 Measurements of bow

In a crooked log, the deflection is measured at every curvature (Figure 6). The deflection measurements are added together and the resultant value is divided by the total length of the crooked section. Crook, C (cm m^{-1}) of a log is calculated using the formula:

$$C = \frac{(D_1 + D_2)}{L}$$

where, D_1 and D_2 are the maximum deflections (cm) of two curvatures, and L is the total length (m) of the crooked section.

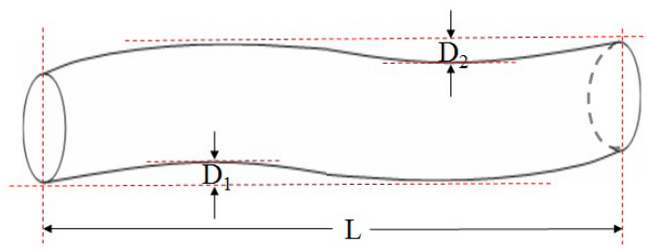

Figure 6 Measurements of crook

PITH ECCENTRICITY

Pith eccentricity is defined as the pith located off-centre of a log cross-section (Figure 7). Pith eccentricity is an indicator of a leant tree, often associated with the presence of reaction wood. A log with an eccentric pith often leads to difficulty in producing the intended sawing pattern. The physical and mechanical properties of timber containing reaction wood are generally inferior compared to normal wood. Thus, timber boards containing reaction wood are usually not permitted for structural uses.

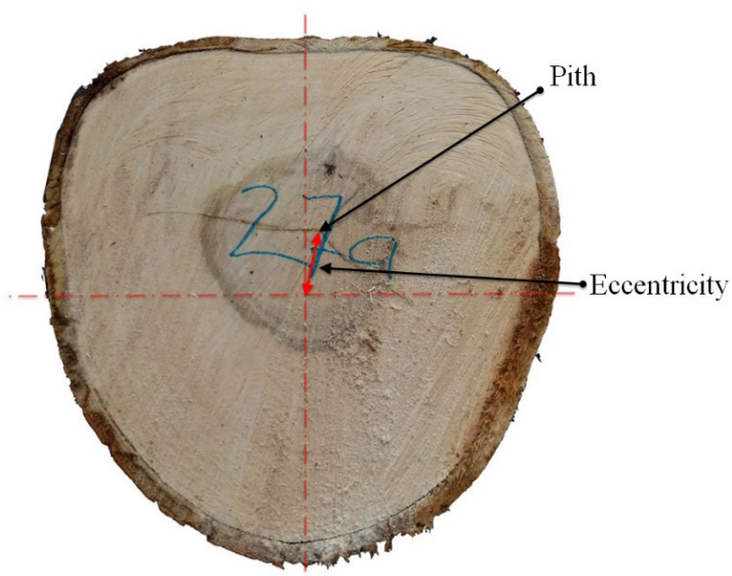

Figure 7 A cross-sectional surface of log with an eccentric pith

Evaluation of eccentricity

The pith eccentricity or offset, E (%) is measured based on the distance between the pith and the approximate geometric centre of the log, calculated using the formula (Tan et al. 2010):

$$E = \frac{E_c}{d_s} \times 100\%$$

where, E_c is the distance (cm) between the pith and the geometric centre of the log and d_s is the smallest diameter (cm) of the log across the geometrical centre (Figure 8).

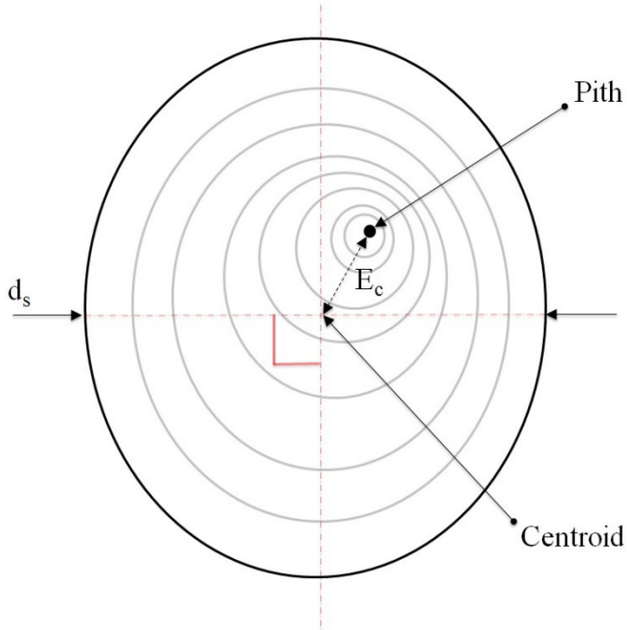

Figure 8 Measurements of eccentricity

OVALITY

Ovality or out-of-roundness is the degree of circular deviation of the log cross-section. The pith may or may not located at the centre of the cross-sectional surface. The cross-sectional surface of a log with reaction wood is normally oval in shape, and it is associated with eccentric pith.

Evaluation of ovality

The ovality, O of a log can be expressed as the ratio of the smallest diameter to the largest diameter, calculated using the formula (Richter 2015):

$$O = \frac{d_s}{d_l}$$

where, d_l is the largest diameter (cm) across the geometric centre of the cross-sectional surface, and d_s is the smallest diameter (cm) across the geometric centre perpendicular to d_l (Figure 9). The ratio of 1 indicates a perfectly circular-shaped log.

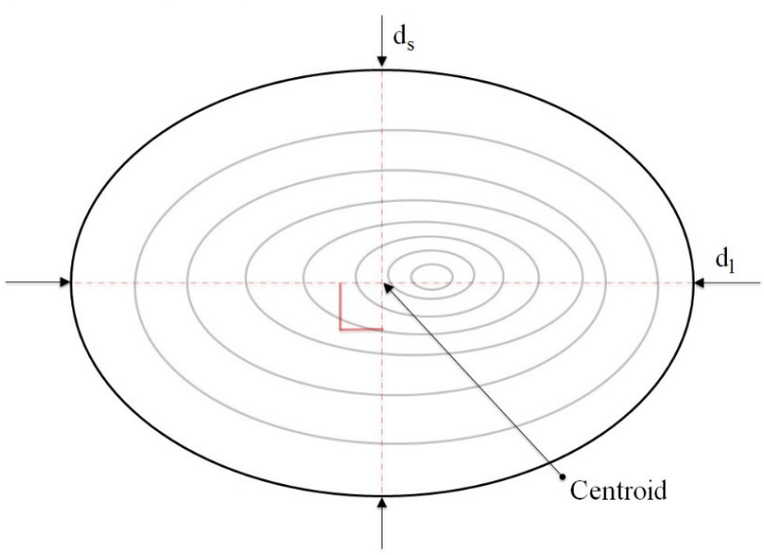

Figure 9 Measurements of ovality

SUMMARY

In exploratory research and laboratorial tests, disregarding the importance of geometrical precision of the round log creates discrepancies in the derivation of wood quality and properties. Deviation from the nominal cylindrical shape may cause significant errors in calculating stem volume and results in economic losses in the sawmilling industry. The recommended analyses of plantation sawlogs include the evaluation of taper, bow, crook, pith eccentricity, and ovality.

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In plantation forestry, quantitative analyses of the commodity are essential to precisely evaluate the productivity and economics of the industry. The accurate assessment of the yields can only be achieved if the parameters of logs are measurable. The analyses of the diameter, cross-sectional area and volumetric calculation of plantation logs are described in Timber Technology Bulletin No. 104. Also, the measurements and analyses of bark and sapwood/heartwood proportion of logs are explained in Timber Technology Bulletin No. 111. This article is a quick reference for the recommended methods of analyses and quantification with regards to the taper, bow, crook, pith eccentricity and ovality of plantation logs.

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