

EFFECT OF MOISTURE CONTENT ON THE DRILL RESISTANCE VALUE IN TAIWANIA PLANTATION WOOD

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ABSTRACT

The effect of moisture content (MC) on the drill resistance values during desorption from a water-saturated condition of Taiwania (*Taiwania cryptomerioides* Hayta) plantation lumber was examined. Results showed that the drill resistance values tended to decrease with the decreasing of MC. Positive significant relationships were found among the MC, bulk density, and drill resistance values. This adjustment of density profiles could help the RESISTOGRAPH® to achieve a better measurement of the drill resistance profile of standing trees.

Keywords: Taiwania (*Taiwania cryptomerioides* Hayata), drill resistance technique, RESISTOGRAPH®, moisture content, bulk density.

INTRODUCTION

The RESISTOGRAPH® instrument is a new and useful minor inspection tool for detection of living trees, logs, sawn-timbers, and wood-based materials to estimate their physical properties. It has been shown to be a suitable and efficient tool for estimating the growth trends of trees. Its drill resistance technique is commonly used to detect growth rings

in trees and decay in poles or timber structures. This device measures the drill resistance by a fine needle as it penetrates the wood. The mean levels of the resistance charts closely correlate to the density of the dry wood, with R^2 values over 0.8 (Rinn et al. 1996). The density parameters of coniferous wood closely correspond to those found in X-ray microdensity charts. Furthermore, the typical tree-ring variations in the resistance chart are very similar to those in the X-ray microdensity

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chart (Helms and Niemz 1994; Mattheck, Bethge, and Albrecht 1997; Moore 1999; Rinn 1994a, 1994b, 1996; Rinn et al. 1996; Mattheck and Bethge, 1993; Winistorfer and Zimmer 1995). Recently, the drill resistance technique was found to be a good measuring tool for the density profile of *Taiwania* in the radial direction (Wang and Lin 2001).

However, when applied to living trees, green logs, and green sawn-timbers, the drill resistance values are significantly affected by water in the lumber (Eckstein and Sass 1994; Le-Naour 1991). No report has been published that details the effects of moisture content (MC) on drill resistance values in lumber. Therefore, it is important to develop information to understand the effect of moisture content on the drill profile of lumber when estimating physical properties by using the technique.

The objectives of this study were to investigate the effects of MC on drill resistance values, and the correlation between MC with drill profile of lumber specimens during desorption stages from water-saturated to air-dried status in *Taiwania* plantation wood.

MATERIALS AND METHODS

Experimental Material

The experimental plantation sites are located at compartment No12, Liukuei Experimental Forest, Taiwan Forestry Research Institute (TFRI), Kaoshiung County, Taiwan, ROC. Three 22-yr-old *Taiwania* (*Taiwania cryptomerioides* Hay.) plantation trees were selected for the present study.

The dimensions of radial direction specimens for measuring drill profile were 20 mm tangential, 10 mm radial, and 180 mm longitudinal. The number of specimens and their average bulk densities were 77 and 0.284 (g/cm³), respectively.

Drill resistance method

The drilling profiles of *Taiwania* plantation wood were acquired using a RESISTOGRAPH® tool. It drives a fine needle into the

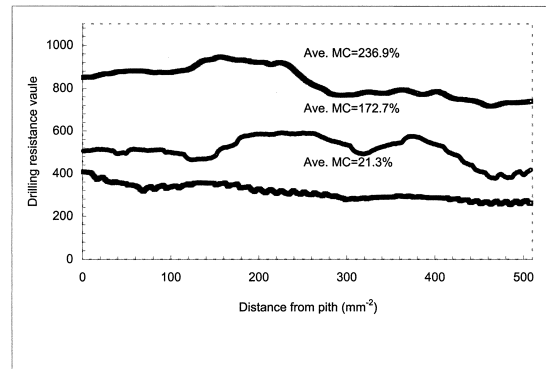


FIG. 1. Drilling resistance records measured on No. 9 specimen.

wood and mechanically measures the drill resistance as it rotates. The needle has a shaft diameter of 1.5 mm and a maximum length of 400 mm. The tip of the needle has a special fish-tail geometry and grinding. The drill resistance concentrates at the tip because the width of the top (3 mm) is double the width of the shaft. The needle rotates continuously at 1,000 rpm. For wood, the feed rate varies from 70 to 1,000 mm/min depending on wood properties. Two 24-V DC motors separately control the linear advancement and rotational speed of the drill (Rinn et al. 1996). The power consumption of the drilling device is electronically measured as a value of the drill resistance. The drill resistance values (profiles) were shown by the DECOM Win 1.5 software (Measurement and presentation of RESISTOGRAPH®-drilling profiles for assessment of trees and timber constructions) (Rinn 2000). Parts of the drilling profiles by the drilling resistance technique are shown Fig 1.

Measurements of drill resistance values

Specimens were treated by the Bethell (full-cell) process method (Wood Handbook 1999) several times until they reached water-saturated status. The drill profile in the radial direction of specimens was measured by RESISTOGRAPH®. Drill profiles were conducted each time weight losses of 5–8 g occurred during desorption from water-saturated to air-dried status.

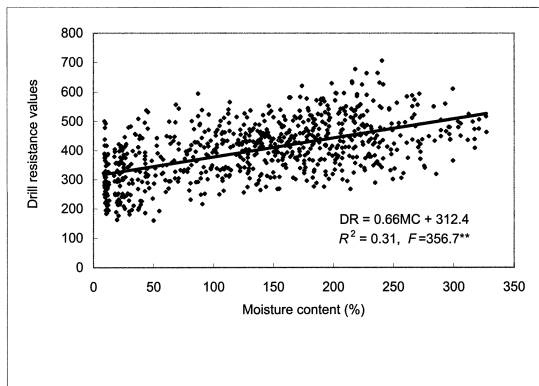


FIG. 2. Relationship between drill resistance values and moisture content between 11% and 320%.

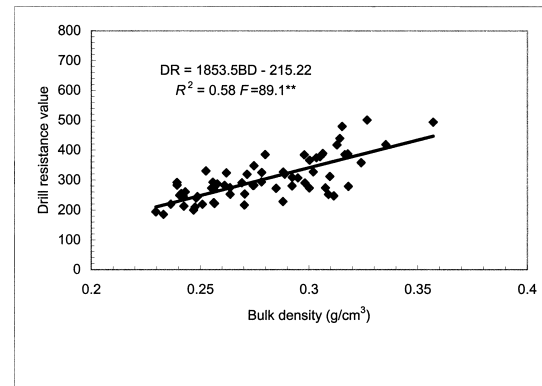


FIG. 3. Relationship between bulk density and drill resistance value for air-dried specimens.

The MC during the procedures was calculated as follows:

$$MCu \% = (Wu - Wo) / Wo \times 100\% \quad (1)$$

Here, MCu(%) is the MC of the test specimens in various test stages (%); Wu is the specimen weight of various test stages (g) and Wo is the oven-dried weight of specimens in their final condition (g).

RESULTS AND DISCUSSION

Effects of moisture content on drill resistance value

The relationship between drill resistance values in the radial direction with MC during desorption from water-saturated condition to air-dried status for *Taiwania* lumber is shown in Fig. 2. Drill resistance values generally decreased with decreasing MC. When expressed as a linear regression relationship, the determined coefficient (R^2) was 0.31. Statistical analysis showed the relationship between drill resistance values, and MC was significant at the 0.01 level.

Effects of bulk density on drill resistance value

The relationship between the drill resistance values of air-dried wood in the radial direction with bulk densities is shown in Fig. 3. These drill resistance values tended to increase with

increasing bulk density (BD). These results are in accordance with the reports (Winistorfer and Wimmer 1995; Wang and Lin 2001); however, the coefficient of determination ($R^2 = 0.58$) obtained from this study was lower.

Effects of moisture content and bulk density on drill resistance value

The various drill resistance values at different moisture content stages in *Taiwania* specimens are shown in Table 1. The drill resis-

TABLE 1. Average drill resistance values at different moisture content stages of *Taiwania* specimens ($n = 77$).

Moisture content (%)	Average drill resistance value
10.7 ^a (1.1) ^b	297.3 (74.5)
23.1 (3.5)	311.6 (77.5)
39.6 (5.1)	335.7 (99.0)
65.2 (8.6)	364.6 (75.1)
89.7 (5.5)	389.6 (86.9)
109.3 (5.2)	406.3 (78.9)
130.1 (5.8)	404.2 (66.1)
150.5 (5.9)	419.5 (69.8)
170.5 (5.8)	435.7 (73.7)
189.8 (5.5)	445.3 (85.4)
210.7 (5.8)	456.0 (106.6)
229.6 (5.6)	458.7 (87.5)
248.6 (5.7)	450.1 (99.6)
269.3 (4.7)	467.7 (85.2)
292.7 (4.9)	468.8 (71.4)
314.8 (7.5)	476.7 (34.3)

^a Average values.

^b Number in () is standard deviation.

tance values through wood substance decreased with the MC reducing process from the water-saturated to air-dry condition. In other words, the drill resistance values of wood were also influenced by density. Winistorfer and Wimmer (1995) and Wang and Lin (2001) indicated that wood real density could be calculated by converting drill resistance values via a linear equation. Therefore, it is necessary to determine the densities converting the factor of drill resistance value before understanding the effect of moisture content in wood.

During the desorption stage, the drill resistance values (RD) decreased with the decrease in MC and bulk density (BD), with a positive correlation that existed among RD, MC, and BD. The relationship can be expressed as

$$\begin{aligned} DR &= -55.6 + 1256.5BD \text{ (g/cm}^3\text{)} \\ &\quad + 0.74MC \text{ (\%)} \\ R^2 &= 0.49, \quad F = 383.8^{**} \end{aligned}$$

Statistical analysis results show that the relationship between drill resistance value with MC and BD were significant at the 0.01 level. The drill resistance values decreased gradually with decreasing MC. Therefore, it is necessary to adjust the resistance values at different MC stages when estimating certain physical properties of wood by this technique.

Some causes for the variation in results may be due to juvenile wood, cell types, and chemical components (percentage), which have various degrees of impact on the drilling properties of wood.

CONCLUSIONS

The effects of average moisture content on the drill resistance values during desorption from a water-saturated condition to air-dried states were examined for *Taiwania* plantation lumber. The drill resistance values in the radial direction tended to decrease with decreasing moisture content. This relationship was expressed as a linear regression equation. Drill resistance also tended to increase with increasing bulk density. Therefore, results acquired from the RESISTOGRAPH® tool should be adjusted for MC and bulk density before es-

timating some physical properties of standing trees.

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