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Original article

Physical and Mechanical Properties of *Eucalyptus urophylla* clone K58

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ABSTRACT

Eucalyptus spp. become important commercial wood as raw materials for various industrial applications in Thailand. But for lumber processing that is limited of basic information to process. *Eucalyptus urophylla* clone K58 is one of the eucalyptus varieties that is grown widely in Thailand. The objective of this study is to investigate the selected physical and mechanical properties of *E. urophylla* clone K58. Physical properties i.e. oven-dry specific gravity, fiber saturation point, shrinkage in tangential, radial and longitudinal direction and desorption isotherm, and mechanical properties i.e. modulus of rupture (MOR), modulus of elasticity (MOE), compression parallel to grain, compression perpendicular to grain, cleavage, hardness and nail holding were determined. The results of *E. urophylla* clone K58 were compared with commercial woods for furniture production such as rubber wood (*Heavia brasiliensis*) and Teak (*Tectona grandis*), and with commercial woods for building structure such as Pradauk (*Pterocarpus macrocarpus*), Daeng (*Xylia xylocarpa*) and Teng (*Shorea obtusa*).

Keywords: *Eucalyptus urophylla*, clone K58, physical properties, mechanical properties

INTRODUCTION

The demand for lumber in Thailand is increasing every year. The prediction of lumber demand will increase from 16.32 to 20.63 million m^3 in the years from 2007 to 2017. The lumber mostly comes from rubber wood (*Heavea brasiliensis*) and teak wood (*Tectona grandis*) etc. but does not come from *Eucalyptus* spp. (Royal Forest Department, 2015)

Eucalyptus is one of the most important commercial woods in Thailand and grows very fast. But the utilization of eucalyptus wood remains restricted in pulp and paper industries, veneer and plywood manufacturing, wood composite industry, pallet production and as fuel wood because of the limited research on the basic properties of wood to use for lumber processing.

K58 is a eucalyptus species (*Eucalyptus urophylla* S.T. Blake), breeding development is by Eucalyptus Technology Company under Suan Kitti Group. The dominant characteristics of this species are: Seedling stage; round-shaped stems, spear wide shaped leaves, alternate arrangement and Mature stage; stems round-shaped and brown color smooth bark, leaves, blade spear-shaped alternate arrangement, dark green leaves, dense canopy, the flowers do not have petals, but are groups of colorful stamens held by a cap, or operculum eucalyptus flowers look like tassels, fruit shapes look like cups, there are 5-7 flowers per inflorescence. Suitable sites that *E. urophylla* clone K58 grows well in are the flat to upland area and loam to sandy loam soil. Should avoid planting in lowland flooding or hard gravel plan layer soils. Growth and productivity, this tree species has continued to grow, high density wood heavy timber when was cut. The rotation of cutting in Thailand is 5 year. The average yield is 22-30 tons of fresh weight per ha. (Hanvongjirawat, 2016)

Eucalyptus becomes a subject of interest as raw material for wood composite panels in many tropical and subtropical countries including Thailand, Chile, Brazil and Malaysia (Nacar *et al.*, 2005). The end-use of sawn timber products determines to a large degree which properties will be important (Wessels *et al.*, 2016). Many *Eucalyptus* species pose serious processing challenges. Some have very high shrinkage coefficients and collapse, which might cause difficulties in certain applications (Chafe, 1990; Malan, 1993; Vermaas and Bariska, 1994; Ilic, 1999; Wessels *et al.*, 2016). Another problem is splitting due to growth stress that is frequently encountered in timber from Eucalyptus species (Malan, 1984, 2003; Wessels *et al.*, 2016).

Mechanical properties on dry condition of *E. urophylla* revealed that modulus of rupture, stress at proportional limit, modulus of elasticity, radial side shearing, tangential side shearing, compression parallel to grain, radial side compression perpendicular to grain, tangential side compression perpendicular to grain and tension were 78.9, 41.9, 9,810, 12.8, 14.6, 37.2, 10.8, 13.2 and 145 MPa respectively. The impact bending was 2.44 kg-m and hardness on radial and tangential side were 3,879 and 3,763 Newton respectively. Physical properties testing of *E. urophylla* samples revealed that their radial shrinkage, tangential shrinkage, longitudinal shrinkage and volume shrinkage were 5.60, 7.66, 0.57 and 13.32 percent, respectively. Moisture content at fiber saturation point was 25 percent, dry density was 684 kg/m^3 , and the specific gravity was 0.66 (Sompoh, n.d.)

The objective of this study is to investigate the selected physical and mechanical properties of *E. urophylla* clone K58. Physical properties i.e. oven-dry specific gravity, fiber saturation point, shrinkage in tangential, radial and longitudinal direction and desorption isotherm and mechanical properties i.e. modulus of rupture (MOR), modulus of elasticity (MOE), compression parallel to grain, compression perpendicular to grain, cleavage, hardness and nail holding were determined. The results of *E. urophylla* clone K58 were compared with commercial woods for furniture production such as rubber wood (*Heavia brasiliensis*) and Teak (*Tectona grandis*), and with commercial woods for building structure such as Pradauk (*Pterocarpus macrocarpus*), Daeng (*Xylia xylocarpa*) and Teng (*Shorea obtusa*)

MATERIALS AND METHODS

E. clone K58 for this study consists of 3 trees coming from Suan Kitti plantation Prachinburi Province, Thailand. The trees were 6 years old and 10 months and had diameters at breast height 14.99, 15.49 and 17.27 cm. The trees were cut down above the ground 10 cm. and cross cut to small logs from bottom to top along stems in lengths 50 cm., 150 cm., 150 cm. and 50 cm. (Figure 1). Small logs were coated with flint coat and sealed with thin plastic at the both end of logs to prevent moisture evaporation and reduce end shake. Six small logs in the length of 50 cm. from 3 trees were used to investigate physical and mechanical properties.

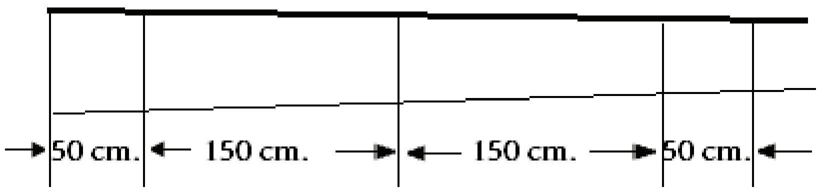

Figure 1 Small logs cross cutting.

Physical properties

Physical properties of *E. urophylla* clone K58 such as specific gravity of oven-dry condition, fiber saturation point, shrinkage and desorption isotherm were investigated. For samples preparation, each small log in length 50 cm. were cut to samples for 4 replications to investigate each properties of physic and mechanic by random method. Samples were cut to tangential and radial direction in dimension of 5 × 5 × 0.3 cm. and longitudinal direction in dimension of 1 × 1 × 5 cm. All samples were marked and conditioned in conditioning chamber at two temperatures of 40 and 70 °C and combined with four relative humidities of 41, 50, 70 and 90 % until constant weight in all conditions. After constant weight, samples were weighted and measured dimensions in tangential, radial and longitudinal direction. After finish for all conditions, samples were dried at 103 ± 2 °C until constant weight and measured dimensions in all directions again after that the volume of samples were investigated by immersion in water.

Specific gravity (G) was determined from oven-dry mass and volume by immersion method of each sample by the following equation:

$$G = \frac{m_o}{V\rho_w}$$

Where m_0 is oven-dry mass (g), V is volume (cm^3), and ρ_w is normal density of water = 1 g/cm^3. Where as $V\rho_w$ is weight by immersion method (g)

Moisture content (MC) was calculated by the following equation:

$$MC(\%) = \frac{m-m_o}{m_o} \times 100$$

Where m is initial mass (g) and m_0 is the oven-dry mass (g)

Shrinkage (S) was calculated by the following equation:

$$S(\%) = \frac{d_1-d_2}{d_1} \times 100$$

Where d_1 is dimension before the test and d_2 is dimension at the test.

Mechanical properties

Mechanical properties of *E. urophylla* clone K58 such as Modulus of rupture (MOR), Modulus of elasticity (MOE), compression parallel to grain, compression perpendicular to grain and cleavage were measured according to BS 373 standard (1985) and such as hardness and nail holding were tested according to ASTM D 143 standard (2007). Before testing all samples were storaged in conditioning chamber at temperature 23 $\pm$ 2 ^{o}C and relative humidity 65 $\pm$ 2 % until constant weight.

RESULTS AND DISCUSSION

Physical properties

Specific gravity is the characteristic property of wood that explain wood strength. The average oven-dry specific gravity of *E. urophylla* clone K58 was 0.72. Fiber saturation point is the point that the wood begin to shrink due to the wood lose moisture in cell wall. Fiber saturation point of *E. urophylla* clone K58 was between 26 to 28 % that the wood began to shrink (Figure 2).

Figure 2 showed that shrinkage in tangential direction was higher than in radial direction between 0 to 2 times by reducing of moisture content from fiber saturation point to 0 %. The percentage of shrinkage in both directions were increased by the reducing of moisture content from fiber saturation point to 0 %. Maximum shrinkage in tangential, radial, and longitudinal were 10, 6.5 and 0.3 % respectively (Figure 2 and Figure 3). For normal wood the longitudinal shrinkage is negligible. This shrinkage in the tangential direction is usually double that in the radial direction in most woods (Siau, 1984). In the radial direction that the restriction of radial shrinkage due to the presence of the ray cells and the presence of bands of low-density earlywood and high-density rate wood decreased shrinkage. But in the tangential direction, the denser and stronger latewood controlled the shrinkage and forced the earlywood to shrink by essential the same amount (Panshin and de Zeeuw, 1980).

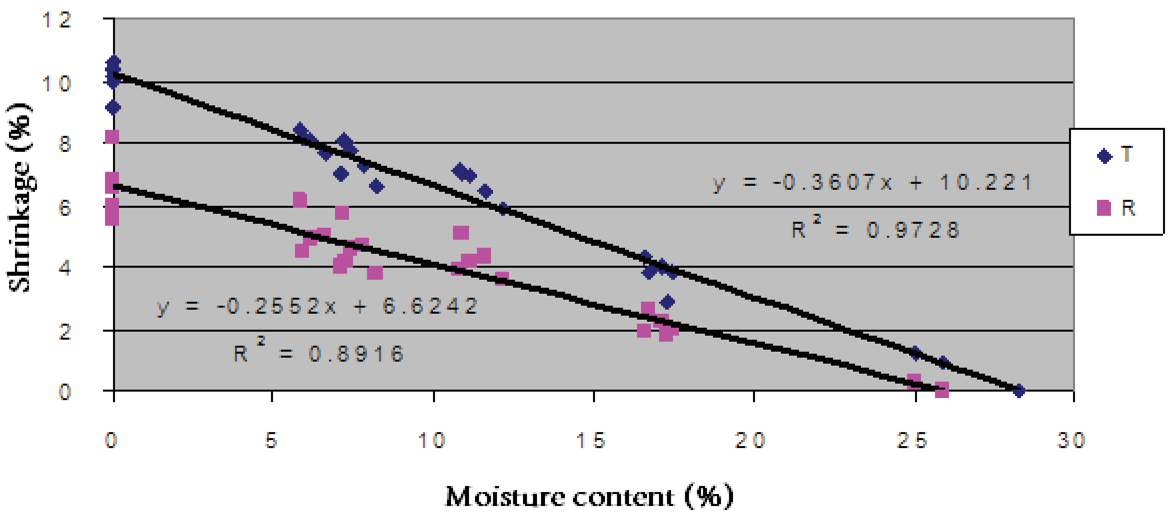

Figure 2 Shrinkage in radial (R) and tangential (T) direction of *E. urophylla* clone K58.

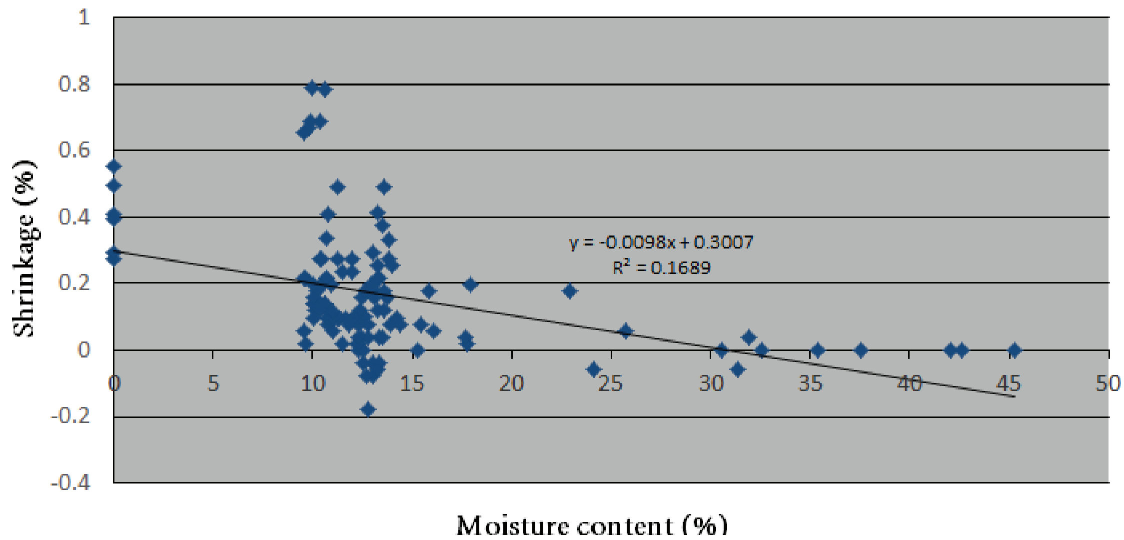

Figure 3 Shrinkage in longitudinal direction of *E. urophylla* clone K58.

The moisture content in equilibrium with a given relative humidity is called the equilibrium moisture content (EMC). The relationship between EMC and relative humidity at given temperature is called the sorption isotherm (Siau, 1984).

Desorption isotherm of *E. urophylla* clone K58 depicted in Figure 4 that EMC of *E. urophylla* clone K58 decreased slightly with rising temperature. EMC decreased with the reducing of relative humidity by constant temperature. Although relative humidity is the most important variable affecting EMC, other factors are mechanical stress, the drying history of wood, the species and specific of wood, the extractive content, and the temperature (Siau, 1984; Skaar, 1972). Sorption isotherm data extremely useful for many practical applications (Siau, 1984).

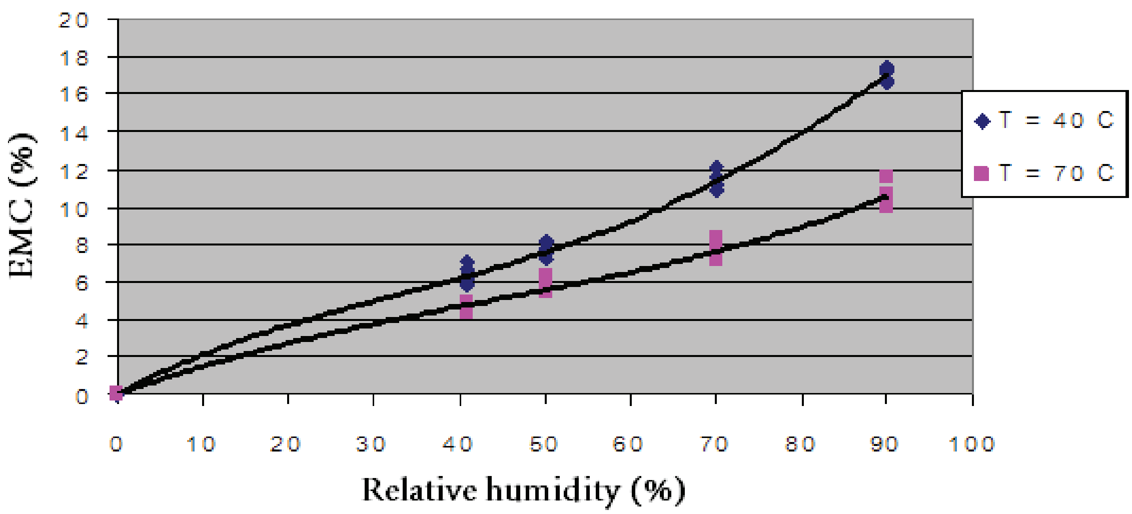

Figure 4 Desorption isotherm of *E. urophylla* clone K58.

Mechanical properties

Before testing all samples were storaged in conditioning chamber at temperature 23 ± 2 ºC and relative humidity 65 ± 2 % until constant weight. The moisture content of all samples were determined. The average moisture content of all samples was 10.33 % and standard deviation 0.63.

Mechanical properties of *E. urophylla* clone K58 showed in Table 1 in comparison with commercial woods for furniture production such as rubber wood (*Heavia brasiliensis*) and Teak (*Tectona grandis*), and with commercial woods for building structure such as Pradauk (*Pterocarpus macrocarpus*), Daeng (*Xylia xylocarpa*) and Teng (*Shorea obtusa*).

MOR of *E. urophylla* clone K58 was 125.18 MPa, that highest than all commercial woods. MOE of *E. urophylla* clone K58 was 11,137 MPa that higher than teak and rubber wood but lower than all commercial woods for building structure.

Compression parallel to grain of *E. urophylla* clone K58 was 63.50 MPa that highest than all commercial woods. Compression perpendicular to grain of *E. urophylla* was 9.20 MPa that higher than Teak, lower than rubber wood and all commercial wood for building structure.

Hardness of *E. urophylla* clone K58 was 6,011 N. that higher than teak and lower than rubber wood, Pradauk, Daeng and Teng. Cleavage of *E. urophylla* clone K58 was 3.35 N/mm. Nail holding of *E. urophylla* clone K58 was 38.39 N/mm.

MOR and Compression parallel to grain of *E. urophylla* clone K58 were 125.18 and 63.50 MPa respectively higher than 95 and 51 MPa respectively according to Forest Products Development Division (2004) that *E. urophylla* clone K58 was classified in class A (highest strength). According to Building Control Bureau (2009) that *E. urophylla* clone K58 can be used for building structure. Other utilizations are furniture, doors, window frame, pole and small pole etc.

Table 1 Mechanical properties of *E. urophylla* clone K58 comparison with commercial woods.

Wood species	Oven-dry Specific gravity	MOR (MPa)	MOE (MPa)	Compression Parallel to grain (MPa)	Compression Perpendicular to grain (MPa)	Hardness (N)	Cleavage (N/mm)	Nail Holding (N/mm)
K58	0.72 (0.03)	125.18 (9.53)	11,137 (962.26)	63.50 (2.51)	9.20 (1.89)	6,011 (663.39)	3.35 (4.55)	38.39 (9.63)
Rubber-Wood	0.65***	100.20***	9,403***	47.01***	14.34***	6,498***	-	-
Teak	0.62*	63.00*	7,996*	32.00*	8.00*	4,864**	-	-
Pradauk	0.82*	114.00*	12,596*	49.00*	20.00*	9,097**	-	-
Daeng	1.05*	117.00*	15,017*	53.00*	21.00*	10,101**	-	-
Teng	1.07*	91.00*	11,323*	43.00*	18.00*	9,454**	-	-

Remark: The value in parentheses are standard deviation of *E. urophylla* clone K58

Sources: * Saneg-ah-tit (n.d.), ** Forest Products Development Division (2004) and *** Riyaphan (2013)

CONCLUSION

The average oven-dry specific gravity of *E. urophylla* clone K58 was 0.72. Fiber saturation point of *E. urophylla* clone K58 was between 26 to 28 % The Shrinkage in tangential direction was higher than in radial direction between 0 to 2 times. Maximum shrinkage in tangential, radial, and longitudinal were 10, 6.5 and 0.3 % respectively. Desorption isotherm of *E. urophylla* clone K58 that EMC decreased slightly with rising temperature. EMC decreased with the reducing of relative humidity by constant temperature.

MOR and MOE of *E. urophylla* clone K58 were 125.18 and 11,137 MPa respectively. Compression parallel to grain of *E. urophylla* clone K58 was 63.50 and perpendicular to grain was 9.20 MPa. Hardness of *E. urophylla* clone K58 was 6,011 N. Cleavage of *E. urophylla* clone K58 was 3.35 N/mm. Nail holding of *E. urophylla* clone K58 was 38.39 N/mm.

The utilization of *E. urophylla* clone K58 are building structure, furniture, doors, window frame, pole and small pole etc.

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