PT003

The Study of Halogen Lamps and Microwave Drying on Mechanical Properties of Oil Palm Timbers

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Abstract

Utilization of oil palm trunk waste for production of timber was studied to comparison was made on drying kinetics and mechanical properties of oil palm timber (OPT) obtained from; i) halogen heaters ii) microwave drying and combine between halogen heaters and microwave drying. A chamber with a size of 500 × 1000 × 1000 mm^3 was made of stainless steel type 316. Materials preparation was OPT, which was selected based on the timber from the stem up to 3 meters for 26 years with a size of 25 × 50 × 250 mm^3. The saw pattern oil palm stems were cobweb sawing. The initial moisture content of fresh disc was approximately 197 ± 3.4% on dry basis (db), while the moisture content of oil palm wood was between 10-12% of a standard timber. The drying process involving microwave power level at 1200, 1600 and 2000 W, and halogen heaters at 2000 W by controlling temperature at 50, 70 and 90°C were compared with the process that combined the microwave power at 1600 W with the halogen heater at 70 and 90°C. It was found that by applying the microwave power of 1,600 W with halogen heater at 70 °C for 400 minutes, compressive parallel to grain, shear strength parallel and static Bending of MOR and MOE 19.43, 0.64, 36.43 and 4474.85 MPa, respectively. The OPT had shown little sign of twist and shrinkage, thus used for interior decoration or furniture fabrication.

Keywords: Oil palm trunk, Oil Palm Wood, Oil Palm Timber, Microwave Drying, Halogen heater.

1. Introduction

Oil palm (Elaeis guineensis) is grown widely in Southeast Asia, South America and Africa near Equatorial. In total, more than 97% of the volumes of palm derivatives sourced from Indonesia, Malaysia Brazil, Colombia, Guatemala, Papua New Guinea and Thailand. It produces more oil per area than any other plant [1,2]. Oil palm is the most important plant from Thailand. It has helped to change the economy. Industrial oil palm had been used for producing oil (crude palm oil, kernel palm oil) and biomass from empty fruit bunches (EFB), palm pressed fibers (PPF), palm shells, oil palm trunks (OPT), and oil palm fronds (OPF) [3-4]. The oil palm trees useful life is about 25 to 30 years, making them to be very high and expensive to the harvest. Basically, the producer countries have been facing a serious environmental problem concerning to the solid bio-waste handling of oil palm industry, particularly the oil palm trunk after replanting activity. It is predicted that more than 20 million cubic meter biomass from oil palm trunk are available annually [5].

Timber is widely used in many industrial and household products. Wood is very important renewable material that can be converted to products for various applications. Commercial wood is expensive and hard to find nowadays, such as hardwood and softwood because of scarcity of wood from natural forests or planting trees. The specific properties can be monitored in order to improve the production chain appropriate to the specified end product [6]. However, careless reduction in moisture content can result in mold growth [7], checks of wood properties, twisting, shrinkage or swelling [8].

In Thailand, old palm trees have been cut down with four methods of re-plantation such as 1.push-felled and windrow or burn 2.chip and windrow or burn 3.drilling and injection of chemicals and 4.move to burn for electricity, is shown in Fig.1-4. The third method, the old palm trees usually takes between five to six years to decompose [9].

All methods created air pollution which is the important issue for the environment.

Figure 1. Push-felled and windrow or burn.

Figure 2. Push-felled chip and windrow or burn.

Figure 3. Oil palm trees, drilled and injected with chemicals before being cut down for re-plantation.

Figure 4. Oil palm trunks for generating electricity.

As far as heating is concerned, a tungsten halogen heater provides near infrared radiation. It will infiltrate into product deeper than the mid-infrared radiation thus resulting in drying time saving [10]. The recent technological advancement concerned with drying hardwood and softwood with microwave [11,12].

This research focused on evolution of physical and acoustic properties of OPT undergoing moisture content reduction with halogen heaters and microwave drying. Oil palm woods (OPW) were selected from the oil palm tree at the age about 25 to 30 years old. It was expected that the oil palm trunks could have better value added by processing it into timbers. The effect of halogen heaters and microwave drying technologies on the kinetics rate and physical, mechanical property of the OPT will be reported in this paper.

2. Materials and Methods

2.1 Oil Palm Trunk Processing.

This research has been prepared OPT for experimental at planted in Chumphon, Thailand. Oil palm tree was 26 years old, the stems were cut the long log of oil palm trunk not more than 3.0 m in shown figure 5.

Figure 5. The stems cut long not more than 3.0 m.

The lower part of oil palm trunk contains vascular bundles distributed at sapwood. In order to get the homogeneous lumber, the bottom part of the trunk was the high-density part as shown in cross-sectional cut in figure 6. This was determined initially in the oil palm wood zoning step. Moreover, eight segments were sawn and processed into lumber as shown figure 7.

After being sawed into pattern by cobweb (Fig.8), oil palm trunk was further cut by chainsaws into slices according to the conditions being set in the experiment [13]. The specimen has the dimension of 50 x 250mm^2, with 25mm in thickness as shown in figure 9. They were boiled in hot water at 85°C for 20 min. OPT was used in experiments with the initial temperature of 28°C, the moisture content of 197 ± 3.4% on the dry basis (db) and the properties of the wood were given in table 1.

Figure 6. Oil palm trunk at transverse section consists of the main part of the trunk, cortex and bark.

Figure 7. Sawing patterns were called cobweb sawing.

Figure 8. The trunk was sawed into pieces by cobweb.

Figure 9. Timber of dimension of 50 x 250, 25mm (thickness).

Table 1. The initial properties of OPT[13]

The properties of timber	value
Natural specific gravity	0.71-0.76
Dry specific gravity	0.39-0.41
Wet specific gravity	0.65-0.67
Moisture content(%db)	197 ± 3.4%
initial temperature	28°C

2.2 Experimental Apparatus.

The chamber of drying with halogen heater and microwave drying is shown in Fig.10. It has the dimension of a 500 × 1,000 × 1,000 mm^3 was made of stainless steel type 316, 1mm thick, cover insulator, 4 x halogen heaters and 4 x magnetrons (Fig.11). Halogen heater has the power output 500W, controlled at 40 to 180°C by a thermostat and equipped with a blower to create air speed of 2.00 m/s. Microwave magnetrons has the power level of 100 – 1,000W at the frequency of 2,450MHz. A circulating fan was installed, distributing hot air and waves in the heating chamber.

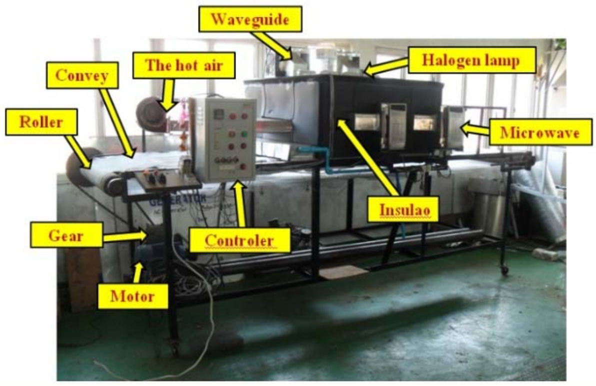


Figure 10. Apparatus of the chamber drier in this study.

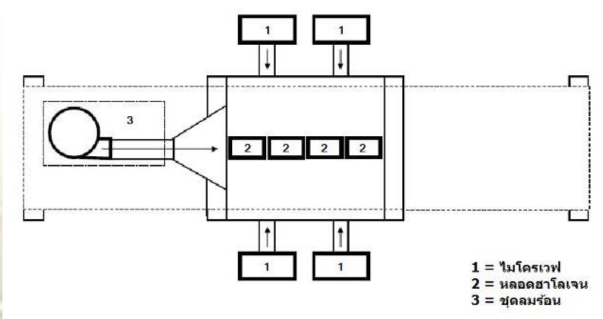


Figure 11. Top view of the chamber drier.

2.3 Method of OPT Specimens Test Conditions.

This drying process apply microwave power level at 1,200 1,600 and 2,000W, and halogen heaters by controlling the temperature at 50, 70 and 90°C and combine microwave power level at 1600W with the halogen heater at 70 and 90°C. One batch of OPT had 40 pieces and serial number. One heating cycle brought out a sample for measurement until the final moisture content reached 10 ± 2% on the dry basis (db).

The OPT has demanded a physical, mechanical properties examination of the effects on various parameters on drying kinetics. The results are divided into, physical properties of moisture content recommended by ASTM D 2395-14 (Standard methods of testing density and specific gravity of wood and wood-based materials) [14], mechanical properties (compressive parallel to grain, shear strength parallel and static Bending) recommended by ASTM D143-14 (Standard methods of testing small clear specimens of timber) [15].

The moisture Content (MC) of the OPT was calculated using this formula [16]

$$MC(\%) = \frac{W_{ini} - W_o}{W_o} \times 100 \qquad (1)$$

Where :

MC, is moisture content of specimen (kg water/ kg dry mass),

W_{ini} is Weight of initial specimen

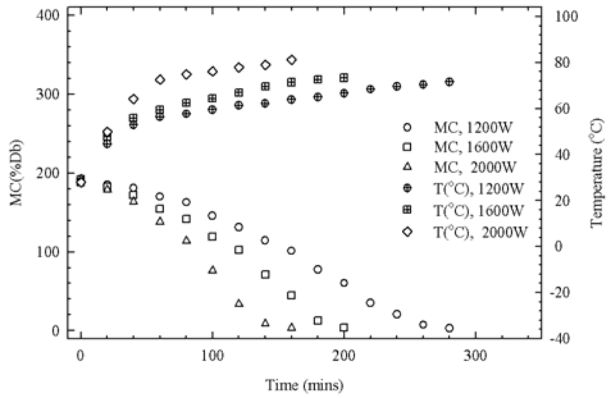
W_o is Weight of oven-dry mass

3. Results and Discussion

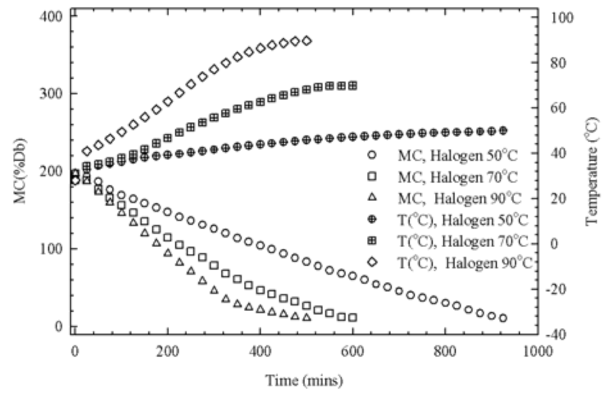
OPT have very high moisture content. The timber industry has been using several methods to reduce the drying time of timber with variety of applications available, these include drying the wood at elevated temperatures with hot air or kilns, drying in radio frequency or microwave ovens, or a combination of these drying methods. Little attention has been given to quantifying the effect of drying method on the mechanical properties of the timber, especially where this involves microwave energy and halogen heater with its interior to exterior heating characteristics. In this study, OPT was dried from pre-determined moisture contents using several drying methods.

3.1 Kinetic rate and temperature in wood during drying.

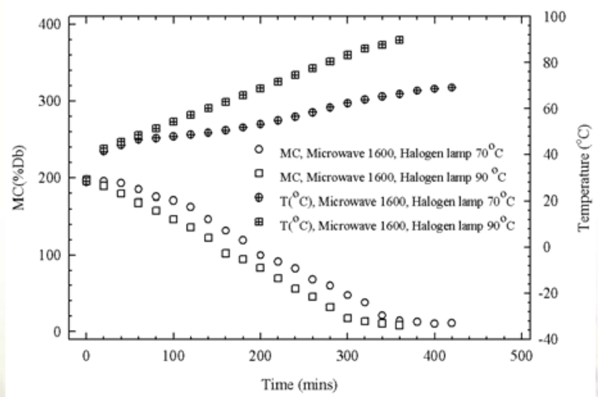
Initial moisture content used the conventional oven at 105°C about 72 hour, the sample of OPT had initial moisture content of 190 ± 3.4% on dry basis (db) which was reduced down to 8 to 12% on the dry basis (db) (standard).



(a)



(b)



(c)

Figure 12. Moisture content and temperature with time of (a) Microwave drying (b) Halogen heater and (c) Microwave drying combined with Halogen heater.

Weight loss of timber in all types of drying corresponded to a decrease in moisture content profiles and an increase temperature profiles with time. The increase in temperature did significantly increase the weight loss of timber (Fig. 12).

Fig.12a suggests that an increase in microwave power level increased the weight loss which is an index of moisture loss. The moisture content profile decreases fastest and temperature profile of the OPT continuously rises faster than that in the case of low microwave power level. The moisture content decreases to 10±2% on dry basis (db), with the drying time 280, 200 and 160 min for powers of 1200, 1600 and 2000 W, respectively. The temperature profiles within the OPT rise up rapidly to 71.6°C, 73.36°C and 81.23°C for powers of 1200, 1600 and 2000 W, respectively, during 280 min of drying process. For microwave power level at 2000W, significant burned and shrinkage was found on OPT.

Fig.12b suggests greater rate of temperature increase by halogen lamb causing greater rate of weight loss which is an index of moisture loss. This was due to the subjection of samples to radiation in the presence of halogen heater. The moisture content profile had decreased to 10±2% on dry basis (db), the drying time was 925, 600 and 500 min for halogen heater at controlled temperature of 50, 65 and 90°C, respectively.

Fig.12c suggests that the microwave at 1600W and halogen heater at control temperature at 70 and 90°C, the higher the weight loss was observed in (Fig. 12(c)). As can be seen that the weight loss was the highest for timber with microwave 1600 w and halogen heater at controlled temperature of 90°C during 0 to 360 min. This indicates that when combining microwave with halogen heater moisture can be removed more effectively than the halogen heater alone.

3.2 Impact of Drying Method on the Mechanical Properties of OPT.

The effect on physical properties such as the strength of the specimen used to halogen heater microwave drying and the combination of both methods. The strength of the timber was found to depend on microwave drying and halogen heater with time. Table 2 shows the results of compressive strength parallel to grain, shear strength parallel and static bending of dried OPT. The results show that an increase in microwave power level at 2000W had resulted in internal burn and reduction in strength of the dried timber.

Table 2 Effect of using heating techniques on OPT mechanical properties.

Microwave power level (W)	Halogen (°C)	Compre-ssive parallet to grain (MPa)	Shear strength parallel (MPa)	Static Bending	
				MOR (MPa)	MOE (MPa)
1200	-	13.57	0.43	16.28	1062.35
1600	-	18.98	0.52	16.48	1995.22
2000	-	11.12	0.51	14.05	1726.67
-	50	11.86	0.38	12.07	1053.02
-	70	16.65	0.51	17.37	4470.67
-	90	14.73	0.46	15.61	3165.58
1600	70	19.43	0.64	36.43	4474.85
	90	16.24	0.49	29.37	4294.96

The dried specimens by halogen at high temperature have higher percentage of shrinkage as compared with those obtained from the halogen heater at low temperature, raising the strength of the dried timber. Finally, it was found that in the case of combined microwave drying and halogen heater yields the best mechanical properties compared to microwave drying and halogen heater alone. Table 2 summarized the mechanical properties of OPT according to the conditions of combined microwave drying and halogen heater at fixed microwave power level of 1600W, halogen heater at temperature of 70°C. The compressive strength parallel to grain, shear strength parallel and static Bending of MOR and MOE were 19.43, 0.64, 36.43 and 4474.85 MPa, respectively.

4. Conclusions

In this paper, the effects of different drying methods on quality of OPT were compared. The combination of microwave drying at 1600W and halogen heater at 70°C had significantly shortened the drying time of OPT and significantly yielding higher rehydration ratio and increase the strength of specimens. Therefore, these methods were recommended for drying of OPT which can be used in the furniture industry. In addition, microwave drying combined with Halogen heater can be recommended to be used if the moisture content of the product is required to be reduced to very low values. Summarize major findings, opinion and resolution of the author which can be drawn from the work.

5. Acknowledgements

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6. References

L'Oréal., 2015. Palm oil progress report, The L'ORÉAL Committed, France.

Poku, K. 2002. Small-scale palm oil processing in Africa. FAO agricultural services bulletin, 148.

Abdullah, N., and Sulaiman, F. 2013. The Oil Palm Wastes in Malaysia, InTech, ISBN 978-953-51-1105-4.

Sheil, D., Casson, A., et al. 2009. The impacts and opportunities of oil palm in Southeast Asia, Indonesia Printer, Jakarta, ISBN 978-979-1412-74-2.

Erwinsyah. 2008. Improvement of oil palm wood properties using bioresin, Institute for logging operations and forestry technology Faculty of Forest, Geo and Hydro Sciences Technical University of Dresden.

Grundberg, S. 1999. An X-ray LogScanner–a Tool for Control of the Sawmill Process, Lule University of Technology, Skellefte.

Geving, S., Holme, J. 2010. The drying potential and risk for mold growth in compact wood frame roofs with built-in moisture, J. Build. Phys. pp 249.

Vikberg, T., Hansson, L., Schajer, G.S. and Oja, J. 1992. Effects on microwave measurements and simulations when collecting data close to edges of wooden boards.

Miodrag Darko Matovic. 2013. Biomass Now, ISBN 978-953-51-1105-4, 552 pages, Publisher: InTech.

G. Sumnu, E., Turabi and Oztop, M. 2005. Drying of carrots in microwave and halogen lamp-microwave combination ovens, Lebensmittel-Wissenschaft und-Technologie, Vol. 38, pp. 549-553.

Vongpradubchai, S., Rattanadecho, P. 2011. Microwave and hot air drying of wood using a rectangular waveguide, Drying Technology, 29, 451–460.

Sahbi, O., Lamine, H., Soufien, A., Sadoth, S. T., Ali, B., Ahmed, K. 2015. Modeling of combined microwave and convective drying of wood: Prediction of mechanical behaviorvia internal gas pressure. Drying Technology, 33, 1234–1242.

Charoenatkul, J., Madsalae, A. 2008. The use of Palm Wood in the work engineering. Rajamangala University of technology Srivijaya.

ASTM-Standard. Annual book of American Standard Testing Methods (ASTM-Standards), Designation: D2395 – 14, 2014. Standard test methods for density and specific gravity (relative density) of wood and wood-based materials, ASTM, USA, 1–13.

ASTM-Standard. Annual book of American Standard Testing Methods (ASTM-Standards), Designation: D143 – 14, 2014. Standard test methods for small clear specimens of timber. ASTM, USA, 1–31.

Sahbi, O., Lamine, H., Soufien, A., Sadoth, S. T., Ali, B., Ahmed, K. 2015.Modeling of combined microwave and convective drying of wood: Prediction of mechanical behavior via internal gas pressure. Drying Technology, 33, 1234–1242.