THE EFFECT OF COMPRESSION LEVELS AND SAMPLING'S POSITION ON LOG ON RUBINATE UPTAKE BY MICROWAVE-HEATED SITKA SPRUCE (*Picea sitchensis* (Bong) Carr.) [1]

(Pengaruh Tingkat Penekanan dan Posisi Pengambilan Sampel pada Dolok Terhadap Penyerapan Rubinate oleh Sitka Spruce yang Dipanaskan Dahulu dengan Mikrowave)

By/*Oleh* :

Karnita Yuniarti [2] & Jeff Hann [3]

ABSTRAK

Penggunaan energi mikrowave pada tingkat cukup tinggi dapat menyebabkan perubahan dimensi kayu akibat patahnya beberapa struktur kayu yang lemah. Modifikasi lebih lanjut dengan resin diikuti penekanan kayu selama proses fiksasi resin dapat memperbaiki kualitas kayu tersebut. Penelitian ini bertujuan untuk menganalisis pengaruh penekanan selama proses fiksasi resin rubinate dan faktor posisi pengambilan sampel kayu terhadap penyerapan rubinate oleh Sitka spruce yang sebelumnya dipanaskan dengan mikrowave. Hasil penelitian menunjukkan bahwa penyerapan akhir dipengaruhi oleh tingkat penekanan yang digunakan selama proses fiksasi resin dan kurang dipengaruhi oleh faktor posisi pengambilan sampel kayu. Penyerapan akhir rubinate juga dipengaruhi oleh interaksi antara kedua faktor tersebut.

Kata kunci: Tingkat penekanan, sitka spruce, mikrowave, rubinate

ABSTRACT

The use of microwave at high level of energy could expand the wood due to the rupture of some weak structures of wood. Treatment of the wood with resin followed by compression during hot-curing process could improve the quality of the microwave-modified wood. This experiment aimed to investigate the effect of different compression levels used during curing process and sampling's position on log on the final uptake

---

[1] Makalah hasil penelitian yang ditugaskan pada saat pelaksanaan studi S2 di University of Melbourne, Australia di bawah bimbingan Dr. Jeff Hann (*Research paper assigned during the study of master program at the University of Melbourne supervised by Dr. Jeff Hann*)

[2] Calon peneliti pada Pusat Litbang Hasil Hutan Bogor (*Yunior researcher at Centre for Forest Product Research and Development Bogor*)

[3] Peneliti pada CRC for Wood Innovation-Australia dan Staf pada University of Melbourne (*Researcher at CRC for Wood Innovation-Australia and Staff at University of Melbourne*)

of rubinate by microwave-heated Sitka spruce. The result showed that the uptake of rubinate was significantly affected by the compression used and less affected by the sampling's position on log. The final uptake of rubinate was also affected significantly by the interaction between two factors.

Key words: Compression levels, sitka spruce, microwave, rubinate

I. INTRODUCTION

A. Background

Sitka spruce is softwood species with wide distribution. It can be found growing in three continents: America, Europe, and Australia. The species has also become the dominant species selected for forest rehabilitation programs in some European countries such as Britain (Thompson 1992), Norway (Magnesen 1978) and Ireland (Lavery *et al.* 1995).

Despite its wide distribution, the timber of this species is difficult to treat with preservative chemicals. Further, according to Alden (1997), even though the wood of Sitka spruce is easy to kiln dry, the seasoned wood apparently has permeability of one to five percent lower than the green timber due to the aspiration of pit membranes as a result of the drying process (Messner, *et al.* 2002). This information is contrary to the general view that drying processes increase the treatability of timber (Bateson 1946; Usta &Guray 2000; Waterson 1997).

The use of microwaves, especially those emitted in a wave-guide applicator, for wood drying process apparently has potency to overcome the permeability issue of this species. A technique to improve the permeability of wood with this particular energy has been patented internationally by Vinden *et al.* (2003).

According to Torgovnikov (1996), wood can absorb a large amount of microwave due to the presence of water molecules inside wood. Barnes *et al.* (1976) said that water molecules have the greatest potential for converting electrical energy into thermal energy. Therefore Torgovnikov (1996) convinced that almost 100% of microwave energy applied to wood can be transformed into thermal energy. Further, Dench (1973) *in* Peykens *et al.* (1984) listed some advantages of using microwave-heating process in comparison with conventional heating methods, which are faster processing, smaller space required by the microwave facility, better final product quality, more stable product dimensions, lower heat loss to the surrounding and greater control of the heating zone.

However, the use of high intensity of microwave emitted in a wave-guide applicator apparently ruptures some weak structures of wood such as ray cells. To some extent, this process then can expand the wood, producing a product called Torgvin. This microwave-heated wood has lower strength properties than the normal wood. Treating this conditioned wood with resin and press them during the resin curing process not only makes the wood regaining its initial dimension but also has increased strength and density. The end product was then called Vintorg, which was derived from the last name of its inventors (Peter Vinden and Grigori Torgovnikov) (Muga 2001).

Rubinate is one of the resins that can be used for treating microwave-heated wood. This resin is the representative of diisocyanate-resin type, which is a popular resin type used for the manufacture of wood composites. Different from formaldehyde-based resin, isocyanate resin is free of formaldehyde (Walker *et al.* 1993). This resin type offers good moisture resistance and suitable for outdoor use (Walker *et al.* 1993).

During the modification of the microwave-heated wood with resin, hot press-curing is a required stage (Vinden and Torgovnikov 2000 *in* Muga 2001). It is expected that through this stage, not only the impregnated resin could be cured inside the wood but also the ruptured structures of wood resulted from the microwave-heating process could be re-bonded. As a result, the strength of the wood will also improve.

Nevertheless, Muga (2001) observed that some amount of resins were lost from the wood during this hot press-curing process. This loss definitely affects the real amount of resin contained in the final product, and in the end will affect the strength properties of the wood itself as well.

Up to now, the influence of hot press-curing of the resin-treated/microwave-heated wood at different compression levels on final uptake of the resin has not been known yet. Likewise, it has not been known either if the sampling's position within the log has influence on the issue.

B. Objectives

The experiment was designed to analyze the influence of the compression levels applied during hot-press curing and the sample's position in the log on the final uptake of resin by microwave-heated Sitka spruce.

II. METHODOLOGY

A. Material and Equipment

The main materials used were 10 logs of Sitka spruce at the length of around 6-7m. The resin chemical used was Rubinate 1780 (Huntsman Polyurethane Australia). The equipments used included a balance, timer, microwave applicator, vacuum-pressure treatment vessel (small capacity (25 l)), Baioni hot press machine, oven and recording tools.

B. Site and Time

The experiment was carried out at School of Forest and Ecosystem Science, Faculty of Land and Food Resources, University of Melbourne-Creswick during the period of July-August 2004.

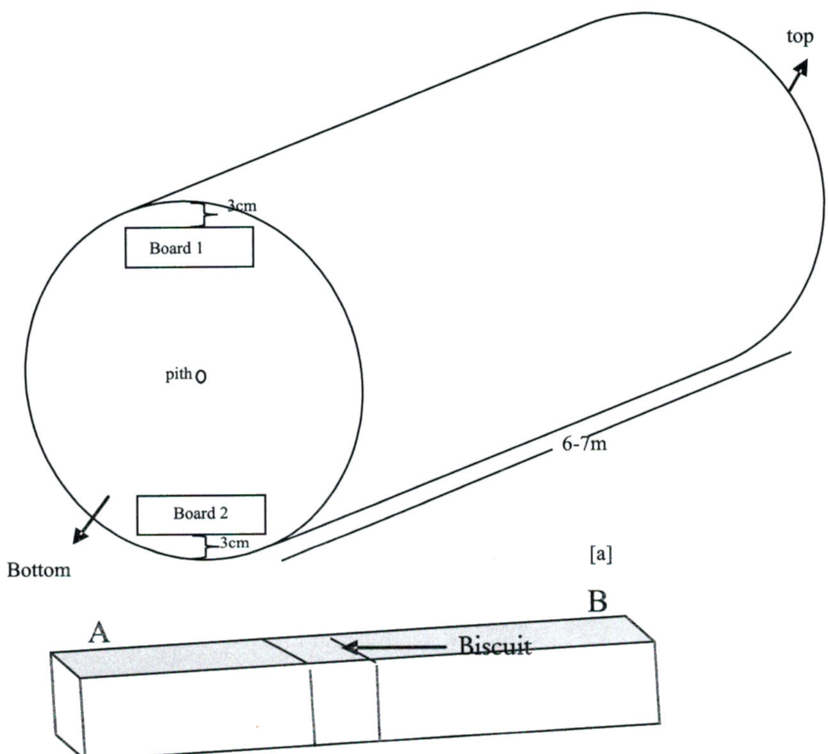
C. Procedure

1. Sampling and microwave-heating process

Two main boards at a distance of 3 cm from each edge of each log were prepared with the width and thickness of each board was 85 mm (8.5 cm) and 40 mm (4 cm) respectively.

Each main board was then cut into 2 (two) 2.7m-length planks with a 2 cm-thick biscuit taken between the planks for moisture content determination. The cutting process was carried out carefully so that planks considered near the bottom position of the log could be differentiated from those near the top position of the log. The cutting process then resulted in 20 planks from the bottom position of the log and 20 planks from the top position of the log. Ten (10) planks from each position were randomly taken for this experiment and the remaining set was used for other purposes. Figure 1 illustrated the sampling process.

One sample at a length of 410 mm was cut from one end side of each board and set aside for other purposes. The remaining length of the plank was heated with microwave energy at 12kW and 13.33mm/s-speed using the wave-guide applicator. Afterward, each heated plank was cut into 5 samples of around 410 mm in length. These 5 samples were randomly grouped into 5 treatments: no-compression and resin treated, 5% compress and resin-treated, 11% compress and resin-treated, and 20% compress and resin-treated.



Note :
A = planks represented the bottom part of the log
B = planks represented the top part of the log

Figure 1. Sample preparation[a] sawing phase ; [b] cutting pattern

2. Treatment and compressing process

All samples were treated with treatment cycle consisting of 5-minute pre-vacuum at 85 kPa and 5-minute pressure at 200kPa. The samples were weighed before and after treatment. The treated samples were then prepared to be cured with Baioni heated platen press machine.

The samples were placed with their radial sides facing the top load of the machine. In this context, the width of the samples became the thickness and vice versa. The samples determined for 0% compression level were heated only without implementing any compression. The samples determined to be compressed to nominal compression level of 5, 11, 17 and 20% were heated and compressed from their initial width (the width after microwave-heating phase). The compression process was assisted by placing some wood stickers between the samples. The stickers acted as stops to control the thickness similar to the desired depth that would like to be achieved for each compression level. Following the curing process, the samples were then reweighed.

3. Data collection and analysis

The data collected were the weight of the samples before treatment, after treatment, and after pressing process. The weight percent gained (WPG) by each sample, which represented the amount of resin uptake, was calculated using Formula 1 below:

$$(WPG) = \frac{(\text{weight after curing} \quad \text{weight before treatment})}{\text{Weight before treatment}} \times 100 \quad .... \quad \text{(Formula 1)}$$

The data on weight percent gained of the rubinate-treated samples were analyzed using ANOVA test provided in Minitab 11 software. The data was set as two-way experimental design with the compression levels as the first factor (A) consisting of 5 levels : 0% (no-compression), 5, 11, 17 and 20%; and the sample's position within the log as the second factor (B) consisting of 2 levels (top and bottom of the log).

Further Fisher's test was carried out following the ANOVA test if the ANOVA test gave significant result. The Fisher's test was carried out using Minitab 11 software in order to analyze any significant difference of the mean values not only between the compressed and non-compressed groups but also between each-two compression groups.

III. RESULTS AND DISCUSSION

Table 1 showed the condition of microwave-heated /rubinate-treated samples. The moisture content of treated samples ranged from 3.66 to 10.21%.The weight percent gained of treated samples ranged from 5.22 to 18.61%. Rubinate-treated samples that were compressed to 17% and came from bottom position of the log (A) had the highest weight percent gained, while those from the same compression group but came from top position of the log (B) had the lowest weight percent gained among the treated samples. In general, compressing samples were found increasing the value of weight percent gained in comparison with the non-compressed samples (0% compression level).

Table 1. General condition of microwave-heated / rubinate-treated Spruce
Tabel 1. Kondisi kayu Sitka spruce yang telah dipanaskan mikrowave dan diimpregnasi dengan rubinate

Compression levels (*Tingkat penekanan*)	Samples position (*Posisi sampel*)	Moisture content (*Kadar air*), %			Weight percent gained (*Jumlah resin terserap*), %			
		Avg (*Rata-rata*)	Max (*Maks*)	Min (*Min*)	Avg (*Rata-rata*)	Max (*Maks*)	Min (*Min*)	Inc. (E*naikan*), %
0%	A	5.96	6.57	4.87	7.80	12.59	5.48	NA
	B	6.64	7.92	5.15	7.76	11.51	5.29	NA
5%	A	6.34	6.95	5.65	8.61	10.30	5.83	10.42
	B	6.50	8.68	3.66	9.79	17.11	5.61	26.10
11%	A	6.65	8.25	4.95	10.07	13.78	7.59	29.03
	B	6.55	9.59	4.75	10.12	14.96	5.22	30.39
17%	A	6.47	7.60	5.30	12.71	18.61	9.37	62.88
	B	6.64	9.23	5.77	7.554	15.80	3.14	-2.87
20%	A	7.04	7.55	6.42	9.98	12.88	7.81	27.90
	B	7.40	10.21	5.89	10.91	15.82	6.05	40.44

Remarks (*Keterangan*) : Avg= average value *(nilai rata-rata)* ; Max = maximum value *(nilai maksimum)*; Min= minimum value *(nilai minimum)*; NA= not available *(tidak tersedia)*; Inc (%) =increase in WPG, compared with the 0% compression level *(kenaikan jumlah resin terserap, dibandingkan dengan sample yang tidak dikompres)*; A= Bottom position *(posisi bawah)* ; B = Top position (*posisi atas*)

The result of 2-way ANOVA test carried out at confidence level of 95% was shown in Table 2. The result indicated that the compression levels used did have significant effect on the amount of Rubinate absorbed by the microwave-heated Sitka spruce. The uptake of rubinate by microwave-heated Sitka spruce was affected by the interaction between sample's position on the log and the compression levels used during the hot-press curing process. It was apparently less affected by the sample's position in the log. This last point apparently does not support the previous assumption of that wood factor was another variable affecting the success of treatment of microwave-heated wood with resin in order to convert it into Vintorg product (CRC Wood Innovation 2003).

Table 2. The-2-way ANOVA (Analysis of Variance) result for analyzing the effect of compression level used during hot-press curing process and sample's original position within the log on the uptake of rubinate by microwave-heated Sitka spruce.

Tabel 2. Uji ANOVA(Analisa Keragaman) untuk pengujian pengaruh tingkat penekanan dan posisi pengambilan sampel pada dolok terhadap penyerapan rubinate oleh kayu Sitkas pruce yang telah dipanaskan dengan mikrowave

Source of variance (*Sumber keragaman*)	Df *(Derajat bebas)*	SS *(Jumlah kuadrat)*	MS *(Kuadrat tengah)*	F-value *(F-hitung)*	P *(Peluang)*
Compression level *(Tingkat penekanan)*	4	87.989	21.997	2.69	0.037*
Position *(Posisi)*	1	8.821	8.821	1.08	0.302
Interaction between Compression and Position *(Interaksi antara tingkat penekanan dan posisi sample)*	4	133.011	33.253	4.06	0.005*
Error *(Galat)*	86	704.271	8.189		
Total *(Total)*	95				

Remarks (*Keterangan*) : * = significant effect; Df= degree of freedom; SS= Sum of square; MS=Mean of square; P=Probability

Further Fisher's test indicated that the rubinate uptake by samples that were not compressed was significantly different from samples compressed to 11, 17 and 20% of their original thickness. This result also meant that pressing microwave-heated Sitka spruce to 5% of its original thickness would possibly not give significant difference in final uptake of rubinate in comparison with the non-compressed samples.

The Fisher's-test also revealed that the rubinate uptake of samples from the bottom position of the log and compressed to 17% of its original thickness was significantly different from the uptake of samples from other groups. Since pressing to 17% gives the highest weight percent gained of rubinate (Table 1), it is probable that compression level of 17% is the optimal level that could be applied for pressing microwave-heated Sitka spruce to achieve better uptake of rubinate resin.

The uptake of resin by wood could be affected, at least, by two variables: the wood condition and the curing process of the resin itself that usually uses heat. The structure of microwave-heated wood apparently provides abundant of void spaces as a result of the rupture of some its weak structures and elimination of some extractives during the microwave-heating process. The impregnated resin is expected to fill in the empty spaces in cell and thus form the bond with the cell wall component.

During the hot-press curing process, two factors- heat and pressure -contribute a lot to the situation. The heat applied here plays important role. It not only fixes the impregnated resin inside the wood permanently, but also softens the wood, causing it much easier to press. When compression is then applied, the impregnated resin possibly could penetrate far deeply inside the wood cell, filling in its void spaces and forming bond with wood cell wall component. As more compression is applied, more portion of the wood is pressed, thus more resin is expected to penetrate into the wood. However, since wood has a certain elastic limit, the compression of the wood will discontinue when this limit is exceeded (Silvester 1967). Possibly due to this elastic limit of wood, compressing rubinate-treated/microwave-heated Sitka spruce to 20% of its original thickness did not give rubinate uptake as optimal as the compression level of 17%.

IV. CONCLUSION AND RECOMMENDATION

1. The final uptake of rubinate resin by microwave-heated Sitka spruce was not affected by the sample's position within the log, but affected by the compression levels used during the hot-press curing process and the interaction between the compression levels and the sample's position on the log.
2. Compression level of 17% could be applied to achieve optimal uptake of rubinate by Sitka spruce previously heated with microwave emitted through a wave-guide applicator at power of 12kW and velocity of 13.33 mm/s.
3. Samples taken from bottom position of log and compressed to 17% had the highest weight percent uptake.
4. Other experiments using different types of resin should be carried out in order to see if the uptake of any resin by Sitka spruce pre-heated with microwave at the same energy level is really affected by the compression level or its interaction with the sample's position within the log.

Acknowledgment

I would like to express my gratitude to Mr. Peter Plews for his assistance in operating the Baioni pressing machine for this experiment.

BIBLIOGRAPHIES

Alden, H.A. 1997. Softwoods of North America. Doc. No. FPL-GTR-102, Forest Products Laboratory, Madison, Wisconsin. 151pp.

Barnes, D., L. Admiral, RL. Pike and V.N.P. Mathur. 1976. Continuous system for the drying of lumber with microwave energy. Forest Product J. 26(5): 31-42. Forest Products Society, Madison.

Bateson, R.G. 1946. Timber Drying and The Behavior of Seasoned Timber in Use. Crosby Lockwood & Son, Ltd. London. 129pp.

CRC Wood Innovation. 2003. Cooperative Research Centre for Innovative Wood Manufacturing: Annual Report 2001-2002. CRC for Wood Innovation. Melbourne.

Gasperz, V. 1991. Metode Perancangan Percobaan. Armico. Bandung. 472pp.

Lavery, D.J., D. McLarnon, J.M. Taylor, S. Moloney and A. Atanackovic. 1995. Parameters affecting the surface finish of planed Sitka spruce. Forest Product J. 45 (5): 45-50. Forest Products Society, Madison.

Magnesen, S. 1978. Sitka spruce in West Norway. Proceedings of The IUFRO Joint Meeting of Working Parties Vol.2, August 21-September 9 at Vancouver. Pp. 159-172. B.C. Ministry of Forests. Canada.

Messner, K., A. Bruce & E. Tucker. 2002. Making refractory wood species treatable by fungal pre-treatment. Proceedings of Enhancing The Durability of Lumber and Engineered Wood Products Conference, 11-13 February 2002 at Kissimme (Orlando). Pp. 111-113. Forest Products Society. Finlandia.

Muga, M.O. 2001. Mechanical properties of wood following microwave and resin modification. MSc. Thesis. School of Forestry, ILFR, University of Melbourne. Melbourne. Unpublished.

Peyskens, E., M. de-Pourcq, M. Stevens & G.J. Schalck. 1984. Dielectric properties of softwood species at microwave frequencies. Wood Science and Technology 18 (4): 267-280. Springer-Verlag GmbH, Berlin.

Silvester, F.D. 1967. Mechanical Properties of Wood. Pergamon Press. Oxford. 141pp.

Thompson, D.A. 1992. Growth of Sitka spruce and timber quality. Pp. 54-60 *In* D.A. Rook (ed). Super Sitka for The 90s. GB For. Comm. Bull. No. 103. London.

Torgovnikov, G.I. 1996. Practical microwave utilisation for timber drying. Manuscript. Creswick. Unpublished.

Usta, I. & A. Guray. 2000. Comparing of the moisture reduction of Sitka spruce and Oriental spruce by kiln drying. Journal of Qafqaz University, Fall (6): 123-130. Qafqaz University. Turkiye.

Vinden, P., F.J. Romero & G. Torgovnikov. 2003. Method for increasing the permeabillity of wood. United of States. US Patent No. 6742278.

Walker, J.C.F., B.G.Butterfield, T.A.G. Langrish, J.M. Harris & J.M. Uprichard. 1993. Primary Wood Processing:Principles and Practices. Chapman & Hall. London. 595pp.

Waterson, G.C., ed. 1997. Australian timber seasoning manual. Australasian Furnishing Research and Development Institute Limited. Launceston. Tasmania. 206pp.