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Preface

The use of Microwave and Radio Frequency for heating applications in industry and scientific research is a dynamic and growing field. Each year, the scientific community produces a significant number of new ideas which are at the heart of novel processing methodologies.

Research and development into microwave and radio frequency processes is carried out globally and spans the full spectrum of scientific and engineering disciplines who are actively engaged in both academic and industrial laboratories throughout the world.

The Association for Microwave Power in Europe for Research and Education (AMPERE) actively promotes the use of MW and RF frequencies for industrial and scientific applications. A major activity of AMPERE is to facilitate forums, in the form of conferences, where researchers and industrialists can meet and exchange novel ideas and share best practice.

This conference is part of a biennial series and this year The University of Nottingham is proud to host the 14th event. The conference takes place between 16th and 19th of September 2013 and is organised by the National Centre of Industrial Microwave Processing which is based in the Faculty of Engineering at The University of Nottingham. It includes oral presentations, special workshops, plenary and keynote addresses from experts in academia and industry.

Particular focus is provided in this meeting to Microwave applications in chemistry, a hugely important sector to the community. The aim is to demonstrate the benefits of Ampere membership to the expanding community of chemists that utilise MW and RF power in their research and who have not necessarily have been associated with AMPERE in the past.

These proceedings include 107 abstracts and papers from the invited speakers and delegates of this conference, representing 23 countries and confirming once more the truly global nature of this meeting.

The local organising committee would like to acknowledge the Faculty of Engineering at The University of Nottingham and the sponsors for their support in organising and hosting the event.

Finally, a great thanks goes to all the delegates and contributors who have helped with the presentation of their papers in making this conference a success.

We look forward to meeting you in Nottingham in September.

S.W. Kingman

Chairman of the Local Organising Committee

Microwave Hardwood Modification Technology for Fast Timber Drying

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Very low permeability of many hardwood species causes problems during timber drying. These include: very long drying times, drying defects, and large material losses after drying, high energy consumption, expensive drying processes. Microwave wood modification can provide an increase in wood permeability for liquids and gases that solves many wood drying problems. MW pre-treatment of eucalyptus sawn timber provides a reduction in drying times and drying defects. The reduction in drying time provides a reduction in associated capital, space, energy and labour costs whilst the reduction in drying defects can increase yields. This technology could be implemented using existing kiln drying facilities. Microwave timber pre-drying costs are in the range of AU$22/m3 to AU$50/ m3. This being acceptable to industry, provides good opportunities for commercialisation.
Keywords: microwave wood modification, timber pre-drying, wood permeability, hardwood drying

INTRODUCTION

Timber industry has permanent problems with hardwood drying: very long drying times, drying defects, and large material losses after drying, high energy consumption, expensive drying processes. Microwave (MW) wood modification can solve many wood drying problems. Many commercial hardwood drying operations impose an extended period of slow air drying to reduce the incidence of drying defects (checking and collapse) prior to kiln drying. MW pre-treatment increases the permeability of the green wood [4], overcoming the propensity of the hardwoods to collapse during kiln drying and provides an opportunity for fast kiln drying immediately after sawing.
The practical application of MW energy to wood requires high intensity power to be applied in short bursts, to provide the required degree of modification. These requirements demand the development of special MW applicators which must have the ability to work at high MW power levels (up to 120 kW) at frequency 2.45 GHz, in order to provide uniform energy distribution within the timber cross section.

The research and development objectives included: design, modelling and manufacturing of applicators for sawn timber modification; experimental studies of MW interaction with timber in the applicators; study of the effect of MW modification on wood quality and drying process; economic assessment of sawn timber MW pre-treatment.

MATERIALS AND METHODS

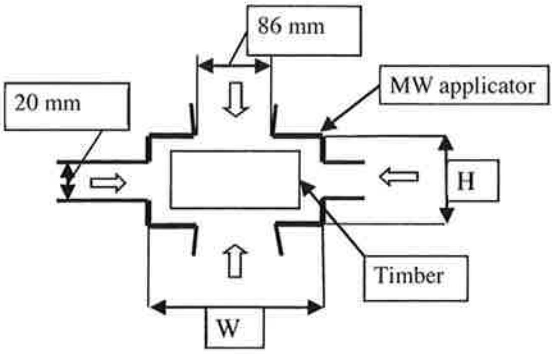
The objectives of the trials outlined below was to study the effect of MW pre-treatment of sawn hardwood timber for fast drying on timber quality, drying process and estimate the cost associated with this technology.

Materials

Sawn timber of four hardwood species: Messmate (Eucalyptus obliqua), Sydney blue gum (Eucalyptus saligna), Black butt (Eucalyptus pilularis), Jarrah (Eucalyptus marginata) were used for experiments. The samples were 32-45 mm in thickness. Timber widths ranged from 107 to 112 mm and lengths were 2400-3400 mm. The moisture content (MC) was in the range from 54 to 121% and green density from 940 to 1240 kg/m3.

Experimental installation

The 60 kW MW experimental plant (two generators 30 kW each) at frequency of 2.45 GHz was used for experimental trial. Main part of the installation is the applicator where MW's interact with wood. MW applicators working at a frequency of 2.45 GHz must provide modification of the full cross section of timber in sizes ranging from 40x60 mm to 60x120 mm. To perform this task a rectangular applicator with four ports was chosen for supplying MW energy to the wood (Fig 1).



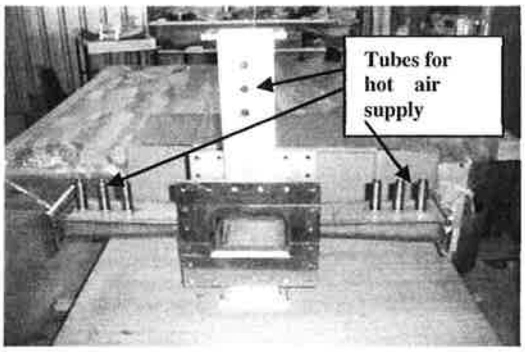


Figure 1. Four port MW applicator at frequency 2.45 GHz for sawn timber processing. H- size of the vertical (narrow) wall, W- size of the horizontal (wide) wall, inlet port size 20x86 mm. Taper waveguides with tubes for suppling hot air (photo).

The actual sizes for the applicator walls were derived by computer modelling using "CST Microwave Studio" software to determine the energy distribution in the timber. These simulations were completed for different cases of electric field vector E orientation in port inlets. Based on these modelling results the following sizes were chosen for experimental applicator: height 80 mm, width 130 mm, length 250 mm. This applicator allowed the use of 4, 3 or 2 ports for MW energy to be supplied to the wood in order to achieve the required energy distribution in timber cross-section. The applicator was manufactured from stainless steel. To remove vapours, dust, wood particles, drops of resins and water from applicator, air flow (temperature 90-105oC) was suppled through port inlets by a blow heater.

MW treatment schedules

After measuring temperature distribution in the cross-sections of boards at different MW power levels and different feed speeds the timber treatment schedules were chosen for groups of samples of different species (Table 1).

Table 1. Schedules for hardwood board MW conditioning.

			Treatment schedules			
Timber species	Timber size (mm). (Number of boards)	MC, (%)	Applied MW power, (kW)	Energy supply via ports	Timber speed, (mm/sec)	Air flow temperature in applicator, (°C)
Messmate (back-sawn)	32 by 110 (18 pc)	70 to 90	13.7	Via 3 ports	14.4	90-95
Messmate (quarter-sawn)	32 by 112 (20)	70 to 90	13.0	Via 3 ports	13.4	90-95
Messmate (back-sawn)	32 by 112 (26)	91 to 121	14.4	Via 3 ports	13.4	90-95
Sydney blue gum	45 by 108 (28 pc)	65 to 80	10.4	Via 2 side ports (50%/50%)	8	95-105
Black butt	45by 108 (41pc)	50 to 74	12.0	Via 2 side ports (50%/50%)	8	95-105
Jarrah	45 by 107 (20 pc)	81 to 112	10.4	Via 2 side ports (50%/50%)	8	90-95

Drying and quality assessment

Following microwave modification, all boards were conventionally kiln dried, along with control samples sourced from the same population, using a standard commercial kiln schedule recommended by Australian Timber Seasoning Manual [1] for each species. The final moisture content of all boards ranged from 10 to 12%.

Comparison of drying quality of the MW pre-treated and control boards were done by counting checks (cracks) in the samples using image analysis. Two millimetre wafers were cut across the grain from the sample blocks and prepared for scanning and image analysis using the method described by

Ilic [3]. Check assessment (for both internal/honeycombing and surface) was carried out by comparing the number of overall checks in each wafer for MW treated samples and control samples. This data was analysed using ANOVA to determine any statistical differences between treatments at 95 % confidence.

RESULTS AND DISCUSSION

Drying quality

The main characteristic of wood drying quality is the quantity of checks (cracks) in the board after drying. Therefore the effect of MW conditioning on check number in the boards is the most important indicator. Comparison of drying quality of the MW pre-treated and control boards were carried out by counting checks in the samples using image analysis (Table 2).

Table 2. Comparison of the MW conditioned boards to controls per percentage of samples without checks for each sample group

Timber species	MC,(%)	Specific applied MW power, (kW/m^3)	MW energy applied, (MJ/m^3)	MC loss after MW treatment, (%)	MC loss after MW treatment and cooling,(%)	Percentage of the samples without checks, (%)	
						Control	**MW treated**
Messmate (back-sawn)	70 to 90	24,400	270	2.4	4.3	31	55
Messmate (quarter-sawn)	70 to 90	27,000	270	1.6	4.3	35	38
Messmate (back-sawn)	91 to 121	27,000	300	2.9	7.1	31	35
Sydney blue gum	65 to 80	14,300	270	1.9	4.9	-	-
Black butt	50 to74	14,300	310	1.8	3.3	32	56
Jarrah	81 to112	13,000	270	2.7	5.0	22	60

Check analyses showed that MW pre-treated boards in all cases had less checks after drying compared to controls. MW pre-treatment of Black butt, Sydney blue gum, Jarrah thick (45 mm) boards reduces check number significantly (1.7 -2.7 times). A low level of MW wood modification does not affect sawn timber drying quality. And in thick boards MW pre-treatment improves the drying quality. This means also that more aggressive drying schedules can be used for hardwood lumber drying to reduce drying time. During MW conditioning boards lost 1.6 - 2.9% of moisture content and after cooling to ambient temperature a total moisture content loss was 3.3 - 7.1%.

Wood properties

Previous research [4] showed that MW energy application up to 70- 90 kWh/m3 to the hardwood timber has no effect to wood strength properties (modulus of rupture, modulus of elasticity, hardness). The study of MW lumber pre-drying treatment carried out in Oak Ridge National Laboratory [2] with White oak (Quercus alba L.) and Red oak (Quercus rubra), Hard maple (Acer saccharum Marsh) demonstrated that a low degree of modification has no effect on timber quality. This research found that low degree modification does not give any statistically significant difference in strength, stiffness, hardness, or glue shear between untreated and pre-treated lumber. And had no difference in the machinability, gluability or the finished quality of MW treated boards compared to controls. Therefore MW conditioning does not have an effect on wood properties and in many cases reduces drying defects.

Drying time

Many commercial hardwood drying operations impose an extended period of slow air drying to reduce the incidence of drying defects (checking and collapse) prior to kiln drying. MW conditioning of hardwoods provides an opportunity for kiln drying immediately after sawing.

Drying experiments with MW conditioned boards showed that drying time can be reduced significantly. Comparison of the drying time for control and pre-treated boards with cross section 45x107 mm at the same convection kiln and standard drying schedules provided drying time reduction by 1.8-2.3 times.

Oak Ridge National Laboratory study [2] of White oak, Red oak, and Hard maple drying after MW pre-treatment also demonstrated drying duration reduction by 2 times. Two times drying duration reduction was received using standard convection kiln drying schedules. However as wood permeability is increased by MW treatment, this will allow the use of more aggressive drying schedules to be developed, thereby enabling drying times to be reduced significantly. MW pre-treatment can alleviate the need for lengthy (3-6 months for eucalyptus lumber) conventionally used air pre-drying before kiln drying and reduce total drying up to 2-3 weeks.

Costs of MW wood pre-drying treatment

An economic assessment of MW wood conditioning for fast drying has been based on technical data from experiments and world prices of the equipment for two frequencies allowed for industrial use 0.922 and 2.45 GHz. Calculations showed that MW pre-drying treatment costs for automatic plant at frequency 0.922 GHz and electricity costs AU$0.06/kWh to AU$0.12/kWh growth from AU$22/m3 to AU$28.8/ m3 at three working shifts per day and from AU$28.3/m3 to AU$35.1/m3 at two working shifts per day. At frequency 2.45 GHz, MW pre-drying costs in similar conditions growth from AU$32.5/m3 to AU$40.1/m3 at three working shifts per day and from AU$42.4/m3 to AU$50/m3 at two working shifts per day. The estimated specific costs include costs associated with capital, maintenance, magnetron replacement, labour, floor space cost and electricity costs. These costs do not include costs of mechanical installation, electrical connections, on costs (overheads) and taxes. Additional costs connected with a new technology use are not significant compared to hardwood lumber prices. This additional 2.3 to 4.9% increase in expanse is not significant and not comparable to the benefits which MW processing brings. This technology could be implemented using existing kiln drying facilities.

CONCLUSIONS

The study of MW hardwood modification for fast drying of sawn timber showed a positive effect of this method on wood quality and drying time reduction. MW pre-treatment does not give any statistically significant difference in strength, stiffness, hardness, or glue shear between untreated and pre-treated lumber. MW pre-treatment provides drying duration reduction by 2 times at standard kiln drying schedules. Microwave energy consumption for low degree wood modification is 70-90 kWh/m^3.

MW pre-treatment for fast drying can provide additional potential advantages: reduction of wood degradation (no long seasoning), energy savings, no need steam conditioning after drying, process from green to dry shortage. MW timber pre-drying costs range is from AU$22/m3 to AU$50/m3 depending on electricity costs and working conditions. These costs are reasonable and acceptable to industry. The technical aspects of the technology are settled and it can be commercialised.

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