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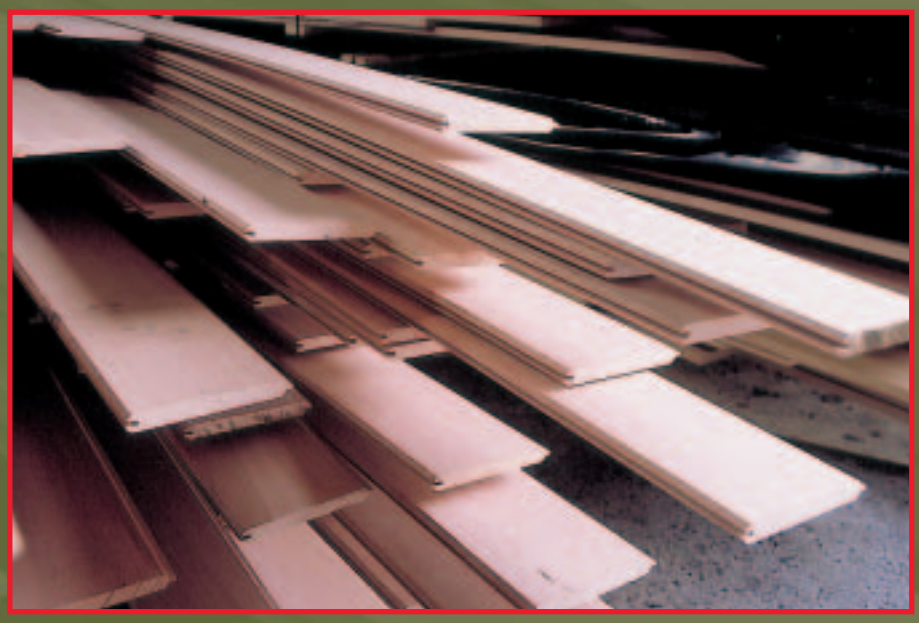
Microwave Modification of Hardwoods



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Microwave Modification of Hardwoods
Final Summary Report

Prepared for the

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Research & Development Corporation

by

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Background

The original background work on the microwave modification of conditioning of green hardwoods for drying indicated that substantial savings could be achieved compared to existing drying methods. However, this work was limited in scope and provided only estimates of potential savings in drying time. The objectives of the research undertaken for the Forest and Wood Products Research and Development Corporation and reported in a series of reports for this project were as follows:

(1) To design and construct microwave applicators suitable for timber modification
(2) Establish optimum parameters for MW timber modification (i.e. maximizing the increase in wood permeability), whilst minimising any reduction in strength properties and maintaining good appearance).
(3) Develop suitable convection drying schedules for MW pre-treated timber whilst minimising drying defects.
(4) Establish parameters for the design of commercial MW plant for timber pre-treatment
(5) Determine the costs of microwave modification to aid commercial adoption of the technology.

During the period 1-7-1999 to 30-6-2001, five confidential reports were prepared for the Forest and Wood Products Research and Development Corporation (FWPRDC) in relation to the microwave modification of hardwood species for drying. The titles of these reports were as follows:

(1) Modelling and Design of Special Applicators for Wood Modification
-Grigori Torgovnikov and Peter Vinden (23 Pages)
(2) Special Applicators for Wood Modification
-Grigori Torgovnikov, Peter Vinden and Mirza Mekhtiev (15 pages)
(3) Wood Modification in Various Microwave Applicators
-Grigori Torgovnikov, Peter Vinden and Mirza Mekhtiev (23 pages)
(4) Microwave Modified Hardwood Drying
-Grigori Torgovnikov, Peter Vinden and Mirza Mekhtiev (22 pages)
(5) Commercial Plant Design and Economic Analysis.
-Grigori Torgovnikov, Peter Vinden and Mirza Mekhtiev (24 pages)

These confidential reports provide detailed results of the experimental work completed. The final report (Report 5) also provides general conclusions for the whole project. The five reports have been completed on time and have successfully met the objectives of the work. The research is proprietary but is not protected by patent because of the costs involved. However, it appears highly likely that the research will be commercialised in time at which stage it will be desirable to protect the interests of the University of Melbourne and Forest and Wood Products Research and Development Corporation.

Results

1) Four types of microwave applicators (frequency 0.992 GHz) have been designed and tested for modifying wood in preparation for accelerated drying.

A "Long Conic" applicator was found to provide a higher degree of flexibility in relation to the shape of the modified zone. The applicator provides an average MW intensity up to 2.4 kW/cm^2 and allows limited energy dissipation along the timber. It also controls energy concentration in the timber cross section. Three zones of modification can be achieved:

- Single-sided modified zone
- Three separate zones of modification within the cross section
- Full cross-section modification

The best modification of Messmate parquet boards was obtained using a pulsing power of 36-54kW using the following schedules:

Conveyor speed 8mm/sec,
Time-on 0.5-1 sec,
Time-off 2-3 sec.

and

Conveyor speed 14.4 mm/sec,
Time-on 0.75-1 sec,
Time-off 1.5-2sec.

2) Pulsation was evaluated and found to be advantageous.

Pulsation provides a reduction in energy consumption as well as reducing various side effects of MW treatment, such a arcing in the applicator and cracking parallel to annual rings. Samples with an initial moisture content of 70-100% lost 21-38% moisture content during MW treatment. MW energy consumption varied, ranging from 80-190 $kW\text{-}h/m^3$. The minimum MW energy required to provide timber modification is 80 $kW\text{-}h/m^3$. This is equivalent to an electricity consumption of 107 $kW\text{-}h/m^3$.

3.0 After MW processing the board with annual rings parallel to the width of the board (flat-sawn) have longitudinal wide surface checks. Internal voids are very narrow, short and acceptable for parquet boards because their sizes are no bigger than vessel elements found in the macrostructure of hardwoods.
The shortcomings of microwave modification applied to flat-sawn boards arise from the appearance of large checks in the early wood parallel to the rings (ring-shakes). Quarter-sawn boards with annual rings perpendicular to the width of the board have no surface checks but some internal voids are too wide and long in the radial direction. Boards with an annual ring orientation ranging from 20-65° are the best for modification. Wood modification of these boards is characterised by having small internal voids and acceptable surface checks.

4) Experiments directed at board processing using a variety of microwave applicators indicate that the frequency 0.922 GHz is not optimum. Similarly power limitations of the Creswick microwave plants, (54 kW), provides restraints on optimising the pattern of wood modification to obtain stable or a consistent quality of wood modification.

There are two strategies for developing the process:

- The use of higher MW power (as a frequency of 0.922 GHz) to provide shorter impulse time. This will reduce the zone of microwave interaction with wood and the size of the voids in the wood;

- The use of a frequency of 2.45 GHz. This provides 3 times higher energy release in the unit volume of wood. This facilitates a reduction in the size of the microwave-modified zone. This has enormous benefits.

Further research must be continued to develop both strategies and include MW applicator development. The objective is to reduce the zone of microwave modification and intensify the energy within the zone for shorter periods of time.

5) Microwave modified Messmate boards have different shrinkage characteristics compared to unmodified wood.

Modified samples have lower shrinkage and the shape of the cross section changes only to a small degree. Collapse checks are also narrower in modified samples. This result verifies an assumption that microwave modification can reduce collapse the wood and obviate the need for steam conditioning after drying.

6) Intensive microwave conditioning of Messmate sawn timber provides substantial improvements in the permeability of this refractory species.

After MW modification, boards 25-30mm in thickness were dried rapidly in a convection kiln. The drying times were reduces 7-11 times (i.e. 4-6 days versus 42-46 days for unmodified boards). The traditional schedules used in drying appeared to produce the best results in terms of drying speed as well as quality if the product, these schedules need to be further investigated and optimised.

Microwave modification appears to minimise the effects of checking and collapse and allows a more aggressive drying schedule. Quarter–sawn boards were found to produce larger checks than back-sawn boards under similar drying conditions. Drying schedules are defined where most of the boards achieve surface and internal checking quality standards that are acceptable to industry.

7) A 100 kW (frequency 0.922 GHz) MW pilot plant fitted with a “Long Conic” applicator was designed for processing hardwood boards ranging in thickness from 15 to 50mm and width from 80 to 105mm.

The plant can provide microwave treatment outputs of 0.75 m^3/h of timber with wood moisture contents ranging from 50 to 110%. The plant has a wide range of treatment parameters. These include:

- Microwave power
- Board speed
- Board position in the applicator
- Air temperature

The flexibility provided by incorporating these features will facilitate the development of microwave processing schedules for various wood species.

The establishment and testing of this microwave plant will provide a commercial assessment of the advantages of the hardwood timber modification for fast drying and the introduction of new microwave technology in to industry.

8) Economic assessment of microwave timber conditioning prior to drying was evaluated for a plant output ranging from 3,000 to 15,000 m^3/year and for electricity costs ranging from $0.02 to 0.12/kW-h and for two frequencies of MW generators. The microwave treatment costs for fast timber drying varies depending on the plant output and electricity costs ($0.02-0.077/kW-h) in the range:

at a frequency of 2.45 GHz and: 3 shifts per day from \$25.5 to 36.9/m^3,
2 shifts per day from \$32.1 to 45.8/m^3,

at a frequency of 0.922 GHz and: 3 shifts per day from \$18.6 to 32.5/m^3
2 shifts per day from \$23.4 to 39.6/m^3

In most instances the costs of microwave timber treatment are acceptable to industry and provide an attractive option for the fast drying of refractory hardwoods.

Capital costs and electricity costs constitute a high proportion of the total costs of MW timber treatment. At electricity costs of $0.077 kW-h the capital costs form 28-43% and electricity 19-34% of the total costs. The significant capital cost makes it preferable the use microwave equipment for three shifts per day.

Using conventional pre-heating of timber before microwave modification can reduce microwave treatment costs. The steam generated during microwave modification can obviously be re-used to heat boards to MW modification.

General Conclusions

The objectives set out in the research proposal have been achieved. These include the design of four new proprietary applicators. These have met the requirements needed for modifying wood for drying. A commercial plant has been designed. Whilst outside the scope and objectives of the work undertaken for the FWPRDC, Report 5 recommended that this plant should be manufactured to progress future commercialisation of the technology. The plant is now being manufactured in Ballarat and should be completed in May 2003. The recommendation was based on an analysis of the economic costs of microwave modification (detailed in report 5) and potential benefits to the forest industry. Other recommendations include the modelling of applicators for experimental and commercial application. This work is on-going within the CRC Wood Innovations and two of the applicators will be tested semi-commercially.

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