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USING METHANOL AND ETHANOL VAPOURS AS DRYING MEDIA FOR PRODUCING BRIGHT COLOUR WOOD IN DRYING OF RADIATA PINE

S. Pang

Wood Technology Research Centre, Department of Chemical and Process Engineering, University of Canterbury, Christchurch, New Zealand.
Email: shusheng.pang@canterbury.ac.nz

Abstract: In kiln drying of high value grade softwood timber, kiln brown stain (KBS) is a major drying defect and induces significant loss. In this work, research has been conducted to dry radiata pine sapwood in alternative oxygen-free drying medium in order to produce bright coloured wood in kiln drying of softwood timber. In the experiment, samples were dried in a newly designed experiment rig by using methanol or ethanol vapours, respectively, at drying temperatures of 90, 100 and 110°C. For comparison, the matched wood samples were also dried in hot air in a tunnel dryer using the same temperatures. The results showed that no obvious KBS were detected on the surface of sample boards when being dried in either the methanol vapour or the ethanol vapour at all of the temperatures tested. However, for hot air drying, KBS was obviously observed. These results indicate that using an alternative oxygen-free medium to dry wood could be an effective way for preventing surface discolouration.

Keywords: kiln brown stain, radiata pine sapwood, oxygen-free drying medium, bright colour

INTRODUCTION

Discolouration of wood during kiln drying is a well-documented phenomenon and has caused significant economic loss by the wood processing industry. In wood discolouration, kiln brown stain (KBS) is the major concern, which forms 0.5 to 2 mm beneath the drying surface of the wood. Millard reactions have generally been accepted as the main cause of discolouration and staining of the wood. The Millard reaction could involve thousands of individual non-enzymatic reactions of amino acids, peptides and protein with sugars (Tomasik, 1989) and result in formation of phenols, furans, nitrogen heterocyclic compounds which are yellow and brown polymers, known as melanoidins (Theander *et al.*, 1993). In a particular situation, certain reactions occur depending on surrounding conditions (such as temperature) and available chemical composition of the system (water activity, pH and sulphur dioxide) (Cioroi, 1999).

Knowing the causes and factors for the formation of KBS, many studies have been carried out to control it, such as compression-rolling of radiata pine prior to kilning (Kreber and Haslett, 1997), drying with low temperatures and high air velocities or high relative humidities in conjunction with medium kiln temperatures (Kreber *et al.*, 1998). All of these conditions have, to a certain extent, reduced the frequency and intensity of kiln brown stain on the compensation of lengthening the drying time.

However, practical drying technologies are yet to be developed which can both effectively prevent the KBS formation and be commercially feasible, except for low temperature drying (McCurdy and Pang, 2006). Although the exact causes of KBS are still not fully understood, it is believed that the oxidation of extractives and sap components contributes to the Millard reactions and, consequently, to the stain development. Previous studies by Pang and Li (2005) have shown that the modified drying medium can significantly reduce the discolouration. This work is the continuation on investigation of developing alternative drying medium for producing bright coloured wood, and used methanol and ethanol vapours, respectively, as drying medium for drying of radiata pine sapwood. The results are compared with the wood dried using hot-air at commercial schedules.

EXPERIMENTS

Equipment

Experiments were performed in the Department of Chemical and Process Engineering, University of

Canterbury. A system has been designed and constructed for the experiment. It consists of a number of components as shown in Fig.1 in the back of this paper. The process and corresponding parts are described as follows.

Under ordinary conditions, methanol and ethanol are in liquid phase (the boiling point for CH_3OH and CH3-CH_2OH are 337.7K and 351.5K, respectively). The conical flask is used to contain methanol or ethanol liquid for the experiments.

Then a pump pushes a controlled amount of methanol or ethanol liquid from the conical flask into the copper coil, which is merged in an oil bath for heat up. The coil is long enough for the methanol or ethanol to evaporate and its vapour is to be heated to required temperatures. The liquid trap bottle is used to collect the condensed methanol or ethanol liquid after drying the wood sample in a stainless steel cylinder which is also merged in the oil bath.

Drying experiment

In the experiments, matched radiata pine sapwood samples were dried at three temperatures: 90, 100 and 110°C. Before drying test, the oil bath was preheated to a controlled point. Then, the wood sample was weighed and placed in the stainless steel cylinder before the experiment started. During each run, the wood sample was taken out near the estimated drying time to check the moisture content. The drying test was stopped when the final moisture content of wood sample was about 12%.

After the drying tests were completed, the colour of the samples was evaluated using a digital spectrophotometer as described in McCurdy *et al.* (2005). Then the results of alternative gas dried samples were compared with those of air-dried samples.

Sample Preparation

The boards used in the experiments were cut from two green boards which were collected from a local sawmill in Christchurch, New Zealand. The boards were cut from an approximately 25 year-old radiata pine log and the board lengths were 1.5m and 1.8m, respectively. After being collected from the sawmill, the two boards were cut immediately to prepare the samples.

From the 1.5 m long board, 50×40×120mm samples were cut for the drying tests and, from each end of these samples, 50×40×20mm sections were prepared for green moisture content and wood density measurements. All of the samples were flatsawn with the growth ring parallel to the flat surface (50 mm wide surface).

After cutting, all of the samples used for the drying tests were painted on the ends and sides with Devshield 216 thus drying occurred only on the flat surfaces in the tests. After sealing, the samples for drying were placed in a fridge at 5°C until required

Drying in a tunnel dryer using hot air

Matched samples were also dried in a tunnel dryer which was controlled by a PC running Advantech® Genie™ data acquisition and control software. This package controlled drying temperature and humidity of the air as well as the air velocity. It recorded data from the mass balance, temperature and humidity readings. Three drying schedules were used for the tunnel drying tests which were the same as commercial drying: (dry-bulb/wet-bulb temperature) 90/60°C, 100/70°C and 110/70°C.

Sample slicing and colour measurement

After drying, a 25×25×50 mm block in each sample was cut from mid-length and mid-width position. The block covered the full thickness thus the 25×25 mm surfaces were part of the board flat surfaces. After this, the block was sliced from the drying surface at approximately 1mm thickness using a specially designed machine. The first ten slices, counted from the exposed board surface, were recorded and kept in a plastic bag. Finally, the colour of the ten slices of each block was measured using a Minolta 2500d handheld reflectance spectrophotometer. The colour data were represented using the CIELAB L*a*b* colour space and stored in the computer for further analysis. In this paper, only brightness (L*) is discussed.

RESULTS AND DISCUSSION

Table 1, in the back of this paper, shows the average lightness values (L*) for all the samples used in the experiments. The average lightness was the mean value averaged over all of the ten slices, core lightness is the mean value for slices 4-10 and surface lightness was the mean value for slices 1-3. Surface darkening was the percentage difference between the surface and the core.

From Table 1, it is found that the average brightness of the boards dried in the vapours of methanol and ethanol had higher values of lightness thus the wood was brighter on average. Theses values are in the similar scale as those of the boards dried at temperatures lower than 60°C using air (McCurdy *et al.* 2003; Pang and Li, 2005). The average brightness for drying with methanol vapour was 78.1 to 79.1 at drying temperatures tested. The corresponding brightness values for drying with ethanol vapour were 79.2 to 80.8. However, the air drying wood was consistently darker than the above wood with brightness values ranging from 76.6 to 77.1.

In terms of surface darkening, both of the alternative drying media gave brighter surface than the air dried wood with an exception of air drying at 100°C where the surface was brighter than the core. Further check of this sample revealed that the wood did not have a good flat sawing pattern thus the water flow in this sample could affect the kiln brown stain formation.

The brightness of the wood dried in both of the methanol and the ethanol vapours were similar as low temperature air dried boards as reported by McCurdy *et al*. (2003) and Pang and Li (2005). Because the main reason of surface darkening is the formation of KBS, the severer darkening on the wood surface indicates the worse kiln brown stain developed. Selected results on colour profile and colour comparison are shown in Figs.2-4 for the sample boards dried in the three drying media (methanol vapour, ethanol vapour and air) at various temperatures (90, 100 and 110°C).

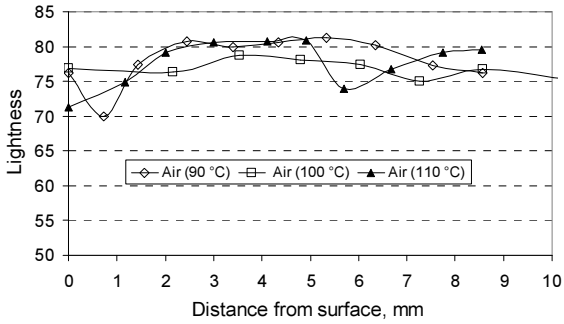

Fig.2. Colour profiles for air dried sample.

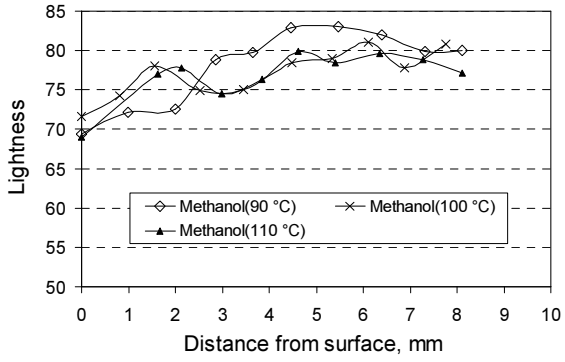

Fig.3. Colour profiles for methanol vapour dried sample.

KBS is a chocolate brown discolouration that develops approximately 0.5 to 2 mm under the board surface during kiln drying, thus lightness profile from surface towards the core can be used as the best indicator for the formation of KBS. From Fig.2, it was observed that with conventional hot air drying the KBS was clearly observed at about one millimetre beneath the surface for drying temperature of 90°C. Higher temperatures were expected to be worse although the colour curves did not show this trend for the samples tested. For air drying the KBS could only be reduced with low temperature drying at 50°C (McCurdy *et al.* 2003; Pang and Li, 2005). However, by using the oxygen-free gases (methanol and methanol vapours), the KBS were almost eliminated and this is confirmed by the lack of dark colour beneath the drying surface. The general darkening right at the surface is believed to be the wood yellowing due to exposure to the atmosphere and light during preparation of the samples.

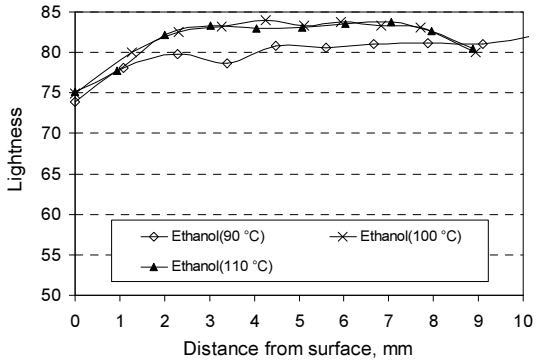

Fig.4. Colour profiles for ethanol vapour dried sample.

The most significant observation from this work is that by using both of the methanol and the ethanol vapours, the drying temperature did not affect the wood colour changes either in terms of average brightness or in terms of surface darkening. This is very relevant as commercial drying needs to consider the drying quality and drying time to achieve maximum economic benefits.

CONCLUSION

Research has been conducted to dry radiata pine sapwood in alternative oxygen-free drying media, respectively, in vapours of methanol and ethanol at three drying temperatures of 90, 100 and 110°C. Matched samples were also dried in a tunnel dryer using these three drying temperature schedules for simulating commercial hot air drying. The results show that conventional air drying induced apparent kiln brown stain (KBS) and only low temperature drying could reduce it. However, for the two oxygen-free vapours tested, KBS were effectively eliminated at all of the three drying temperatures tested. The colour at the wood surface for all of the boards was darker than the core which is believed to be the wood yellowing during the sample preparation. These results indicate that using a modified medium to dry the wood could be an effective way for preventing surface discolouration. With particular interests to industry is that by using the methanol and ethanol vapours, high temperature drying can be used, thus the wood could be dried at a fast drying rate. Further

study is currently being undertaken to validate the findings of this study and to investigate the economic feasibility by taking into account the costs of the oxygen-free gases.

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Table 1. Drying temperatures and wood colour changes

Drying Medium	Temperatures (°C)	Final MC (%)	Average Lightness (L*)	Core lightness (L*)	Surface Lightness (L*)	Surface Colour Change
Methanol Vapour	90	10.9	79.1	80.8	75.2	7.0
	100	8.1	78.1	78.8	76.6	2.9
	110	7.2	78.4	79.3	76.4	3.6
Ethanol Vapour	90	14.4	79.2	81.2	76.5	5.7
	100	9.0	80.8	81.6	78.8	3.4
	110	11.6	80.8	82.1	77.6	5.6
Air	90/60[a]	12.3	76.6	77.7	74.1	4.6
	100/65[a]	12.4	76.6	76.1	77.2	-1.4
	110/70[a]	10.1	77.1	78.5	73.8	5.9

a: dry-bulb/wet-bulb temperatures

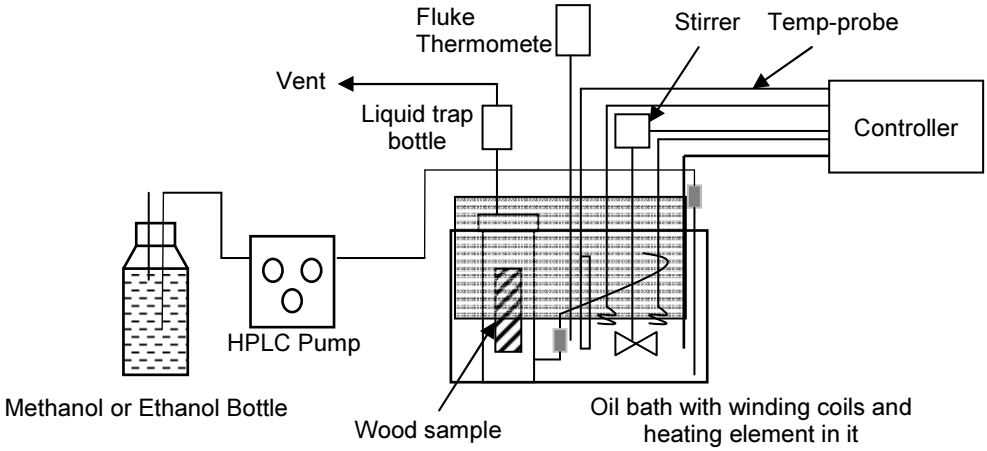

Figure 1: Methanol and Ethanol drying experiment setup.