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VARIATIONS IN HARDNESS AND SCREW WITHDRAWAL RESISTANCE OF HEAT-TREATED MEDIUM DENSITY FIBERBOARDS

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ABSTRACT

A series of MDF panels were exposed to a post-manufacture heat-treatment at various temperatures and durations using a hot press and just enough pressure to ensure firm contact between the panel and the press platens. Screw withdrawal resistance (SWR) and Janka hardness (JH) of the MDF panels were significantly decreasing with increasing post-treatment press temperature. The panels treated at 225 °C for 30 min had the lowest SWR and JH values among the treatment groups, while the highest performance was found for the panels treated at 175 °C for 15 min. The highest JH value was of 672.3 kg for the control and the lowest was of 561.3 kg for the panels treated 225 °C for 30 min. The lowest SWR value with 158.4 kg was found for 225 °C at 30 min, while the control group had the highest SWR value with 196.1 kg. Although JH and SWR values of the treated MDF panels decreased with increasing post-treatment temperature, the values met minimum SWR and JH requirements specified in ANSI-A208 Standard.

KEY WORDS: Janka hardness, mechanical properties, medium density fiberboard, screw withdrawal resistance, heat-treatment, wood

INTRODUCTION

Heat-treatment of wood has been known for long as an effective method to modify the properties of wood (Hillis 1984). Heat-treated wood has longer service life than the untreated one because it has both higher resistance against fungi and better weathering behaviour (Okino et al. 2007). Heat-treatment also improves swelling and expansion properties of the wood based panels, resulted from moisture absorption. It is very well known that heat-treatment has a harmful effect on mechanical properties of wood although it improves dimensional stability and biological resistance of wood (Korkut et al. 2008, Brischke et al. 2005, Poncsak et al. 2006, Unsal and Ayrilmis 2005).

Specifically for wood-based panels, such as particleboard and oriented strand board, there are several methods of treatment or strategies to improve dimensional stability that can be divided according to three different modes of application: pre-treatment, post-treatment and production technology (Del Menezzi and Tomaselli 2006). In the second group are the methods applied to the consolidated panel and direct heat-treatment is the most usual. According to this method, wood based panels treated under mild conditions using a hot-press, where the pressure is applied just to provide contact between press platens and surfaces of the board (Hsu et al. 1989). Recently, Del Menezzi and Tomaselli (2006) employed this treatment in a single layered OSB and reported a very promising method to improve dimensional stability of OSB panel. The main difference from the well known heat-treatment processes is in using lower temperature, but fast heating by conduction, and shorter time.

Many experiments have shown that high drying temperature reduces the hardness and screw withdrawal resistance of solid wood (Korkut et al. 2008, Brischke et al. 2005, Poncsak et al. 2006). These properties are not usually determined for post heat-treated wood based panels. The lack of that information is especially evident for dry-process MDF which is post heat-treated. An extensive literature search did not reveal any information about the effects of post heat-reatment on surface hardness and screw withdrawal resistance properties of dry-process MDF made using phenol-formaldehyde (PF) resin. The objective of this research was to investigate the effects of the post heat-treatment on the SWR and surface hardness properties of the manufactured MDF panels.

MATERIAL AND METHODS

The MDF material used in this study was a commercially manufactured, 16-mm thick, PF-bonded, exterior, dry-process MDF panel used in the exterior siding and trim market. These MDF panels had been bonded with a PF resin and shipped without the coatings or primers typically applied for typical exterior applications. Panels bonded with PF resin were chosen for this study because PF resin is a more heat-resistant, exterior-type resin. It is commercially used in the fiberboard industry, but not as much as urea-formaldehyde (UF) resin. PF-bonded MDF panels were choosen for this study instead of UF-bonded MDF panels because UF resin might have been degraded when exposed to the prolonged high temperature conditions of our post heat-treatment. Thirty 120 cm x 240 cm commercial MDF panels were then cut into smaller test panels (100 cm x 100 cm). The sixty 100 cm x 100 cm test panels were then randomly assigned to four experimental groups (an untreated control and three levels of heat-treatment).

The MDF panels were loaded into a heated press using a computer controlled single-opening hot press and heat-treated at either 175 °C for 15 min, 200 °C for 30 min or 225 °C for 30 min. This press system includes specially designed temperature-pressure probes for measuring internal panel temperature and gas pressure during pressing. A platen contact pressure of 150 (kPa) was applied to provide light but uniform contact between press platens and the panels' surfaces. To demonstrate that the process did not constitute a fire hazard, several 16 mm thick panels were prepared and heated for 30 min at 225 °C in a preliminary study without problems. After heat-treatment, all panels were cooled prior to stacking to further minimize fire hazards. The average density values of heat-treated and control panels varied from 780 to 810 $kg.m^{-3}$. The treated samples at all temperature levels showed no differences in density when compared to the control samples.

Prior to the tests, each sample was conditioned in a climate chamber at 20±2 °C and 65 (±5 %) relative humidity. For screw withdrawal resistance (SWR) perpendicular to the plane of the board (face SWR), ten samples with dimensions of 50 mm x 50 mm x 16 mm for each of the experimental groups were tested according to BS EN 320 (1993). The force required to withdraw each screw was recorded in kg.

The modified Janka ball, 11.28 mm in diameter with a 100 mm^2 projected area, was used to determine surface hardness of samples with dimensions of 75 mm x 150 mm according to ASTM D 1037 (1999). Face hardness is defined as the load at which the ball has penetrated to half its diameter. The load was continuously applied to the samples throughout the test at a rate of 6 mm/min. The maximum load required to embed the ball to one half its diameter was recorded the measure of hardness. To achieve the minimum thickness for the JH test, two pieces had to be glued so as to produce one sample. Ten samples from each of the experimental groups were used for Janka hardness tests.

For Janka hardness and screw withdrawal resistance, all multiple comparisons were first subjected to an analysis of variance (ANOVA) at $p<0.01$ and significant differences between mean values of the untreated and treated MDF test samples were determined using Duncan's multiple range test.

RESULTS AND DISCUSSION

Surface JH values of the MDF panels were decreasing with increasing post-treatment temperature. All treatment groups were significantly different from each other and control group. Significant differences between treatment groups were determined individually by Duncan's multiple-comparison tests (Tab. 1). The highest JH value was of 672.3 kg for the control and the lowest was of 561.3 kg for the panels treated 225 °C for 30 min. The average JH value of the panels treated at 225 °C for 30 min (16.5 % lower than control) was followed by the panels treated at 200 °C for 30 min (11.4 % lower) and 175 °C for 15 min (5.2 % lower).

Tab. 1: Variations in average Janka hardness (JH) and screw withdrawal resistance (SWR) of the samples, resulted from heat-treatment

Panel type	Thermal-treatment level (temperature/ time)	Panel density ($kg.m^{-3}$)	JH (kg)	SWR (kg)
A	Control	810 (0.02) A[a]	672.3 (28.3)[b] A	196.1 (7.5) A
B	175°C-15 min	780 (0.01) A	637.5 (52.1) B	181.4 (6.1) B
C	200°C-30 min	800 (0.02) A	595.5 (18.9) C	168.8 (12.3) C
D	225°C-30 min	790 (0.02) A	561.3 (33.3) D	158.4 (7.5) D

[a] Groups with same letters in column indicate that there is no statistical difference ($p< 0.01$) between the samples according to the Duncan's multiply range test.

[b] Values in parentheses are standard deviations.

A similar trend to the JH values was observed for the SWR samples. All treatment groups were significantly different from each other and control group. The average SWR values were directly related to heat-treatment temperature. The lowest SWR value with 158.4 kg was found for 225 °C at 30 min while the control group had the highest SWR value with 196.1 kg. The average SWR value of the panels treated at 225 °C for 30 min was 19.2 % lower than control samples, followed by the panels treated at 200 °C for 30 min (13.9 % lower) and 175 °C for 15 min (7.5 % lower). All control and heat-treated MDF samples met minimum face SWR (144.5 kg for nominal panel thickness ≤ 21 mm) requirement for grade 150 MDF specified in ANSI-A208.2 (2002). These results were in agreement with a study performed by Okino et al. (2007) on post heat-treated OSB panels. In the same study, it was reported that contact post heat- treatment had a significant negative effect on SWR of the panels and found that SWR value of the treated panels decreased from 188.8 kg from to 154.4 kg after heat-treatment at 190 °C for 12 min. Although surface SWR values (158.4-181.4 kg) of the heat-treated MDF panels were lower than control panels, their values were higher than those (96-109 kg) of general purpose MDF panels (Ayrilmis 2000).

Surface JH values of untreated general purpose MDF panels made using UF resin and having a density of 760 $kg.m^{-3}$ range from 520 to 570 kg (Ayrilmis 2000). Tab. 1 shows the variations in the average JH and SWR of the samples, resulted from heat-treatment. Although JH of the MDF panels made using PF resin was adversely affected by post heat-treatment, they were higher than those of the general purpose MDF panels made using UF resin. This was an expected result because density values (780–800 $kg.m^{-3}$) of the MDF panels used in this study were higher than those of the commercial MDF panels (common density: 700–760 $kg.m^{-3}$) (Ayrilmis 2000). Particleboard (density: 640 and 840 $kg.m^{-3}$) Standard, ANSI A208.1 (1999), was used here for comparison of JH property since there was no established minimum property for MDF in ANSI A208.2 (2002) Standard. All treated MDF panels met the minimum requirement of the JH value (222.5 kg) for commercial particleboard M-3 and underlayment grades specified in ANSI A208.1 particleboard standard. In general, previous studies reproted that reduction in SWR and JH in wood was the result of elevated temperatures for an extended time (Korkut et al. 2008, Brischke and Rapp 2005, Poncsak et al. 2006). These changes are generally attributed to the thermal degradation of the wood substance, especially the degradation of hemicelluloses which are less stable to heat than cellulose and lignin (Yildiz et al. 2006). The loss in mechanical properties could be related to formation of soluble acidic chemicals; such as formic acid and acetic acid, from the hemicellulose degradation (Sundqvist et al. 2006). These acids accelerate depolymerization of the carbohydrates by breaking down the long-chain carbohydrates to shorter chains. Depolymerization and shortening of the cellulose polymer could affect MOE and MOR of wood.

CONCLUSIONS

The following conclusions have been drawn from the results of the present work:

1. Compared to untreated MDF panels, significant reductions in SWR (7.5 % to 19.2 %) and JH (5.2 % to 16.5 %) properties were obtained for all of the post heat-treated MDF panels.
2. Although surface JH and SWR values of the commercial MDF panels decreased with increasing post-treatment temperature, these values met minimum face SWR and JH requirements specified in ANSI-A208.
3. Post heat-treated MDF panels made using PF resin can be used as laminate flooring, bathroom furniture, kitchen cabinets, and benchtops for high indoor humidity applications.

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