EFFECT OF NANO-SILVER ON REDUCTION OF HOT-PRESSING TIME AND IMPROVEMENT IN PHYSICAL AND MECHANICAL PROPERTIES OF PARTICLEBOARD

Hamid Reza Taghiyari,[a,]* Hossein Rangavar,[a] and Omid Farajpour Bibalan [a]

Effects were studied of 200 ppm nano-silver suspension on physical and mechanical properties of particleboard made on an industrial scale at the Iran-Choob Factory. Nano-silver suspension was added to the mat at two levels of 100 and 150 milli-liters/kg dry weight wood particles and compared with control boards; all the other manufacturing variables remained constant. Results showed that hot-pressing time was reduced by 10.9% and 10.1% when 100 and 150 mL of nano-silver were used, respectively. Also, both levels of nano-silver consumption had improving effects on physical and mechanical properties, although in some cases not statistically significant. It can be concluded that heat-transfer property of nano-silver particles in the mat can be used to reduce the hot-press time as the bottle-neck of nearly all wood-composite factories, as well as to reduce the heat gradient and consequently to improve physical and mechanical properties of composite-boards.

Keywords: Composite Board; Heat Transfer Property; Nano-Silver; Particleboard; Physical and Mechanical Properties.

*Contact information: a: Wood Science and Technology Department, Faculty of Civil Engineering, Shahid Rajaee Teacher Training University; * Corresponding author: Hamid Reza Taghiyari; htaghiyari@srttu.edu & htaghiyari@yahoo.com ; Cellphone: (+ 98) 912-2000235; Fax: (+ 98-21) 22970021.*

INTRODUCTION

Hot-presses are usually considered to be a bottle-neck for nearly all wood-composite manufacturing factories (Doosthoseini 2001). Minimum pressing time of a particleboard primarily depends on heat transfer, which in turn varies with thickness, press temperature, closing rate, and mat moisture distribution. When high internal steam pressures are involved, the presstimes necessary to prevent damage resulting from the release of gases depend on such factors as resin type, density, press temperature, and total MC (Lehmann *et al.* 1973). Based on non-heat-conductivity nature of wood, several methods have so far been created to shorten presstime, saving time and energy. Still, except where controlled by high internal pressures or excessive moisture contents, the time required to maintain centerline temperatures varies only slightly. Also, final pressure, although a good indicator of minimum presstime within a board type, varies considerably (Lehmann et al. 1973). However, in the case of urea-formaldehyde (UF) resin, there is a limitation of MC level (Papadopoulos 2006).

The heat-conductive nature of nano-metal particles (Taghiyari 2011; Taghiyari et al. 2012; Taghiyari 2012) might be used to better transfer the heat from platens to the core of the mat. Nanoclay is reported to improve physical and mechanical properties of particleboards with UF resin (Moosavi Hosseini 2009). The thermal conductivity of nanofluids containing dispersed metallic nanoparticles has been studied in a research project (Warrier and Teja 2011); the results provided strong evidence that the decrease in the thermal conductivity of the solid with particle size must be considered when developing models for the conductivity of nanofluids.

Enhancement in the thermal conductivity of common heat transfer fluids when small amounts of metallic and other nanoparticles were dispersed in these fluids has been reported by many researchers (Choi et al. 2001; Eastman et al. 2001; Kang et al. 2006; Patel et al. 2003; Li and Xuan 2006; Yu et al. 2010; Jana et al. 2007; Li et al. 2008). The effect of silver nano-particle in heat conductivity in particleboards has not yet been studied. The present study was therefore conducted to evaluate if nano-silver particles may contribute to the heat transfer and decrease presstime while maintaining, or even increasing, physical and mechanical properties of particleboard. In order to assess the possibility of using this process on an industrial scale, nano-silver-boards were manufactured at industrial dimensions at the Iran-Choob factory using the same machines and equipment as for commercial particleboards.

EXPERIMENTAL

Particleboards were made at the Iran-Choob factory, Ghazvin, Iran. Boards were 16 mm in thickness and 0.7 g/cm^3 in density. Chips were comprised of poplar spp. The temperature of hot-press plates was fixed at 200 °C. The specific pressure of plates was 25 kg/cm^2, and the total nominal pressure of the plates was 200 kgf. The press machine was equipped with electronic sensors measuring evaporation of gases and the pressure to determine press time. Dimensions of the boards produced on an industrial scale were 530 × 130 × 1.6 cm. Urea-Formaldehyde (13%), plus 1% ammonium chloride (NH_4Cl) as hardener, was used as the resin.

A 200 ppm nano-silver suspension was produced using an electrochemical technique in cooperation with Jafr Sorkhe Fajr Co. (Ltd.). This was added to the resin before mixing the resin with wood particles. The pH and viscosity of the resin were kept constant for all treatments in the present study. Nano-silver was used at two levels of 100 and 150 mL/kg wood particle, based on the dry wood basis; therefore, there were three treatments of: 1- control, 2- 100 mL of NS/kg, and 3- 150 mL of NS/kg. Four boards were manufactured for each treatment. Boards were kept at the warehouse for two weeks before the mechanical and physical tests were done.

Physical and mechanical tests, as well as number and location of the specimens, were done in accordance with the ISIRI 9044 PB Type P2 (compatible with ASTM D1037-99) specifications. A schematic chart of sampling location of physical and mechanical specimens for each manufactured particleboard is illustrated in Fig. 1 (ISIRI 9044 PB Type P2).

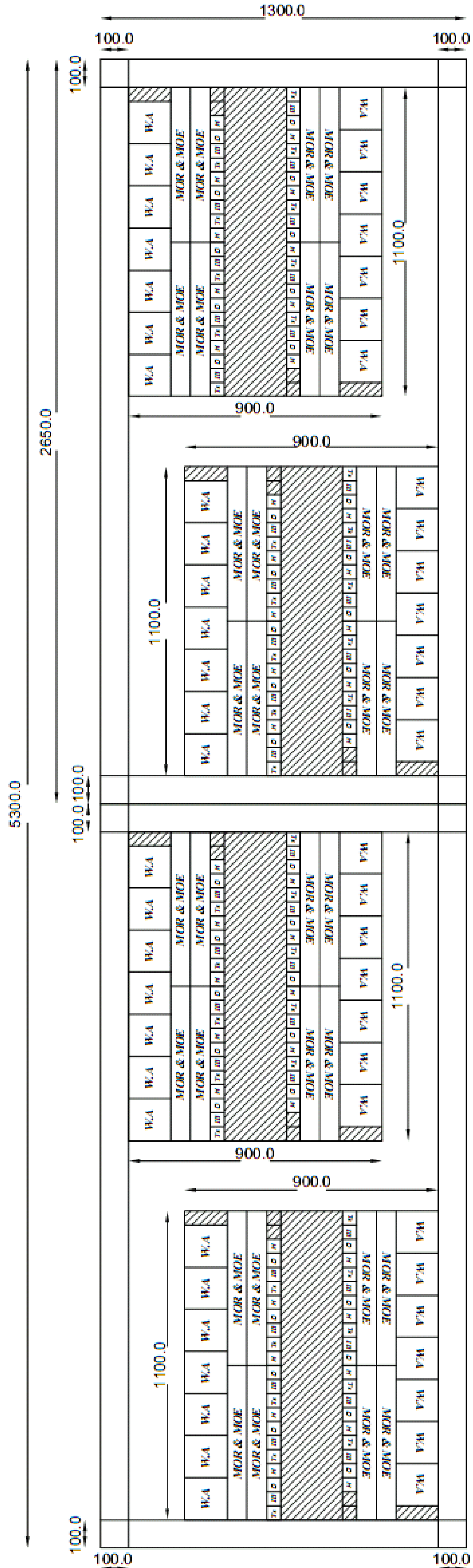

Fig. 1. Schematic chart of sampling location of physical and mechanical specimens for each manufactured particleboard

Three-point bending test

Three-point static flexural tests were performed to measure modulus of rupture (MOR) and modulus of elasticity (MOE). Nominal sizes of the specimens were 380 × 70 × 1.6 mm, with loading speed of 5 mm/min. 20 samples of the same location for each treatment were tested using an INSTRON 4486 test machine, with 5 KN capacity.

Physical properties

Thickness swelling and water absorption (2 and 24 hours) were measured (Equations 1 and 2). Nominal dimension of specimens was 20 × 10 × 1.6 cm with 20 replications for each treatment. Specimens were weighed to a precision of 0.01 g with a digital scale. Thickness swelling was monitored at 5 points of each single specimen with a 0.01 mm precision digital caliper; the 5 points included one in the center of the specimen, and four other points at every corner; the average of 5 points is reported.

$$Thickness\ Swelling = \frac{T_X - T_0}{T_0} \times 100 \tag{1}$$

In Eq. 2 the quantities T_x and T_0 are thickness (mm) at time x and the initial thickness (mm), respectively. Likewise, the percent water absorption was calculated from,

$$Water\ Absorption = \frac{M_X - M_0}{M_0} \times 100 \tag{2}$$

where M_x and M_0 are weight (g) at time x and dry weight (g), respectively.

For measuring wood chips slenderness (length/Thickness ratio) 100 g particles was taken at random and with the precision of 0.01mm the slenderness was determined. Specifications of the chips are summarized in Table 1.

Table 1. Specifications of the Chips Used in this Study

Specifications of the chips	Mean Value
Length of the chips (mm)	9.71
Thickness of the chips (mm)	1.26
Slenderness Ratio	7.72

Statistical Analysis

Statistical analysis was conducted using SPSS software program, version 15. One-way ANOVA was performed to discern significant difference at the 95% level of confidence level. Grouping was then made between treatments using the Duncan test.

RESULTS AND DISCUSSION

Hot-Press Time Reduction

Results showed that 100 mL of nano-silver/kg wood particles caused presstime to decrease from 202.5 to 180.5 seconds (10.9%) (Fig. 2). A treatment level of 150 mL/kg, though, made the time decrease by 19.5 seconds (10.1%). Heat-conductivity property of nano-silver particles increased heat transferred from hot press plates to the inner central parts of the mat, making polymerization of the resin take place sooner. Hot-press time-reduction not only speeds up production of particle boards, as to the fact that hot press is considered the bottle-neck of nearly all composite-board manufacturing factories, but also saves time and energy, increasing the benefits to the company.

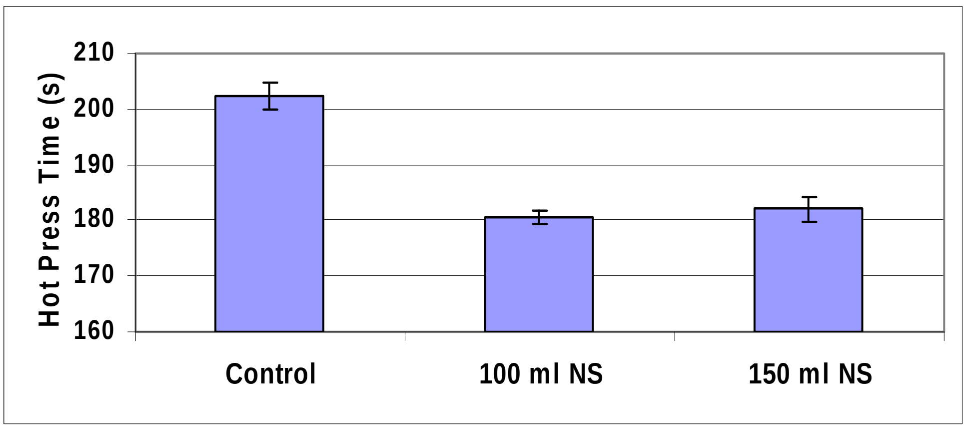

Fig. 2. Hot press time (second) in control sample boards, 100 mL nano-silver, as well as 150 mL nano-silver/kg dry weight particles.

Modulus of Rupture (MOR)

Nano-silver increased MOR by more than 7.5% (Table 2). 150 mL/kg nano-silver showed the highest increase in MOR, although not significantly different from 100 mL/kg. It seems that heat was better transferred from hot-press plates making resin-polymerization process take place more efficiently in the inner central parts of the mat. In the present study, resin and hardener contents were not changed in the control samples or nano-silver boards; still different resin and hardener contents should be studied in further research to determine the ultimate amount of resin and hardener in surface and middle layers of the mat.

Modulus of Elasticity (MOE)

150 mL/kg nano-silver showed a significant increasing effect on MOE (Table 2). 100 mL/kg, although higher in value than that of control samples, didn't show significant increase.

Table 2. Mechanical and Physical Properties of Control, 100 mL/kg, and 150 mL/kg Nano-silver Particle Boards

Physical or Mechanical Property	Control Samples	100 mL/kg nano-silver	150 mL/kg nano-silver
Modulus of Rupture (kg/cm^2)	190.3 (B)*	204.3 (A)	205.2 (A)
Modulus of Elasticity (kg/cm^2)	23974.9 (B)	24047.6 (B)	27127.7 (A)
Internal Bond (kg/cm^2)	11.39 (B)	12.29 (A)	11.90 (AB)
Water Absorption (2 h) (%)	38.94 (A)	38.82 (A)	37.78 (AB)
Water Absorption (24 h) (%)	62.94 (A)	61.97 (AB)	61.89 (AB)
Thickness Swelling (2 h) (%)	16.32 (A)	15.91 (AB)	15.85 (B)
Thickness Swelling (24 h) (%)	27.80 (A)	27.74 (A)	27.67 (A)

* Duncan grouping at 95% significant level.

Internal Bond (IB)

Nano-silver had an increasing effect on IB for both nano-silver consumption levels, although not so significant to estimate a clear trend between the two levels of nano-silver consumptions. The greatest IB value was found at the 100 mL/kg nano-silver consumption level. This clearly shows better polymerization of resin in the core layer of the mat. Different hardener contents in the middle layer should be studied to be in a position to conclude the reason of less IB value in 150 mL/kg nano-silver content level in comparison to 100 mL/kg. A lower IB value for 150 mL/kg in comparison to 100 mL/kg NS consumption level might indicate that 100 mL/kg was the optimum NS-level and that a higher level might result in breakdown of resin bonds as to the excessive heat transferred to the core of the mat. Still, further studies are needed to finalize a reliable conclusion in this regard.

Water Absorption (WA) and Thickness Swelling (TS)

Although not significantly much different, both nano-silver consumption levels showed decreasing effects on WA and improving effects on TS (Table 2). These two physical properties clearly showed that better bonds took place in the surface as well as middle layers of the boards due to the better transfer of heat from platens to the surface and core layers of the mat. Both 24-hour WA and TS tests, during which there was enough time for water to penetrate particleboard specimens, showed that there was not much difference between the three treatments. However, 2-hour WA and TS showed that 150 mL/kg specimens were clearly grouped separately. This may indicate that better bonds were formed in the core of the mat, preventing water from penetrating the specimens.

Cluster analysis, carried out based on all the mechanical and physical properties as well as the press time, showed that 100 mL and 150 mL treatments were clustered closely together, whereas the control treatment was clustered quite separately (Fig. 3). This shows the overall similarity of the two treatments in which nano-silver suspension was used.

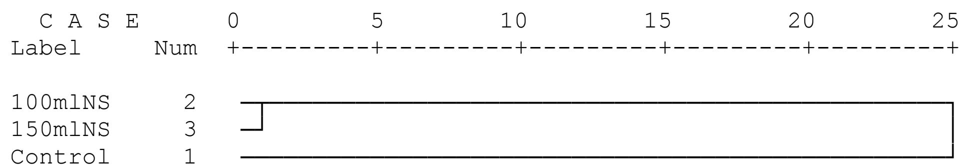

Fig. 3. Cluster analysis based on all the mechanical and physical properties as well as the press time

Other nano-metal particles with different consumption levels per wood particles or wood fibers, as well as their effects on other aspects of composite boards, require further studies to come to a final conclusion on the possible use of nano-metal particles on an economical scale.

CONCLUSIONS

1. The low heat-conductivity coefficient of wood makes transfer of heat from hot press plates to the inner parts of a particleboard mat a problem to be solved in the composite-manufacturing industry. Nano-silver particles seem to solve this problem to some extent.

2. Nano-silver particles decreased hot press time, which is usually a bottle-neck at most composite manufacturing factories, saving time and energy.

3. Nano-silver particles showed improving effects on physical and mechanical properties of the particleboards produced.

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