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Effect of Nanosilver on the Rate of Heat Transfer to the Core of the Medium Density Fiberboard Mat

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ABSTRACT

Effect of nanosilver (NS) on the heat-transferring rate to the core section of medium density fiberboard (MDF) mat was studied here. A 400 ppm aqueous nanosilver suspension was used at three consumption levels of 100, 150, and 200 mL/kg, based on the weight of dry wood fibers; the results were then compared with the control MDF panels. The size range of nanosilver was 30-80 nm. Results showed that the uniform and even dispersion of nanoparticles throughout the MDFmatrix significantly contributed to the faster transfer of heat to the core section. As to the loss of mat water content after the first 3-4 minutes under the hot press, the core temperature slightly decreased in the control panels. However, heat transferring property of nanosilver contributed to keeping the core temperature rather constant in the nanosilver-150 and 200 treatments. The surface layers of the mat rapidly absorbed the heat, resulting in the depolymerization of part of the resin. It can therefore be concluded that the optimum nano suspension content should not necessarily be the highest one.

Keyword: Composite board; Heat transferring property; Metal nanoparticles; Nanosilver; Thermal conductivity coefficient; Wood fiber.

1. INTRODUCTION

Shortage of wood resources and natural regeneration of forests necessitates the use of fast growing trees as well as harvesting them at short rotations [1]. The harvested wood of these trees usually are not suitable for furniture industry; however, they provide a sustainable source for paper and composite manufacturing industries. Wood composite panels offer the advantage of a homogeneous structure which may be important for many design purposes [2]. Due to the low thermal conductivity coefficient of wood [3], many studies have so far been carried out to increase the rate of heat transfer

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to the core of the wood composite mat. Hot press time is dependant on the thickness of the composite mat, press temperature, closing rate, and most importantly, moisture distribution throughout the mat [4]. Moisture of the mat can not always be increased as it in turn increases the hot press time, or causes blows in wood composite panels. Furthermore, for urea-formaldehyde (UF) resin, there is a limitation of moisture content (MC) level [5]. Finding new ways to increase the heat transferring rate to the core section of the composite mat is always a challenge before the wood composite manufacturing industry.

Heat transferring property of metal nanoparticles [6-8] was reported to improve some properties in solid woods as well as wood composite materials. However, little or no direct measurements at the core section of the mat was carried out to practically investigate if the temperature was really increased, or the improvement in physical and mechanical properties was merely due to the formation of bonds between wood fibers or particles and the nano materials used in the composite matrix. Therefore, the present study was therefore carried out to directly measure the temperature at the core section of the composite mat and find out the probable increasing trend.

2. MATERIALS AND METHODS

2.1. Specimen procurement

Wood fibers were procured from Sanaye Choobe Khazar Company in Iran (MDF Caspian Khazar). The fibers comprised a mixture of five species of beech, alder, maple, hornbeam, and poplar from forests of Gillan province. Boards were 16 mm in thickness and 0.68 g/cm^3 in density. A laboratory hot press produced by Mehrabadi Machinery Mfg. Co. was used; the size of the hot plates was 50×50 cm. The total nominal pressure of the hot plates was 160 bars. The total nominal pressure of the plates was 160 bars. The temperature of the plates was fixed at 150°C. Hot pressing continued for 10 minutes. Urea Formaldehyde resin (UF), as a popular thermosetting resin in composite manufacturing factories of Iran, was procured from Pars Chemical Industries Company, Iran. 10% of UF with 200-400 cP in viscosity, 47 seconds of gel time, and 1.277 g/cm^3 in density was used in the composite based on the dry weight of wood fibers. Specimens were kept in conditioning chamber (30±2°C, and 45±2% relative humidity) for three weeks before the tests were carried out on them. The moisture content of the specimens at the time of testing was 7%. Five boards were made for each treatment group.

2.2. Nanosilver application

A 400 ppm aqueous suspension of silver nanoparticles nanosilver (NS) was produced and applied to the specimens using electrochemical technique. The nano suspension was prepared by transferring the silver metal ion from the aqueous phase to the organic phase, where it reacted with a monomer. The formation and size of the nanosilver was monitored by transmission electron microscopy (TEM). Samples for TEM were prepared by drop coating the Ag nanoparticle suspensions on to carbon coated copper grids. Micrographs were obtained using an EM-900 ZEISS transmission electron microscope. The size range of nanosilver was 30-80 nm. The pH of the suspension was 6-7; two kinds of surfactants (anionic and cationic) were used in the suspension as stabilizer; the concentration of the surfactants was two times the nanosilver particles. The nano suspension was applied at three consumption levels, including nanosilver 100 (NS-100; 100 mL/kg), nanosilver 150 (NS-150; 150 mL/kg), and nanosilver 200 (NS-200; 200 mL/kg). After impregnating the wood specimens with the silver nano suspension, SEM micrographs showed uniform dispersion of nanoparticles on wood fibers (Figure 1).

2.3. Temperature measurement at the core section of the mat

A digital thermometer with temperature sensor probe was used to measure the temperature at the core section of the mat at 5 second intervals (Figure 2). The probe of the thermometer was directly inserted for about 50 mm into the core of

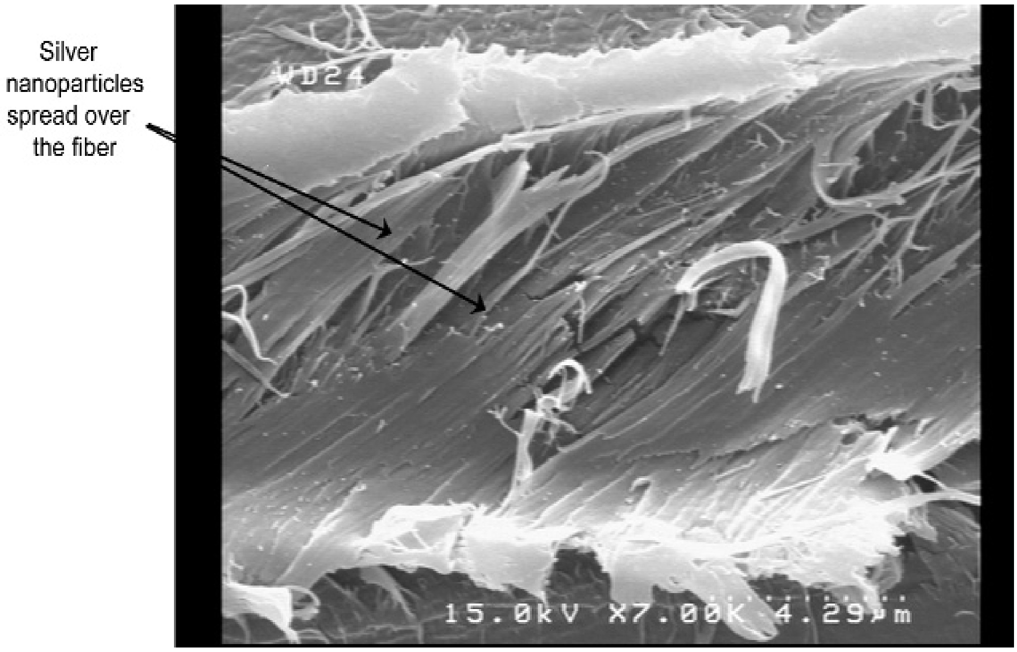

Figure 1: *SEM micrograph showing nanosilver scattered all over the fibers.*

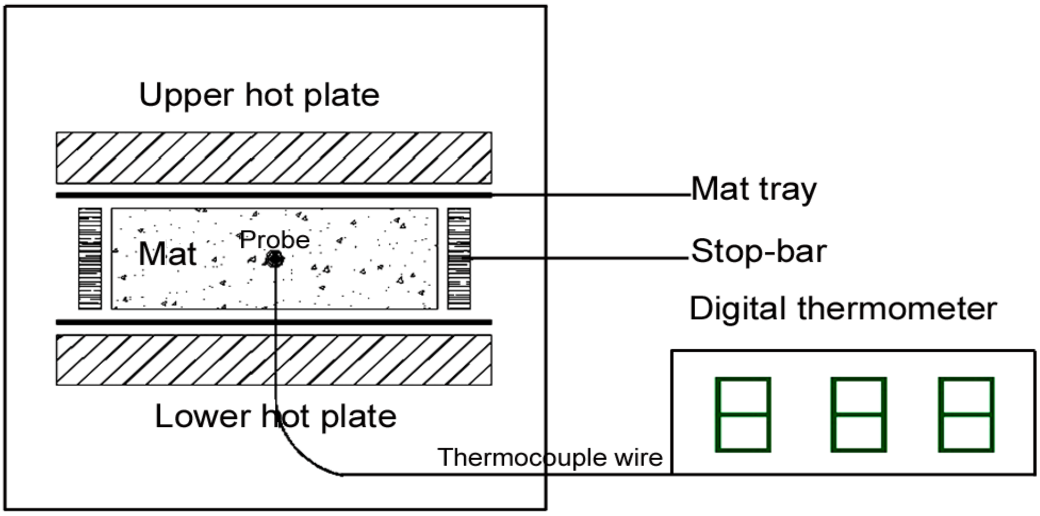

Figure 2: *Temperature measurement using a digital thermometer with its sensor probe inserted into the core section of the composite board mat.*

the mat (from the edge boarder of the mat), in the horizontal direction. Temperature measurement was started immediately after the two hot plates reached the stop bars. Temperature was measured with 0.1°C precision.

2.4. SEM imaging

SEM imaging was done at thin film laboratory, FE-SEM lab (Field Emission), School of Electrical & Computer Engineering, The University of Tehran; a field emission cathode in the electron gun

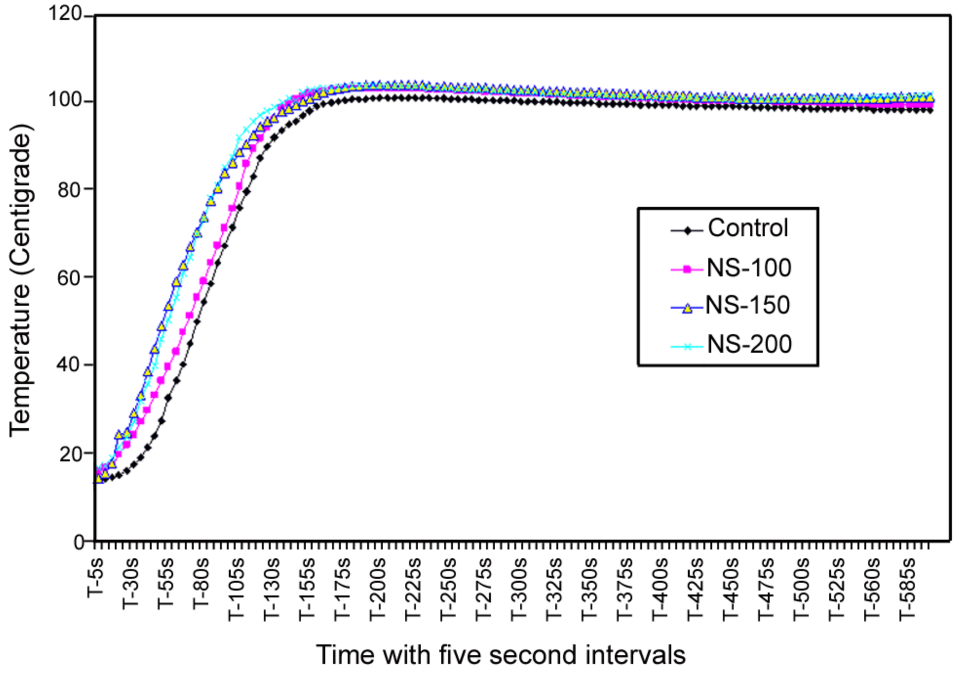

Figure 3: *Temperature at the core section of the medium-density fiberboard mat with five-second intervals (NS= nanosilver content mL/kg).*

of a scanning electron microscope provided narrower probing beams at low as well as high electron energy, resulting in both improved spatial resolution and minimized sample charging and damage.

3. RESULTS AND DISCUSSION

Measurement of temperature at the core section of the mat (immediately after the upper plate of the hot press reached the stopbars) indicated significant difference between the temperatures of the four treatments of control, NS-100, NS-150, and NS-200 (Figure 3). During the first minute of hot pressing, the increasing rate of heat in the core section of the mat showed significant higher rate in the nanosilver treated mats in comparison to the control panels. As the times passed (during the second minute), NS-100 came closer to the control mat, although it was still significantly different. NS-150 and NS-200 were both higher than both NS-100 and control treatments; however, no significant difference was observed between them in the first two minutes of hot pressing.

During the third to the seventh minutes of hot pressing, control panels showed significantly lower temperatures in comparison to all three NS treated mats (Figure 4). Although NS-100 was a bit lower in temperature, but no significant difference was observed in the temperatures of the NS treated panels. During this time (the third to the seventh minutes of hot pressing), a decreasing trend in temperature of all treatments was observed; it was due to the decrease in moisture content of the mat. In fact, the evaporation of water content resulted in decreasing of the heat transferred to the core; consequently, it decreased the core temperature. In the final two minutes of hot pressing though (the 8^{th} to 10^{th} minutes), an increasing trend in temperature was seen in NS-150 and NS-200 treatments. This slight increasing trend was because much of the moisture content of the mat was evaporated by this time; therefore, the heat

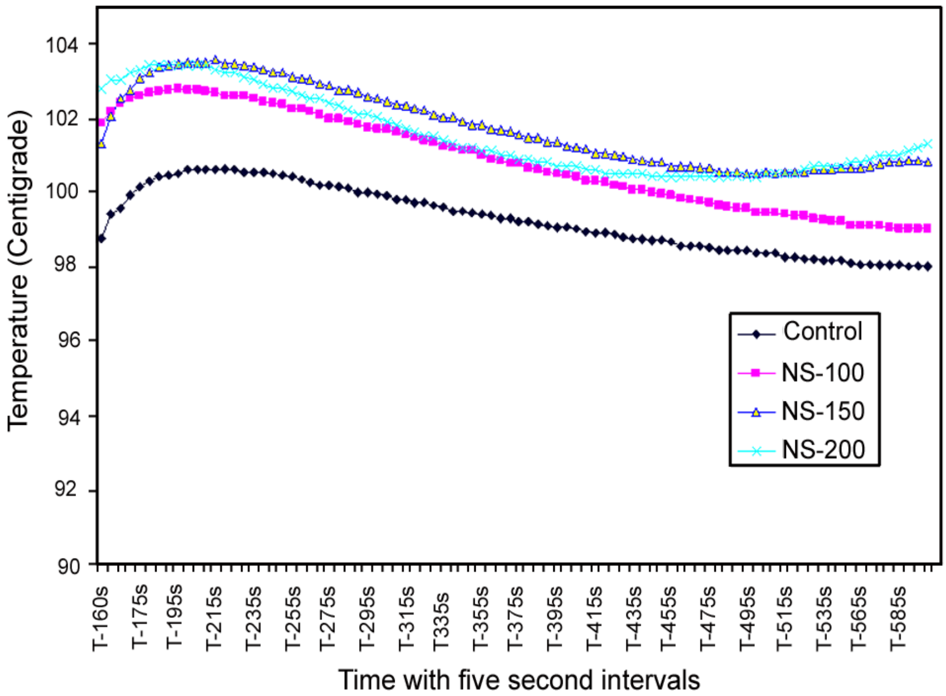

Figure 4: *Temperature at the core section of the medium density fiberboard mat after the third minute of hot pressing with five second intervals (NS= nanosilver content mL/kg).*

transferred to the core resulted in the increase in the temperature. The control and NS-100 treatments showed no increasing trend in the last two minutes of hot pressing; in fact they tended to be rather flat.

The depolymerization of the surface resin bonds in the surface layers of panels with high metal nanoparticle content can be related to the increasing trend in the final minutes of the hot pressing; that is, in the final minutes when all moisture content was nearly evaporated in the surface layers, the heat resulted in the depolymerization and breaking down of resin bonds. The depolymerization increased the fluid flow in the composite matrix. Similarly, the increase in the internal bond in nanocopper treated panels was due to the higher heat transfer rate to the core section of the composite mat, resulting in better polymerization of UF resin [9].

As to the fact that rapid transfer of heat to the surface layers of the mat would eventually result in the depolymerization of resin, ending up in decrease in some of the physical and mechanical properties, authors are working on possible spread of metal nanoparticles or mineral nanofibers in only the core section of composite mats to facilitate the heat transfer to this part; this would also prevent over heating of the surface layers and the consequent resin break down.

4. CONCLUSIONS

Effects of a 400 ppm aqueous suspension of nanosilver on the heat transferring rate from the hot press plates to the core section of medium density fiberboards (MDF) was studied here. Nanosilver suspension was applied to the mat at three consumption levels of 100, 150, and 200 mL/kg based on the dry weight of wood fibers. The obtained results proved significant higher heat transferring rate to the core of the mat in the NS treated panels. The high heat transferring rate was also the reason for the depolymerization of resin bonds in the surface layers of composite boards. It may therefore be concluded that addition of metal nanoparticles to increase the heat transferring rate to the core section of composite mats should not necessarily improve all physical and mechanical properties. Furthermore, the optimum consumption level for metal nanoparticles is dependent on many factors, including the hot press temperature, hot press duration, thermal conductivity coefficient of metal nanoparticles, and the type and density of composite panels.

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