

ИЗУЧЕНИЕ ФИЗИЧЕСКИХ СВОЙСТВ ДРЕВЕСНОВОЛОКНИСТЫХ ПЛИТ СРЕДНЕЙ ПЛОТНОСТИ, ИЗГОТОВЛЕННЫХ С ПРИМЕНЕНИЕМ МЕДНЫХ НАНОЧАСТИЦ

Хоссейн РАНГАВАР, *Университет подготовки преподавателей Шахид Раджи* ⁽¹⁾

hrangavar@yahoo.com

⁽¹⁾Университет подготовки преподавателей Шахид Раджи, Тегеран, Иран

В статье изучен эффект влияния медных наночастиц, использованных при изготовлении древесноволокнистых плит средней плотности (МДФ) на набухание плиты при поглощении ею воды (от 2 до 24-х часов). Наночастицы использовались в двух дозировках от 60 до 80 мл/кг (6–8 %) от сухой массы древесины. Физические свойства полученной доски сравнивались с контрольными образцами. Для производства доски использовалось горячее прессование продолжительностью 5, 6 и 7 минут. Результаты испытаний показали, что лучшие физические свойства показали образцы серии «5 мин – NC8 %». Свойство теплопередачи меди вызывало полимеризацию смолы в серединной части плиты, следовательно, физические качества плиты улучшались. Увеличение длительности горячей прессовки снижали физические свойства плит с нанодобавками как при 6 %, так и при 8 %-м их содержании. При более длительной термообработке эффект распространялся с серединной на периферийную часть материала, при этом смоляные связи разрушались. Таким образом, рекомендовано использовать дозировку медных наночастиц от 6 до 8 %, и при длительности термообработки 5 минут и дозировке 6 % материал МДФ рекомендуется для промышленного использования как обладающий наилучшими физическими свойствами.

Ключевые слова: наночастицы меди, древесноволокнистые плиты средней плотности, набухание, влагопоглощение, полимеризация смолы.

Introduction

In composite-board factories, 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. 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).

The heat-conductive nature of nano-metal particles might be used to better transfer the heat from platens to the core of the mat. The thermal conductivity of nanofluids containing dispersed metallic nanoparticles has been studied in a research project (Warrier and Teja 2011); the results provided

ed 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 copper nano-particle in heat conductivity in composite-boards has not yet been studied. The present study was therefore conducted to evaluate if copper nanoparticles may contribute to the heat transfer and improve physical and mechanical properties of MDF.

Materials and methods

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 the neighboring forests. Boards were 16 mm in thickness; the thickness of the boards was controlled by stopper bars. Increase in the density of the boards has been reported to improve board properties (Karlinasari et al. 2012), so in the present study, the density of all treatments was kept the

same (0.75 ± 0.03 g/cm³), in order not to make any source of differentiation between the treatments from this point of view. The moisture content of the fiber mat before hot pressing was kept constant at 10 % in all treatments. The total nominal pressure of the plates was 160 bars. The temperature of the plates was fixed at 175°C. Hot-pressing continued for 5, 6, and 7 minutes for different treatments. Urea-Formaldehyde resin (UF) was procured from Sari Resin Manufacturing Company in Sari, Iran. Twelve percent of UF-resin was used for all treatment based on the dry weight basis of the fibers; the specifications of the UF-resin are in Table 1. No hardener was used. Five replication boards were made for each treatment.

A 400 ppm aqueous nanocopper (NC) suspension was produced using an electrochemical technique in cooperation with Jafr Sorkhe Fajr Co. (Ltd.). The size range of copper nanoparticles was 20-90 nm. This was applied to the fibers in two ways as pretest: 1– directly spraying on the fibers, drying them, and then applying the resin on them; 2– adding the NC to the resin before applying it to the fibers. The pH and viscosity of the resin were kept constant for all treatments in the present study. For pretests, 80 mL/kg of nanocopper suspension was used. Boards were hot-pressed for 6.5 minutes.

Once the outcome of the pretests was revealed and the best method for mixing NC with the fibers was found, final tests were carried out. Nano-copper was used at two levels of 60 and 80 mL/kg wood particle (6 and 8 %), based on the dry wood basis; therefore, there were three treatments of: 1– control, 2– 60 mL of NC/kg, and 3– 80 mL of NC/kg. Five boards were manufactured for each treatment. Boards were kept conditioning room ($30 \pm 2^\circ\text{C}$, and 40–43 % relative humidity) for two weeks before the physical tests were carried out. Physical tests were carried out in accordance with the ISIRI 9044 PB Type P2 (2010) (compatible with ASTM D1037-99) specifications.

Physical properties

Thickness swelling and water absorption (2 and 24 hours) were measured. Nominal dimension of specimens was $200 \times 100 \times 16$ mm 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.

Statistical Analysis

Statistical analysis was conducted using SAS software program, version 9.1 (2003). One-way analysis of variance (ANOVA) was performed on the data to conclude significant differences at the 99 % level of confidence. Hierarchical cluster analysis, including dendrogram and using Ward methods with squared Euclidean distance intervals, was carried out by SPSS/16 (2007).

Results and discussion

Increase in hot-press time significantly improved physical properties of control specimens in some cases (Figures 1-5). This shows better polymerization of the resin in the inner part of the mat (the center of the mat) because of the longer time. Addition of copper nanoparticles to the resin, both for 6 and 8 %-NC treatments, significantly improved all physical properties in 5-min boards (Figures 1-5). In fact, the heat-transfer properties of NC-particles facilitated the heat-transfer to the core parts of the mat and polymerization completed much easier and faster. Increasing in hot-press time drastically showed negative impact on the physical properties in NC-treated boards. This negative impact was more as the NC-consumption level increased from 6 % to 7 %. The extra heat that was easily transferred to the surface and core parts of the mat in NC-treated of 6– and 7– min boards made the polymerized resin break down and consequently it had negative effect on the properties. Similar heat-transfer property of silver nanoparticles was also reported to improve the properties in particleboard (Taghiyari et al., 2011). The lower nanosilver-consumption level (100 mL/kg) showed formation of better polymerization of the resin, and consequently, stronger bonds among the wood particles (Taghiyari 2011); increasing of nanosilver-consumption level to 150 mL/kg resulted in the de-polymerization of the resin (Taghiyari et al 2011; Taghiyari 2011); ultimately the properties were decreased to some extent.

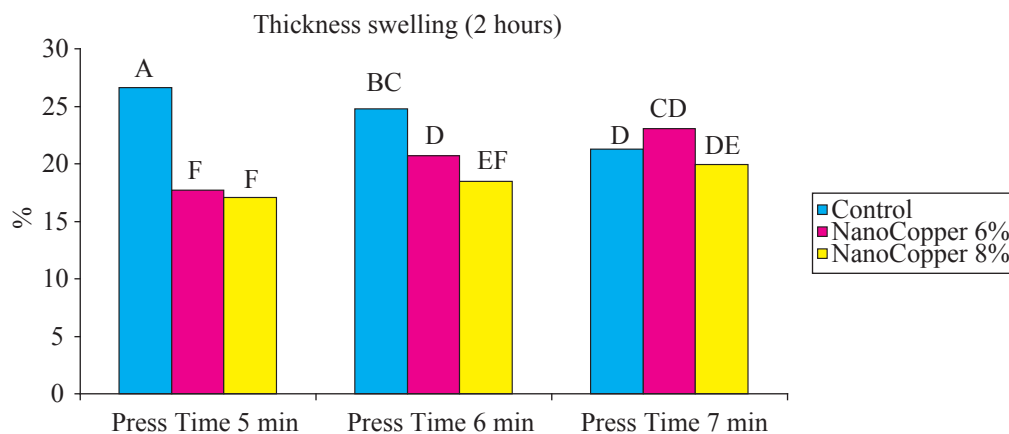


Fig. 1. Thickness swelling (2 hours) values of the nine treatments (3 different hot-press time for each element of the control, NC-6 %, and NC-8 %) (alphabets on the columns are the Duncan groupings at 99 % level of confidence)

Рис. 1. Толщина набухания (2 часа) значения девяти обработок (3-х различных время горячего пресса для каждого элемента управления, NC-6 %, и NC-8 %)

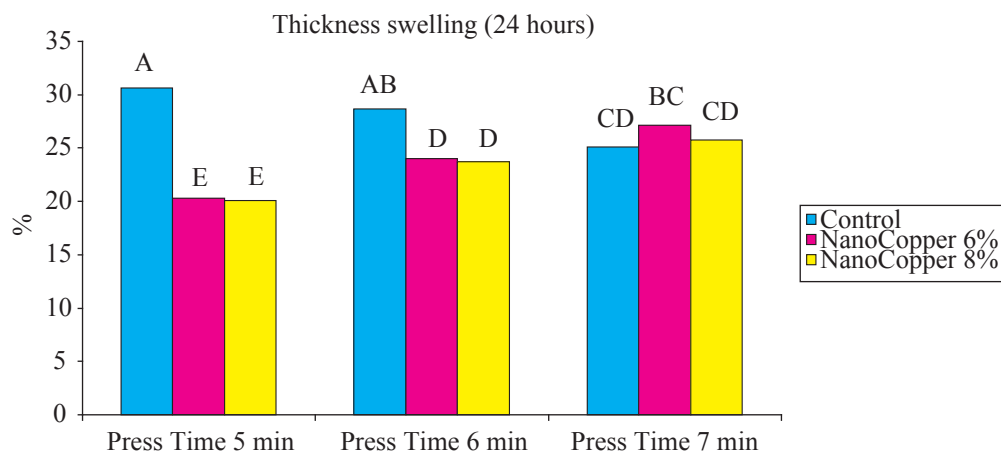


Fig. 2. Thickness swelling (24 hours) values of the nine treatments (3 different hot-press time for each element of the control, NC-6 %, and NC-8 %) (alphabets on the columns are the Duncan groupings at 99 % level of confidence)

Рис. 2. Толщина набухания (24 часов) значения девяти обработок (3-х различных горячего пресса время для каждого элемента управления, NC-6 %, и NC-8 %)

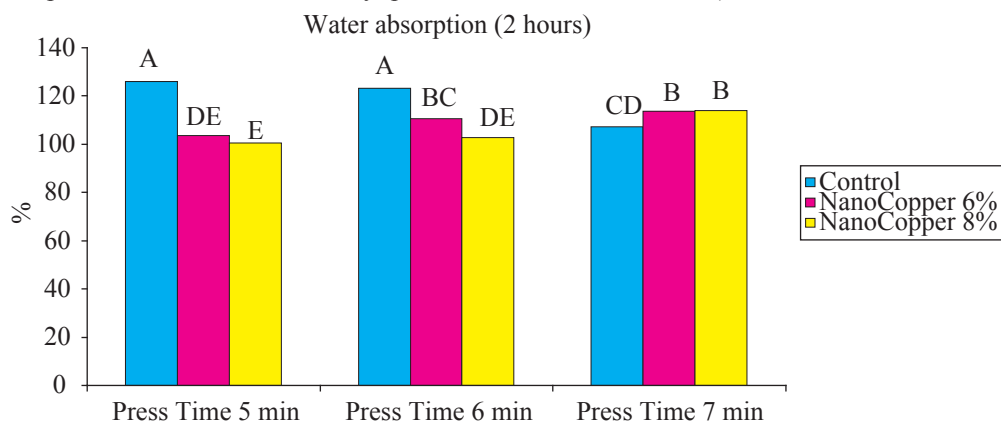


Fig. 3. Water absorption (2 hours) values of the nine treatments (3 different hot-press time for each element of the control, NC-6 %, and NC-8 %) (alphabets on the columns are the Duncan groupings at 99 % level of confidence)

Рис. 3. Поглощение воды (2 часа) значения девяти обработок (3-х различных горячего пресса время для каждого элемента управления, NC-6 %, и NC-8 %)

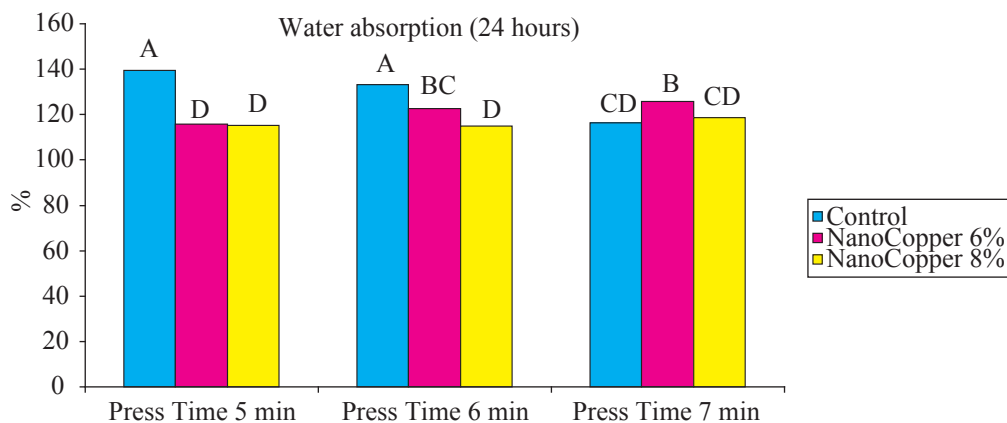


Fig. 4. Water absorption (24 hours) values of the nine treatments (3 different hot-press time for each element of the control, NC-6 %, and NC-8 %) (alphabets on the columns are the Duncan groupings at 99 % level of confidence)

Рис. 4. Водопоглощение (24 часа) значения девяти обработок (3-х различных горячего пресса время для каждого элемента управления, NC-6 %, и NC-8 %)

Conclusion

1– Heat-transfer property of copper nanoparticles facilitates the polymerization of the urea formaldehyde resin in the center part of the MDF mat;

2– Six percent of aqueous nanocopper suspension (60 mL of NC/kg), based on the dry weight basis of MDF fibers, may be recommended to be used the production of NC-treated MDF in order to improve physical properties in 16-mm thick MDF, provided the hot-press time be not higher than 5 minutes.

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STUDY OF PHYSICAL PROPERTIES OF MEDIUM-DENSITY FIBERBOARD MANUFACTURED BY NANOCOPPER

Hossein Rangavar, Wood Science and Technology Department⁽¹⁾

hrangavar@yahoo.com

⁽¹⁾ Wood Science and Technology Department, The Faculty of Civil Engineering, Shahid Rajaei Teacher Training University, Tel.: + 98 9124402051; Fax: + 98 21 22970071. Lavizan, Shabanloo St, Tehran, Iran.

In this study, the effects of copper nanoparticles on physical properties of medium density fiberboards (MDF) was investigated. Nanocopper (NC) was mixed with UF-resin at two levels of 60 and 80 mL/kg, based on the dry weight basis of fibers, and the properties of the boards produced were compared with control specimens. Three hot-press times of 5, 6, and 7 min were used. Results showed that the highest physical properties were observed in 5-min-NC 6 %. The heat-transfer property of copper facilitated polymerization of resin in the core-section of the mat; consequently, the properties were improved. Increase in hot-press time significantly decreased properties in NC-treated specimens, both in NC-6 and -8 % treatments. Here, the extra heat that was transferred to the surface and core sections resulted in the breaking down of the resin bonds. As to the rather similar results of NC-6 and -8 % treatments, 5-min-NC 6 % can be recommended to be used at industrial scale to improve physical and mechanical properties of MDF.

Keywords: Copper nanoparticles, Medium-Density Fiberboard, physical properties, polymerization of resin