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Cold Water Immersion Pretreatment of Post-Consuming Particleboards for Wood Chips Recovery by the Hydromechanical Process

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Abstract: In this research work, the effect of 20-day immersion of various types of reclaimed particleboards on thickness swelling and water absorption is investigated. This simple procedure has been chosen as the pretreatment to facilitate the chips' recovery by the hydromechanical (water jet) method. Maximum swelling was achieved after 20-day immersion but the differences between 10 and 20-day immersion were small, indicating that the time of 10-day immersion can be chosen as the pretreatment time. It was found that the bond between wood chips' particles was not completely failed since the permanent swelling after immersion and drying was lower than the maximum swelling. Hence, the proposed method needs to be improved by increasing the cross-section areas of particleboard samples after their breaking in order to create irregular pieces and facilitate the water action against the bond of wood particles.

Keywords: particleboards; hydromechanical process; cold water immersion

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1. Introduction

Waste wood is a valuable secondary raw material, which covers much of the wood-based panel industry's needs and also is a major source of renewable energy. In industrial practice, the management of waste wood is mainly determined by its specific category and contamination. According to the European Panel Federation, waste wood can be classified as: (a) untreated wood containing no halogenated organic compounds or heavy metals; (b) non-hazardous treated wood not exceeding the limits for chemical contamination or not treated with hazardous substances such as, e.g., wood preservatives; and (c) hazardous waste wood treated with wood preservatives that is highly flammable, irritant, harmful, toxic, and carcinogenic. Still, a very large fraction of waste wood ends up in landfills or composting with severe environmental impacts to the air, water, and soil [1]. A large part of waste wood comes from households (furniture, doors, windows, floors, etc.) and production residues from wood industries. These waste wood fractions are contaminated by chemicals such as lacquers, paints, coatings, and adhesives (mainly formaldehyde-based), as well as not with preservatives, and therefore differences arise during their recovery.

Promoting sustainable raw material management and increasing the recycling of waste materials are two strategic paths that open large domains for new technologies and innovations [2]. The development of alternative value-added wood composites that use waste materials or recycled materials is becoming beneficial due to overexploitation of natural resources. Nowadays, the products manufactured from recycled materials or by-products are especially paid attention to in the view-point of environmental problems [3–7].

The recycling of waste wood-based panels such as particleboards and the wood chips recovery are carried out by mechanical methods of hydrothermal treatments. During the mechanical method, the waste material is re-chipped or hammermilled and, after screening, the recovered wood chips can be re-used for panel production. The mechanical method is a continuous process and requires heavy equipment as well as a high amount of energy; the quality of new wood chips is inferior than the initial chips and a high amount of wood dust is produced [8–13].

In hydrothermal methods, the post-consuming particleboards are pretreated with hot water [14–16], steam [17–20], and weak acids and alkalis [21–23] at various temperatures, pressures, concentrations, and times in order to weak the glue bond by hydrolysis. Hydrothermal methods require installations consuming high amounts of energy, the treatment procedure is not continuous due to successive fillings and dischargings of the treatment vessel, and there is a risk of pollution from the effluents produced.

Various researchers have dealt with the possibility of recycling wood-based panels as well as re-using board production residues. Sandberg [17] and Pfleiderer Unternehmensverwalt [18] presented methods which make possible the re-use of board residues after steaming and in the production of particleboards or other wood-based material. In a related patent published by Moeller [24], a method for the recycling of wood products and waste containing wood is described. The application of the method includes mechanical handling of waste followed by processing for the production of by-products or end-products. Roffael [9] presented a method for re-using wood particles and fibers derived from waste panels bonded with tannin-based adhesive. The formaldehyde required to cross-link the tannin was generated by the hydrolytic decomposition of the adhesives of the waste boards during hot pressing. Boehme and Michanickl [25,26] presented a method with which it is possible to recover particles and fibers from waste-containing wood, old furniture, and other wood product residues. The wood waste is comminuted and then impregnated with a solution consisting of urea, ammonia, and soda. After this impregnation, the wood products are heated in order to dissolve the adhesive bonds between the fibers and particles.

In previous work [27], the wood chips recovery from waste particleboards was investigated by application of a new hydromechanical process. This method was applied on waste particleboard samples (7 × 8 cm) after pretreatment by immersion in cold water. For the recovery of chips, the swollen particleboard samples were mechanically processed either with ball milling agitation in water medium in a rotating drum or with water jet disintegration at 180 bar pressure. The results showed that the yield of recovered chips reached up to 50% of the initial green weight of the pretreated samples. It is worthy to state that the installations and equipment required are simple and of low cost, the consumption of energy is low (the only energy is that for hydro-jet operation), the waste recovery procedure is continuous, and the quality of the recovered chips is similar to that of the initial particles.

The aim of this study is to investigate the effect of the size of samples and duration of pretreatment in cold water for various types of particleboards in order to achieve the maximum thickness swelling and, as a result, the glue bond between the wood chips. The advantages of this method are the low energy consumption and low cost of the procedure, the minimized water pollution, and the possibility of re-use of water effluents after mechanical filtration.

2. Materials and Methods

The experimental material used in this investigation came from waste-glued wood products (particleboards) in the form of three-layered panels, which had a density value between 0.65 and 0.85 g/cm^3. The material used was collected from various types of waste particleboards that were distinguished into three categories (one uncovered particleboard C, one veneer-layered F, and five melamine-covered particleboards A, B, D, E, and G) of nominal ranging thickness between 16 mm and 18 mm. The collected boards were manufactured with urea formaldehyde resins and were P2 boards for interior fitment for use in dry conditions. From each of the seven types of particleboards, five samples with the dimensions 2.5 × 2.5 cm, 5 × 5 cm and 10 × 10 cm were prepared. The samples were immersed in cold water at ambient temperature for twenty days. The thickness swelling and water absorption were determined at the end of each day. After the immersion period, the samples were left to air dry and the permanent thickness swelling was determined. The sample dimension of 5.0 cm × 5.0 cm for the determination of thickness swelling was selected as this was specified in EN 317 [16]. The other two sets of dimensions, namely 2.5 cm × 2.5 cm and 10 cm × 10cm, were selected because they are pretty close to the dimensions specified in the standards in order to have comparable results.

3. Results and Discussion

The results are shown in Figures 1–3, which represent the rate of thickness swelling of seven particleboard categories and for specimens 2.5 cm × 2.5 cm, 5.0 cm × 5.0 cm, 10 cm × 10cm after their immersion in water for a period of twenty days. It can be seen that the differences in the thickness swelling between the ten and twenty-day immersion was small for all particleboard categories and specimens' dimensions. The above-mentioned result is in line with the results found by other researchers already referred to, such as Michanickl [28,29]. The rate of swelling for all cases can be expressed by highly correlated logarithmic equations of the form y = a × ln(x) + b, where y is the thickness swelling (percentage) and x is the immersion time in days.

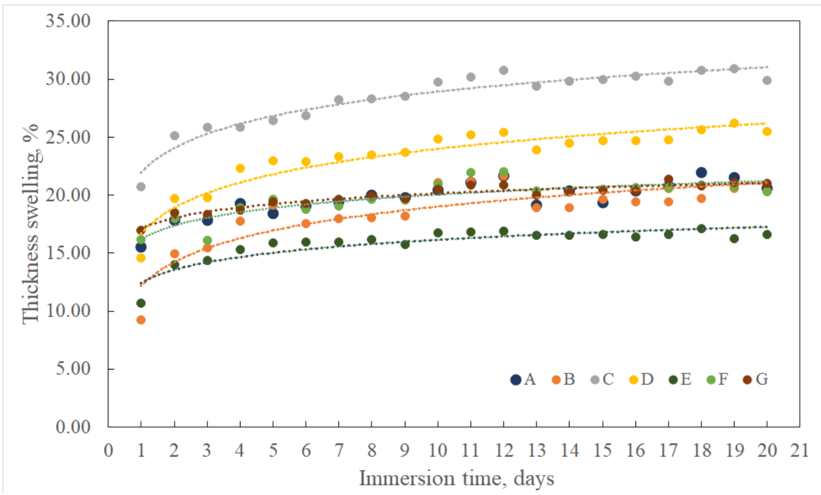

Figure 1. Relationship between immersion time and thickness swelling of particleboard samples with dimensions 2.5 × 2.5 cm for all categories (A–G).

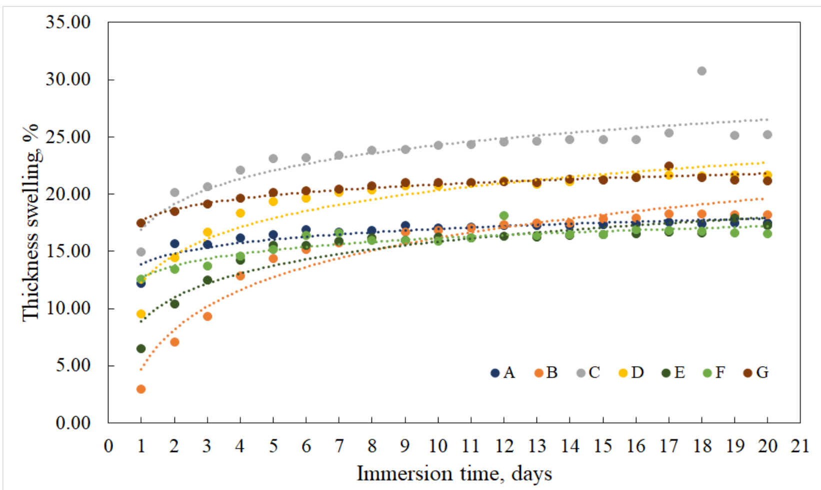

Figure 2. Relationship between immersion time and thickness swelling of particleboard samples with dimensions 5.0 × 5.0 cm for all categories (A–G).

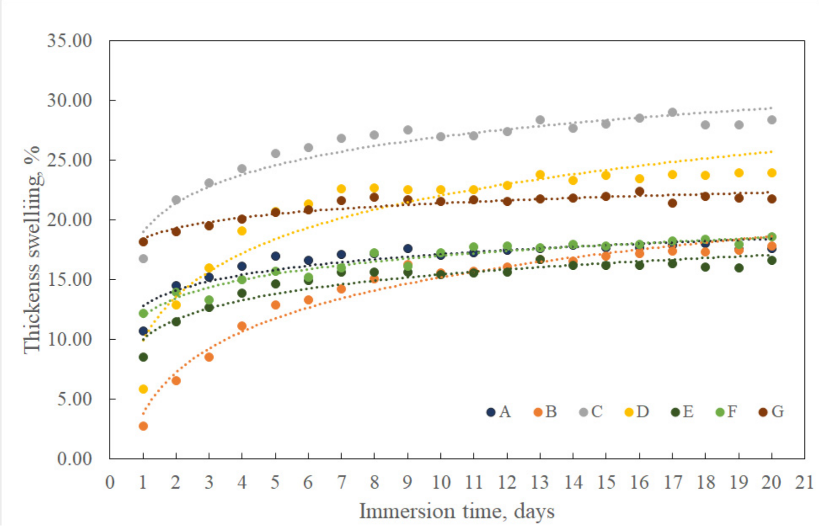

Figure 3. Relationship between immersion time and thickness swelling of particleboard samples with dimensions 10.0 × 10.0 cm for all categories (A–G).

From Figures 2 and 3, it can be found that the differences between the ten and twenty-day immersions are small and lower than 3.5%. For practical reasons, the thickness swelling after the ten-day immersion can be preferred instead of that after the twenty-day immersion. The small differences in the water absorption between the 10 and 20-day immersion also support this preference. Water absorption ranged between 77.23% and 100.58% for the 10-day immersion, and between 84.08 and 107.50% for the 20-day immersion. Such pretreatment of particleboard samples by their immersion in cold water up to a level of water absorption of 60% was used by Lykidis [15] in order to facilitate the disintegration of samples by hydrothermal treatments. Additionally, Figure 3 includes the permanent thickness swelling after the period of the twenty-day immersion and air drying as well as the corresponding water absorption after ten and twenty days of immersion. This permanent swelling ranged between 1/4 and 1/2 of the thickness swelling of the twenty-day immersion. This size of permanent swelling indicates that after the pretreatment used in the present work, the bond between the wood particles was reduced but not to a satisfying degree in order to achieve better disintegration and the chips' recovery.

Between the three specimens' dimensions tested, the thickness swelling was higher in 2.5 cm × 2.5 cm compared with the others probably due to the high proportion of crosscut to flat surfaces. Between the 2.5 cm × 2.5 cm and 5.0 cm × 5.0 cm specimens, the differences in the thickness swelling were not consistent.

In order to improve the procedure, the cross-cut surfaces can be increased by creating irregular surfaces after the application of bending forces perpendicular to flat forces or by hammermilling to produce irregular pieces. In addition, in fully swollen conditions, it can be proposed to apply shear forces in order to achieve splitting of particle samples in two halves.

4. Conclusions

The conclusions of the present work regarding the pretreatment of recycled particleboards by immersion in cold water before the recovery of chips by the hydromechanical (water jet) method may be summarized as follows.

The thickness swelling and water absorption of the various particleboard categories tested were not practically different between the 10 and 20-day immersion in water.

In most cases, the thickness swelling and water absorption of 2.5 cm × 2.5 cm particleboard samples were slightly higher than the other two types of dimensions (5.0 cm × 5.0 cm and 10.0 cm × 10.0 cm).

Due to the aforementioned small differences, the pretreatment time that may be chosen is the 10-day immersion or less.

The magnitude of the permanent swelling after immersion and drying of particleboard samples was found to be lower than the maximum swelling. This indicates that the bond between the wood particles is not completely failed in order to facilitate the recovery of chips.

Further research centralized on improvement of the experimental procedure may include mechanical methods to produce particleboard pieces with increased "cross-cut" surfaces before their immersion in water.

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