Physical Consolidation of Rattan Furniture Waste Fibers in Self-bonded Boards under Morphological Analysis

Zahurin Halim*, Maisarah Tajuddin, Zuraida Ahmad

Department of Manufacturing and Materials, Kulliyyah of Engineering, International Islamic University Malaysia, Gombak, 53100 Kuala Lumpur, Malaysia

Abstract

High concerns on the health risks and environmental issues owing to the usage of synthetic resin had revolved the alternative on fabricating producing self-bonded boards, by utilizing rattan furniture waste (RFW) as the main material. These boards were hot-pressed with pressing parameters of 1.5MPa, 180^{o}C and 5 minutes. This study focuses on analyzing the self-bonding mechanism occurred among the fibers inside the boards, under Scanning Electron Microscope (SEM) with 100x magnification. RFW had good deformation ability of cell wall due to the high dimension ratio of lumen to cell wall and flexibility of parenchyma cells when being pressed. These factors enhanced the physical consolidation of fibers, and improved the inter-fiber bonding. The disorientation of fibers and fiber surface might affect the properties of self-bonded boards produced. Thus, sufficient pressing pressure and pressing temperature must be applied to ensure resilient physical consolidation of fibers to produce good quality self-bonded boards.

Keywords: furniture waste, deformation ability, morphology, fiber bonding

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*Corresponding author: Zahurin Halim; email: zahureen@iium.edu.my

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Introduction

Self-bonded boards manufactured with the lessen usage of synthetic resin, as synthetic resin had appalling effects on human health, not eco-friendly and required high cost. Numerous studies on the boards produced without or by reducing the synthetic resin used, through different fabrication processes [1-2] using natural fibers. The fibers usually had a good amount of chemical components for example, lignin content that works as a natural binder for the fibers inside the board. Several factors could affect properties of boards produced such as pre-treatment process, additional material added and others [3-4].

These self-bonded boards produced were more environmental-friendly and cheaper in production cost, and most importantly had comparable properties with the boards in the current market. The properties of the self-bonded boards produced should meet the minimum requirement of the industrial standards, as most of these boards emphasis as structural products in construction and house furniture.

Majority of rattan species had found to have similar structures comprises of the epidermis, parenchyma cells, vascular bundles and xylem [5-6], as illustrates in rattan furniture wastes (RFW). The outer layer consists of epidermis that reacts as a wall to evade parasite attacks and inhibits water loss. Xylem has an unlignified cell wall and intensely coated with silica, which brings the water and minerals from roots up to the leaf. Parenchyma cells have ample intercellular spaces that work as operative loading place for photosynthesis.

These structures illustrates in the previous study by Ahmad and her friends [6], where the RFW had various diameter sizes of vascular bundles ranged from 200µm to 400µm, performed as carriage structure in the plant. These vascular bundles comprised of metaxylem, protoxylem and phloem located in the middle of rattan stem, covered around by parenchyma tissue and other fibers.

The fundamental part in the hot-pressing process is to ensure the heat and pressure sufficiently spread all over the fibers throughout the process at the appropriate pressing time [1, 3]. Our previous studies [7-8] revealed the self-bonded boards produced from RFW with fiber sizes of 50µm, using optimum pressing parameters of pressing pressure of 1.5kPa, pressing temperature of 180^{o}C and pressing time of 5 minutes, accomplished in producing good properties for self-bonded boards. These resulted in board strength, internal bonding and thickness swelling of 28.5 MPa, 0.26 MPa and 19.6%, respectively, which met the minimum requirement of Japanese Industrial Standard (JIS). Hence, this study focuses on analyze the self-bonding mechanism transpired in the self-bonded boards, using morphological analysis.

Materials and Methods

The primary material used in the study were rattan furniture wastes (RFW) in fiber sizes of 50, 100, 250 and 500 µm. These RFW fibers were sieved, dried and poured inside the stainless steel mould. The mould pressed using hot-pressing machine under different pressing parameters, which fixed pressing pressure of 1.5MPa, pressing temperature of 170^{o}C, 180^{o}C, 190^{o}C, and pressing time of 4, 5, 6 minutes. Subsequently, the testing on Modulus of Rupture (MOR), internal bonding (IB), dimensional stability and morphological analysis done to determine the optimum properties of self-bonded boards produced under the optimum pressing parameters. The results for these testing discussed in earlier studies [7-8].

This study focused on evidencing the self-bonding mechanism through morphological analysis by using a scanning electron microscope (SEM) to examine the samples. The morphological analysis of structures of RFW and self-bonded boards produced were examined via SEM in QUASI Lab, Universiti Kebangsaan Malaysia (UKM), at 15kV at the magnification of 50X and 100X.

RFW was cut into the size of 1cm X 1cm, and slowly blow-dried in order to eliminate dust on board surfaces. The samples of RFW and boards were non-conductive, were put on top of aluminium frames that layered with a thin layer of gold to increase conductivity and evade sample charging, for worth image qualities.

Results and Discussion

The qualities of self-bonded boards produced pressed under the hot-pressing process were affected by several factors, such as the material used, the pressing parameters involved and few others. It alleged that the heat and pressure applied onto the fibers equally distributed on the whole parts of the boards produced. This study discussed the self-bonding mechanism based on the outcomes attained from the properties of self-bonded boards produced which focused on the physical consolidation of the fibers inside the boards.

The schematic diagram in Figure 1 [9], illustrates the large pores of intercellular cell spaces of lumen dimension compared to cell wall dimension. These dimension created fibers with high ratio of lumen to cell wall dimension, thus increased the flexibility of fibers. The fibers were more vulnerable to deformation during the hot-pressing process which occasioned to good intercellular adhesion and inter-fiber bonding [3, 9-10].

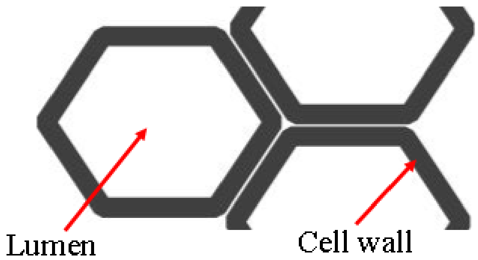

Figure 1: A schematic diagram of on lumen and cell wall [9]

The schematic diagram of a self-bonding mechanism for this study demonstrated in Figure 2. Fibers were gradually pressed under heat and pressure during the hot-pressing process, in line with the selected pressing parameters. Pressing pressure was the compression placed onto the fibers, to allow sufficient contact for the physical and chemical bonding reactions to take place [11]. Higher pressing pressure reduced the pressing time required, as ascertained by previous studies [3, 12]. This is due to the activation of the natural binder by the interlocking of protein penetration on porous fibers surface and attractive molecular forces by Van der Waals and hydrogen bonds. The schematic illustrates the fibers had deformed sufficiently with no air space between the fibers, as the pressure continuously applied. It resulted in good fiber-fiber bonding, which deterred macroscopic permeability occurred [2, 4, 13]. A similar situation obtained from the exhibited figures in earlier studies, showed that the parenchyma was fully compressed and degraded after the hot-pressing process [6, 14].

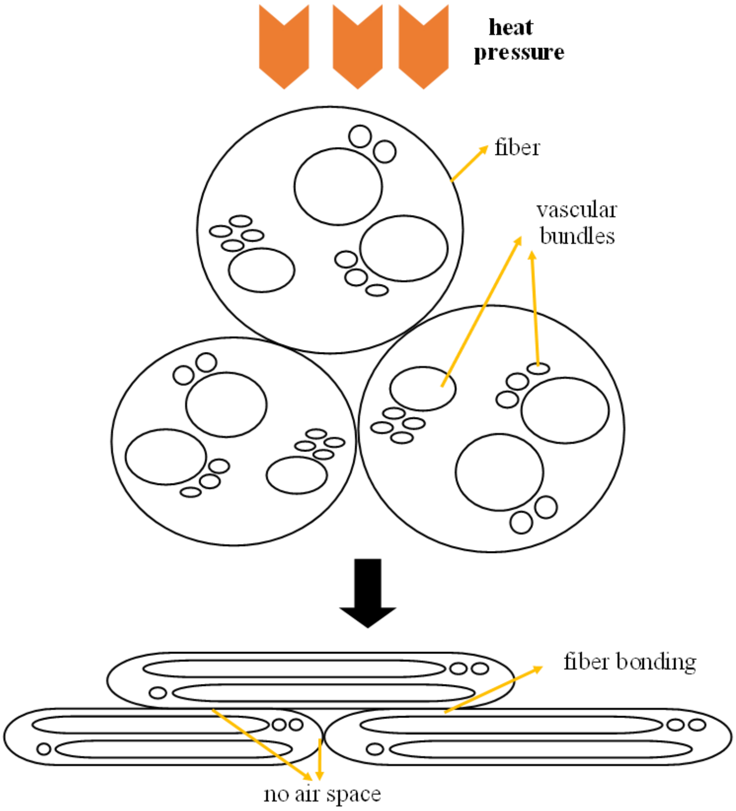

Figure 2: Physical consolidation of fibers for self-bonding mechanism in self-bonded boards during hot-pressing process

RFW had an extra advantage with distinctive features of flexibility and deformation ability as discussed earlier [3, 15]. During the rubbery state of polymers, the pressing temperature was higher than the glass transition temperature (Tg) leads to the occurrence of maximum deformation of cell and contributed to the large contact areas between fibers. It should be noted that fiber surface parts for instance the fiber surface geometry and fiber surface entanglement, were vital and functioned as interphase contact between fibers to be bonded [16].

Figure 3 displays the compressed and deformed fibers under heat and pressure using SEM at 100X magnification. It is indicated that the fibers had weak bonding with loose physical consolidation which caused the self-bonded boards produced had low values in strength, internal bonding and dimensional stability. However, there were trivial values of board strength due to chemical reaction happened inside the boards. For the self-bonded boards with large fiber sizes, it is desired to set high pressure onto the fibers to attached and interlocked together. The vascular bundles required to be fully compressed to avoid occurrence of voids for better properties of self-bonded boards.

On the other hand, some conditions such as irregularity of fiber surface, non-uniformity of fiber arrangements, board defects also could leads to loose physical consolidation [4, 16]. Rattan skin, ruptured and pullout of rattan fibers triggered the orientation of the disorderly fibers, which created less adhesion among fibers that reduced the board properties [1, 3-4, 13].The bonding performance could be enhanced through the chemical and physical factors on fiber surface such as friction among fibers and interaction of lignin-lignin from lignin deposition that increased van der Waal forces resulted in higher degree of mechanical entanglement.

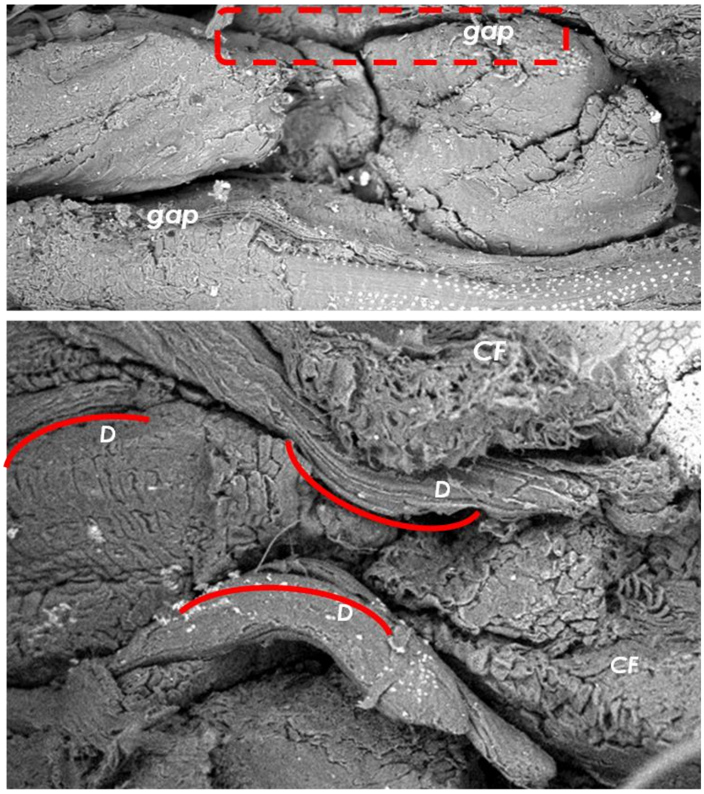

Figure 3: Deformation ability of rattan waste fibers under SEM analysis

Strong physical consolidation from heat and pressure applied amongst compressed cell wall fibers, along with the ample chemical interactions and interlocking between fibers occasioned in good properties of self-bonded boards produced. It is suggested that there were another two self-bonding mechanisms occurred inside RFW fibers during the hot-pressing process [1, 9, 13]. The final application of self-bonded boards produced mostly focused on furniture parts which relies on the strength of boards.

Conclusions

Self-bonded boards were successfully produced via hot-pressing process, with pressing parameters of 1.5MPa, 50µm, 180°C, 5 minutes, resulted in MOR 28.5MPa, IB 0.26MPa, TS 19.6%. High ratio of lumen over cell wall dimension contributed to good deformation ability and flexibility when pressed. Pressure must be applied until there was no air space between fibers to ensure fibers deform and compressed sufficiently to get intimate fibers contact and prevented occurrence of voids. Loose physical consolidation amongst fibers and disorderly fiber orientation created weak fiber bonding and reduced board strength. Thus, sufficient pressing pressure and pressing temperature must applied to ensure resilient physical consolidation of fibers to produce good quality self-bonded boards.

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Author Contributions

Maisarah Tajuddin carried out the experiment and manufactured the boards. Zahurin Halim and Zuraida Ahmad helped supervised the project. All the authors contributed to writing of the manuscript.

Disclosure of Conflict of Interest

The authors declare that there is no conflict of interest.

Compliance with Ethical Standards

This manuscript does not contain any studies with human or animal subjects.

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