Self-Bonding Characterization of Non-Wood Lignocellulosic Materials

Ragil Widyorini
Laboratory of Sustainable Materials, RISH, Kyoto University

Adhesive is generally accepted to be the most expensive raw material for making wood composite. Rising prices of petroleum and great uncertainties of its future supply, however, caused the forest product industry to focus on the necessity of self-sufficiency and the development of adhesives from natural or renewable raw material. A process, which converted the lignocellulosic materials into panel boards without using of synthetic resin binders, has been developed and patented by Shen in the mid eighties [1]. Studies on manufacturing process of binderless board have been conducted for years. Considering that no synthetic adhesive was applied, the bonding performance of binderless boards was greatly affected by the chemical changes of materials during manufacturing process. It was believed that degradation of hemicelluloses during steam and heat treatments play an important role in the self-bonding of binderless boards [1]. However, the self-bonding mechanism during steam and heat treatments has not been completely elucidated so far.

In recent years, non-wood lignocellulosic materials have been considered to produce various composite products. These resources are abundantly available in many countries; including residues from annual growth plants [2]. In general, physical and chemical characteristic and structures of non-wood lignocellulosic materials are different from those of wood. Non-wood lignocellulosic materials, which are usually rich in hemicelluloses, are supposed to be potential materials for binderless boards production [3][4][5].

The objective of this study was to investigate the chemical changes of non-wood lignocellulosic material during steam-injection pressing and hot-pressing treatments, in order to characterize the self-bonding of binderless boards. Kenaf (*Hibiscus cannabicus L.*) core and sugarcane (*Sugarcane officinarum L.*) bagasse were used as raw materials of binderless particleboard. The raw materials and its boards were analyzed for extractives, holocellulose, cellulose, and lignin. The neutral sugar composition of the water–soluble fraction was determined using an alditol-acetate method, while the lignin was analyzed using pyrolysis coupled to gas-chromatography-mass spectrometry (Py-GC-MS). Furthermore, the effects of chemical changes on the self-bonding performance and dimensional stability of binderless boards were discussed. Considering the chemical characteristics of non-wood materials were different from those of wood, it was necessary to discuss the role of cinnamic acids during steam and heat treatments.

Chemical analysis of kenaf core binderless particleboards showed that hemicelluloses, lignin and cellulose were significantly degraded during steam treatment. The partial degradation of those chemical components by mild steam-injection treatment increased the bonding performance (see Fig.1) and dimensional stability of the binderless board. Neutral sugar composition of water-soluble polysaccharide from hot-pressed boards was relatively similar with that of untreated kenaf core. In addition, analysis of lignin showed that syringyl/guaiacyl (S/G) ratio of hot-pressed board was not significantly different with that of untreated kenaf core. Compared with steam-injection pressing, the conventional hot pressing caused a lower degree of degradation of chemical components [6]. The hot-pressed kenaf core binderless board showed poor bonding performance. These results indicated that even though the hot pressing treatments also caused degradation of chemical components, but not to a significant degree to improve their binding ability. Similar trends to the kenaf core were observed for bagasse binderless boards [7].

Cinnamic acids, as postulated for cell wall of grasses/non-wood lignocellulosic materials, were identified by Py-GC-MS analysis with presence of tetra methyl ammonium hydroxide (TMAH) as methylating agent. The ratio of S/G and cinnamic acids/guaiacyl (C/G) decreased with an increase in pressing time and steam-pressure, indicating the modification and degradation of lignin has occurred [8]. The results showed that some parts of ester-linked cinnamic acids were cleaved due to the degradation of hemicelluloses and lignin during treatment. It was also found that there was correlation between decreasing of the C/G ratio and shear strength of binderless kenaf core composites [8]. In order to obtain the optimum conversion of chemical components, the proper control of high-pressure steam treatment became significant. In this study, the optimum bonding properties of kenaf core composites was obtained after steaming at 0.8-1 MPa for 10-15 min.

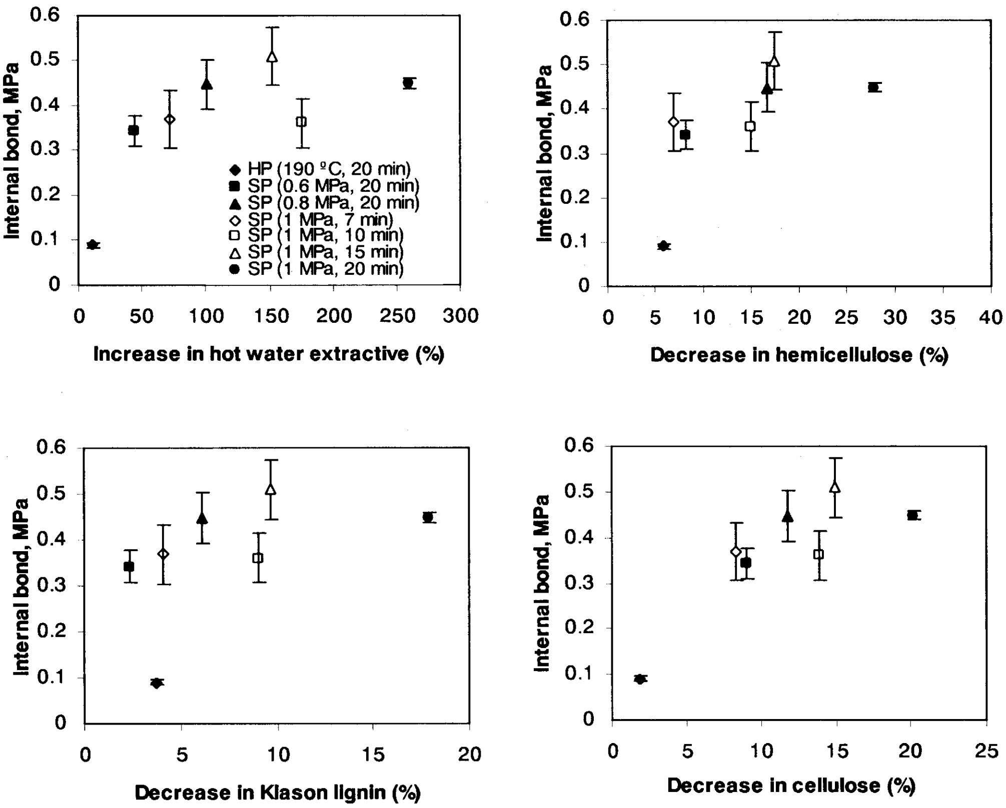

Fig. 1. The effect of chemical changes by steam and heat treatments on internal bond strength of kenaf core binderless boards. The corrected density of binderless boards was 0.5 g/cm^3. HP, hot pressing; SP, steam-injection pressing

Thus, it was found that chemical components of non-wood materials degraded significantly in varying degree during steam and heat treatments. Not only hemicelluloses, other chemical components of non-wood materials were also degraded during treatments. The partial degradation of those chemical components by mild steam-injection treatments increased the mechanical properties of the binderless boards, and gave better quality than those made by hot-pressing treatments. In addition to three major components, the cinnamic acids also contributed in the self-bonding mechanism of non-wood lignocellulosic binderless boards.

REFERENCES

[1] Shen, K.C. (1986) United States Patent 4627951
[2] Rowell, R.M. (1998) Proceedings of the 4th Pacific Rim Bio-Based Composites Symposium, Bogor Indonesia, 1-18
[3] Suzuki, S., Shintani, H., Park, S.Y., Saito, K., Laemsak, N., Okuma, M. and Iiyama. K, (1998) Holzforschung 52: 417-426
[4] Xu, J., Sugiwara, R., Widyorini, R., Han, G. and Kawai, S. (2004) J. Wood Sci., 50:62-68
[5] Velasquez, J.A., Ferrando, F., Farriol, X. and Salvado, J. (2003) Wood Sci. and Technol., 37:269-278
[6] Widyorini, R., Xu, J., Watanabe, T. and Kawai, S. (2005) J. Wood Sci., 51:26-32
[7] Widyorini, R., Xu, J., Umemura, K. and Kawai, S. (2005) J. Wood Sci., *in press*
[8] Widyorini, R., Higashihara, T., Xu, J.Y., Watanabe, T. and Kawai, S. (2004) Proceedings of the 7th Pacific Rim Bio-Based Composites Symposium, Nanjing, China, 1:21-27