World Academy of Science, Engineering and Technology
International Journal of Materials and Textile Engineering
Vol:18, No:03, 2024

Influence of Synergistic Modification with Tung Oil and Heat Treatment on Physicochemical Properties of Wood

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Abstract : Heat treatment has been widely recognized for its effectiveness in enhancing the physicochemical properties of wood, including hygroscopicity and dimensional stability. Nonetheless, the non-negligible volumetric shrinkage and loss of mechanical strength resulting from heat treatment may diminish the wood recovery and its product value. In this study, tung oil was used to alleviate heat-induced shrinkage and reduction in mechanical properties of wood during heat treatment. Tung oil was chosen as a modifier because it is a traditional Chinese plant oil that has been widely used for over a thousand years to protect wooden furniture and buildings due to its biodegradable and non-toxic properties. The effects of different heating media (air, tung oil) and their effective treatment parameters (temperature, duration) on the changes in the physical properties (morphological characteristics, pore structures, micromechanical properties), and chemical properties (chemical structures, chemical composition) of wood were investigated by using scanning electron microscopy, confocal laser scanning microscopy, atomic force microscopy, X-ray photoelectron spectroscopy, and dynamic vapor sorption. Meanwhile, the correlation between the mass changes and the color change, volumetric shrinkage, and hygroscopicity was also investigated. The results showed that the thermal degradation of wood cell wall components was the most important factor contributing to the changes in heat-induced shrinkage, color, and moisture adsorption of wood. In air-heat-treated wood samples, there was a significant correlation between mass change and heat-induced shrinkage, brightness, and moisture adsorption. However, the presence of impregnated tung oil in oil-heat-treated wood appears to disrupt these correlations among physical properties. The results of micromechanical properties demonstrated a significant decrease in elastic modulus following high-temperature heat treatment, which was mitigated by tung oil treatment. Chemical structure and compositional analyses indicated that the changes in chemical structure primarily stem from the degradation of hemicellulose and cellulose, and the presence of tung oil created an oxygen-insulating environment that slowed down this degradation process. Morphological observation results showed that tung oil permeated the wood structure and penetrated the cell walls through transportation channels, altering the micro-morphology of the cell wall surface, obstructing primary water passages (e.g., vessels and pits), and impeding the release of volatile degradation products as well as the infiltration and diffusion of water. In summary, tung oil treatment represents an environmentally friendly and efficient method for maximizing wood recovery and increasing product value. This approach holds significant potential for industrial applications in wood heat treatment.

Keywords : tung oil, heat treatment, physicochemical properties, wood cell walls
Conference Title : ICWSET 2024 : International Conference on Wood Science, Engineering and Technology
Conference Location : Paris, France
Conference Dates : March 25-26, 2024