

Development of eco-friendly and robust structural materials via binder-free lamination of waste biomass with help of finite element method

Quanliang Wang^{a,1}, Longxiao Zhu^{a,1}, Min Wang^{b,1}, Liping Cai^c, HaoranYe^c, Zhongfeng Zhang^d, Yi Ren^d, Yang Yang^d, Chunxia Chen^{e,*}, Shengbo Ge^{c,*}, Wentao Gan^{b,*}

(a College of Mechanical and Electrical Engineering, Northeast Forestry University, Harbin, Heilongjiang 150040, China; b Material Science and Engineering College, Northeast Forestry University, Harbin, Heilongjiang 150040, China; c Jiangsu Co-Innovation Center of Efficient Processing and Utilization of Forest Resources, International Innovation Center for Forest Chemicals and Materials, College of Materials Science and Engineering, Nanjing Forestry University, Nanjing, Jiangsu 210037, China; d College of Furniture and Art Design, Central South University of Forestry and Technology, Green Furniture Engineering Technology Research Center in Hunan, National Forestry & Grassland Administration, Green Home Engineering Technology Research Center, Changsha, Hunan 410004, China; e College of Chemistry, Chemical Engineering and Resource Utilization, Northeast Forestry University, Harbin 150040, China)

Abstract: To achieve the goal of carbon neutrality, it is of great significance to develop the high-performance and sustainable structural materials. In this work, an eco-friendly, high-strength, super-hydrophobic, and thermally stable structural materials were fabricated through a scalable binder-free lamination process using waste biomass (e.g., wood residues, crop straw and waste paperboard). The biomass was first separated into cellulosic fibers by the pulping technology, then further molded into mats and laminated into structural materials without commercial adhesives. The moisture content in the mat was used for regulating the softening of cellulosic fibers. In virtue of the water-induced cell wall plasticization, the laminated material showed a high internal bonding strength of 2.24 MPa and excellent flexural strength of 134.81 MPa. Benefitting to the silica modification, the materials exhibited a super-hydrophobic surface with the high-water contact angle of 154.1°, good dimensional stability with the thickness swelling of 14.8%, and superior mechanical stability with 94.3% flexural strength remained after two months of ultraviolet radiation. The finite element method (FEM) was used to simulate the destruction behaviors under various loads and find the weakest zones of components. The weakest zones were reinforced by the H₂O₂ spraying treatment and the flexural strength was improved from 80.12 to 120.35 MPa, counting to an increase of approximately 50%. The utilization of FEM to enhance the strength of biomass binder-free composites is unique in productions of biomass composites. This work provides a new strategy to develop eco-friendly structural materials with high-strength, super-hydrophobic and thermally stable performance exhibiting huge potential in furniture applications.