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Effect of adding rubber powder to poplar particles on composite properties

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ABSTRACT

The effect of adding rubber powder derived from waste tires to poplar wood particles on mechanical and water-resistant properties of particleboards was examined. Sixty panels were made with rubber contents of 0–40% at hot-pressing temperatures of 140–180 °C, methylene diphenyl diisocyanate resin contents of 2–6% and panel densities of 0.6 to 1 g cm^{-3}. Although the modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB) strength were reduced by adding rubber powder, the thickness swelling (TS) was reduced by 7.3–61% when 10–40% rubber powder was added. Four regression equations (rubber content, pressing temperature, resin content and target panel density as functions of MOR, MOE, IB and TS) were developed and a nonlinear programing model was derived with operation research theory to obtain the most desirable panel properties under some production constraints.

1. Introduction

The annual consumption of rubber was more than 15 million tons and the output of rubber products was more than 31 million tons worldwide in 2000 (Chen and Qian, 2003; Warith and Rao, 2006). Due to increasing amounts of rubber waste and limited landfill capabilities, reutilization of rubber as additives to concrete (Eldin and Senouci, 1993, 1994; Khatib and Bayomy, 1999; Hernandez-Olivares et al., 2002) and wood composites (Schmidt et al., 1994; Zhao et al., 2008, 2010; Ayrilmis et al., 2009a,b) has been explored.

The major problems of wood composites are associated with the hydrophilic character of the cellulose. Various materials such as preservative-treated waste wood, cement, construction and demolition waste, agricultural fibers, plastics, and metal have been used with wood for manufacturing wood-based composites with increased resistance against microorganisms and/or improved physical and mechanical properties (Schmidt et al., 1994; Felton and DeGroot, 1996; Vick et al., 1996; De Souza et al., 1997; Munson and Kamdem, 1998; Wolfe and Gjinolli, 1999; Huang and Cooper, 2000; Chang et al., 2009; Huuhilo et al., 2010).

Wood-rubber composites have gained acceptance in modifying the properties of wood composites by providing excellent energy absorption, characteristically large elastic deformation, better sound insulation, less thickness swelling (TS) and abrasion resistance (Fu, 2003). Prompunjai and Sridach (2010) even produced an environmentally friendly composite by combining saw dust, cassava starch and natural latex rubber and showed that the addition of the rubber reduced brittle failure and increased flexural strength. Zhao et al. (2008) investigated the effects of the panel density, pressing time and temperature on the internal bond (IB), modulus of rupture (MOR) and modulus of elasticity (MOE) of wood/rubber composites and found that the optimal panel manufacturing conditions were a pressing temperature of 170 °C for 300 s and a panel density of 1 g cm^{-3}. A later study (Zhao et al., 2010), reported that the sound insulation property of wood-rubber composites was better than that of commercial wood-based particleboards.

Utilization of waste tire rubber in the manufacture of particleboard was explored by Ayrilmis et al. (2009a). Although the MOR values were reduced by 12–58% due to the rubber particles, the TS values were reduced by 9–53%. Furthermore, Ayrilmis et al. (2009b) incorporated rubber particles into oriented strand board (OSB) and found that the IB values were reduced by 16–50%, and the water resistance of the OSB panel was considerably improved due to the hydrophobic property of rubber.

Although it is well known that the strength performance of particleboard increases with an increase in resin content and panel density, it is desired to know the exact relationship between these parameters and the panel properties to obtain an optimal manufacturing process. In an attempt to improve the water or moisture resistance of poplar wood/rubber composites, the manufacturing parameters, rubber content, pressing temperature, resin content and panel density, were investigated as functions of the panel properties, MOR, MOE, IB, and TS. Using nonlinear regression and operation research theory, models were developed to estimate the optimal panel properties based on some practical production constraints.

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