超声水/NaOH 协同 DMDHEU 处理对臭椿材吸湿尺寸稳定性的影响机制研究

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摘　要:【目的】探究超声/NaOH 协同 DMDHEU 处理对臭椿材尺寸稳定性的影响及作用机制。【方法】选用约 20 年树龄臭椿木材，制成 2 cm×2 cm×2 cm（弦向×径向×轴向）臭椿木块，进行 NaOH（质量浓度 1%、4%）、超声（320 W，25 kHz，2 h）预处理，再用氮羟甲基树脂（DMDHEU）浸渍处理。测试 DMDHEU 浸渍前后样品的绝干密度、增重率和吸湿尺寸稳定性（11.3% RH, 25 ℃）变化。采用扫描电子显微镜、衰减全反射傅里叶变换红外光谱和 X 射线光电子能谱探究样品的微观结构、树脂分布和化学基团变化。【结果】DMDHEU 浸渍处理材的增重率和绝干密度均高于 DMDHEU 浸渍未处理材。DMDHEU 树脂浸渍材的游离羟基峰强度下降明显，且 1710 cm-1 和 1230 cm-1 处代表 C=O 和 C-N 的峰强度增加。DMDHEU 树脂进入木材内部，浸渍材的 C 价态发生变化，DMDHEU 树脂与细胞壁发生化学键结合，使具有亲水性的游离羟基转化为疏水的酯键和醚键。树脂固化后，DMDHEU 浸渍超声水预处理材的导管内壁出现均匀的树脂膜。超声 1% NaOH 处理材导管壁纹孔内有树脂沉积，超声 4% NaOH 处理材导管内壁出现隆起膜状树脂沉淀。与未处理材相比，DMDHEU 浸渍材的弦向和径向吸湿尺寸稳定性均有不同程度的提高。未处理材的弦向和径向湿胀率分别约为 2.01%和 1.22%，其中 DMDHEU 浸渍超声 4% NaOH 处理材的弦向和径向湿胀率分别降至约 0.55%和 0.38%。【结论】超声水预处理和超声碱预处理均可改善 DMDHEU 树脂的浸渍效果。超声预处理有利于 DMDHEU 树脂与细胞壁游离羟基发生结合，降低游离羟基的含量。DMDHEU 浸渍超声 NaOH 处理材的导管内部出现隆起状树脂分布，形成结构致密的树脂膜，能在一定程度上阻断木材吸湿水分通道。本研究中 DMDHEU 浸渍超声 4% NaOH 处理臭椿材的吸湿尺寸稳定性得到了最大程度的提升。

关键词：臭椿； DMDHEU； 超声水预处理； 超声碱预处理； 吸湿尺寸稳定性

Effect of Ultrasonic Water/NaOH Synergistic DMDHEU Treatment on the Hygroscopic Dimensional Stability of Ailanthus Altissima Wood

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Abstract: 【Objective】The objective of this study was to investigate the impact and contribution mechanism of ultrasonic water/NaOH synergistic DMDHEU treatment on the hygroscopic dimensional stability of Ailanthus altissima wood.【Method】Ailanthus altissima wood, approximately 20 years old, was selected and made into 2 cm

× 2 cm × 2 cm (tangential × radial × longitudinal) blocks. The samples were pretreated with NaOH (1 wt%, 4 wt%) and ultrasonication (320 W, 25 kHz, 2 h) and then impregnated with 1,3-dimethylol-4,5-dihydroxy ethylene urea (DMDHEU). The absolute dry density,the weight percent gain, and the hygroscopic dimensional stability (11.3% RH, 25 °C) were measured before and after DMDHEU impregnation. Scanning electron microscopy, attenuated total reflection Fourier transform infrared spectroscopy, and X-ray photoelectron spectroscopy were applied to investigate the microstructure, resin distribution, and chemical group changes of the samples.【Result】The weight percent gain and the absolute dry density of DMDHEU-impregnated samples were higher than those of DMDHEU-impregnated-untreated samples. The peak intensity of the free hydroxyl group of DMDHEU-impregnated samples decreased significantly, while the intensity of the peaks representing C=O and C-N at 1710 cm^{-1} and 1230 cm^{-1} increased. The valence state of C in DMDHEU-impregnated samples changed when resin entered into the wood. The DMDHEU resin was chemically bonded to the cell wall, converting the hydrophilic free hydroxyl groups into hydrophobic ester and ether bonds. After curing of the resin, uniform film distribution was observed on the inner walls of DMDHEU-ultrasonic-water-treated samples. Resin deposits were found in the pores of the ultrasonic-1%NaOH-treated samples, while film-like resin deposits were observed on the inner wall of the vessel in the ultrasonic-4%NaOH-treated samples. The tangential and radial hygroscopic dimensional stability of DMDHEU-impregnated samples improved to varying degrees compared with the untreated samples. The tangential and radial swelling rate of the untreated samples was 2.01% and 1.22%, respectively, while the tangential and radial swelling rate of the DMDHEU-ultrasonic-4%NaOH-treated samples was reduced to 0.55% and 0.38%, respectively.【Conclusion】The impregnation effect of DMDHEU resin was improved by both ultrasonic-water pretreatment and ultrasonic-alkali pretreatment. Ultrasonic pretreatment facilitated the binding of DMDHEU resin with the cell wall, and reduced the content of free hydroxyl groups. Spot-like resin distribution with a densely structured resin film formed inside the vessel of DMDHEU-ultrasonic-NaOH-treated samples , which could partially block the moisture absorption channels of the wood. In this study, the hygroscopic dimensional stability of DMDHEU impregnation with ultrasonic-4% NaOH-treated Ailanthus altissima wood was the best.

Keywords: Ailanthus altissima; DMDHEU; Ultrasonic-water pretreatment; Ultrasonic-alkali pretreatment; Hygroscopic dimensional stability