杨木单板阻燃染色工艺研究及优化

石鑫，秦生磊，刘扬光，储德淼*，沈晓双*，刘盛全*

（安徽农业大学林学与园林学院 林木材质改良与高效利用国家林业和草原局重点实验室 安徽合肥 230036）

摘要：【目的】磷酸二氢铵(ADP)是一种氮磷型无机阻燃剂，环保无毒。经 ADP 处理的木材可以增强其热稳定性、阻燃性。将 ADP 与酸性大红 3R 复配，在赋予木材优良阻燃性的基础上，进一步提高其装饰效果，从而制备出一种染色兼阻燃多功能化的木材。【方法】本文以杨木单板为试验研究对象，通过常压浸渍法对单板进行阻燃染色同步处理。其中，试验选取阻燃剂质量分数（0%、5%、10%、15%、20%、25%、30%）、染料质量分数（0.5%、1%、1.5%、2%、2.5%、3%）、温度（40℃、50℃、60℃、70℃、80℃、90℃）和时间（0.5h、1h、1.5h、2h、3h、4h）为主要影响因子，通过单因素试验，探讨各因子分别对上染率、色差、氧指数这 3 种评价指标的影响变化规律。在此基础上，利用模糊数学综合评判法对这 3 个评价指标进行综合评判，进而确定单板最佳复合改性工艺参数。【结果】阻燃剂浓度与单板上染率、色差呈现先上升后下降的趋势，与氧指数变化规律成正相关：当阻燃剂浓度为 15%、20%时，上染率与色差别达到最大值 15.27%、69.38NBS；染料浓度与单板上染率、色差呈现先上升后下降的趋势，与氧指数变化规律成负相关，当染料浓度为 1.5%、2%时，上染率与色差分别达到最大值 14.58%和 71.46NBS；温度与上染率、色差和氧指数总体上具有相似的变化规律，均是呈现先上升后下降的趋势，在温度为 80℃时，三者均达到了最大值，此时上染率最大为 13.89%，色差最大值 69.38NBS，氧指数最大为 50.1%；时间与单板上染率、色差呈现先上升后下降的趋势，氧指数先增加后逐渐趋于稳定，在时间为 2h、3h 时，上染率与色差分别达到最大值 13.89%和 69.56NBS。通过数学模糊综合评判法得出单板阻燃染色最佳的复合改性工艺参数为阻燃剂 30%，染料浓度 0.5%，温度 80℃，时间 3h，此时单板达到最佳的综合性能。【结论】阻燃剂带正电荷的 NH_4^+能与酸性染料带负电荷的磺酸基(-SO_3H)阴离子发生反应形成磺酸盐，产生较强的作用力，大幅提高酸性染料对木材表面的上染率，此外染料浓度增大不利于阻燃剂分子向木材内扩散，导致氧指数下降。

关键词：磷酸二氢铵；酸性染料；阻燃染色；数学模糊综合评判法

Research and optimization of flame retardant and dyeing process of poplar veneer

SHI Xin, QIN Shenglei, LIU Yangguang, CHU Demiao*, SHEN Xiaoshuang*, LIU Shengquan*

(Key Laboratory of Forest Wood Quality Improvement and Efficient Utilization, College of Forestry and Landscape Architecture, Anhui Agricultural University, Hefei, Anhui, 230036)

Abstract: 【Objective】Ammonium dihydrogen phosphate (ADP) is a nitrogen-phosphorus-type inorganic, environmentally friendly and non-toxic flame retardant. Thermal stability and flame retardancy of wood could be

enhanced by the ADP. In this study, ADP was compounded with acid Dahong 3R to further improve the decorative effect on the basis of giving wood excellent flame retardancy, so as to prepare a dyed and flame retardant wood. 【Methods】In this paper, poplar veneer was used as an research object, and flame retardant and dyeing of veneer was simultaneously treated by atmospheric pressure impregnation method. Mass fraction of flame retardant (0%, 5%, 10%, 15%, 20%, 25%, 30%), dye mass fraction (0.5%, 1%, 1.5%, 2%, 2.5%, 3%), temperature (40°C, 50°C, 60°C, 70°C, 80°C, 90°C) and time (0.5h, 1h, 1.5h, 2h, 3h, 4h) were selected as the main influencing factors. The impact and variation patterns of various factors on three evaluation indicators: dye uptake rate, color difference, and oxygen index were explored based on the single factor testing. On this basis, fuzzy mathematical comprehensive evaluation was used to comprehensively evaluate these three evaluation indicators, and the optimal process parameters of modified veneer were then determined.【Results】The concentration of flame retardant, dyeing rate and color difference on the veneer showed a trend of first increasing and then decreasing, which was positively correlated with the change of oxygen index: when the concentration of flame retardant was 15% and 20%, the difference between dyeing rate and color reached a maximum value of 15.27% and 69.38NBS; When the dye concentration is 1.5% and 2%, the dyeing rate and color difference reach the maximum value of 14.58% and 71.46NBS, respectively; Temperature and dyeing rate and color difference and oxygen index have a similar change in general. A trend of first rising and then falling at a temperature of 80°C was showed. The maximum staining rate was 13.89%, the maximum color difference was 69.38NBS, and the oxygen index was 50.1%. Between time and the dyeing rate and between time and chromatic difference showed a trend of first rising and then decreasing, and the oxygen index first increased and then stabilized. When the time was 2h and 3h, the dyeing rate and chromatic difference reached the maximum values of 13.89% and 69.56NBS, respectively. Through the mathematical fuzzy comprehensive evaluation method, it was concluded that the best process parameters of flame retardant and dyeing of veneer was 30% flame retardant, 0.5% dye concentration, 80°C temperature, 3h time. 【Conclusion】 The positively charged NH_4+ of the flame retardant can react with the negatively charged sulfonic acid group (-SO_3H) anion of the acid dye to form sulfonate, which produced a strong force and greatly increased the dyeing rate of the acid dye on the surface of wood. In addition, the increase of dye concentration was not conducive to the diffusion of flame retardant molecules into the wood, resulting in a decrease in oxygen index.

Key words: Ammonium dihydrogen phosphate; Acid dyes; Flame retardant and dyeing; Fuzzy comprehensive evaluation method