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Near-infrared Spectroscopy Detection Method for Compressive Strength of Fraxinus mandschurica

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***Abstract*—**This study used near-infrared (NIR) spectroscopy as a non-destructive test to predict the compressive strength (*i.e*., modulus of rupture (MOR) and the modulus of elasticity (MOE)) of *Fraxinus mandshurica* parallel to the wood grain. Tests were conducted with 120 small and clear wood samples to obtain the diffuse NIR reflectance spectra of the radial and tangent surfaces of the wood samples. Standard normal variable transformation (SNV) combined with Savitzky-Golay (SG) convolution smoothing algorithm was used to filter the raw NIR spectra. Uninformative variables elimination (UVE) and a genetic algorithm (GA) were utilized to identify specific wavelengths in the spectra that directly correlated to compression strength. Finally, a partial least squares (PLS) regression model was developed with the identified wavelengths to determine the MOR and MOE of the samples. The results showed the correlation coefficients of the prediction models for MOR and MOE were 0.88 and 0.89, respectively. The root mean square errors of prediction for MOR and MOE models were 7.37 and 0.49, respectively. Based on these results, it is feasible to accurately estimate the compressive strength of *Fraxinus mandshurica* (parallel to the grain) using NIR spectroscopy.

***Keywords*—**Near-infrared spectroscopy; Compression strength (parallel to wood grain), Uninformative variables elimination, Genetic algorithm.

I. Introduction

FRAXINUS mandshurica, a commonly used structural material, requires a high degree of structural performance and reliability, particularly with its compressive strength parallel to the wood grain. Traditional testing of wood compressive strength is to conduct destructive tests on small and flawless wood samples using a universal testing machine in accordance to standardized laboratory protocols. This method is accurate and reliable, but the sample preparation is cumbersome and the amount of testing time required is high. It cannot meet the actual needs of the forestry industry and the wood processing industry. Therefore, a non-destructive laboratory test method that can measure the mechanical properties of wood would have important application value and practical benefits to engineers.

Near-infrared (NIR) spectroscopy is a fast, non-destructive, and indirect analysis technology that has been widely used with some success in the areas of agriculture, food, medicine, paper testing, petroleum processing, and winemaking, in addition to other fields. In recent years, the application of NIR spectroscopy in the wood sciences has become increasingly extensive. This tool has been used to estimate the lignin and cellulose content in trees, and to analyze the mechanical, physical and chemical properties of wood [1][2][3]. Thumm and Meder used NIR to assess the stiffness of dry radiata pine clearwood and demonstrated that when the load is applied to the radial face then NIR spectra obtained from the radial face are preferred to that obtained from the tangential face, due to spectral information being obtained from both latewood and earlywood. Tong and Zhang estimated the mechanical properties of thermally-modified softwood (southern pine) using NIR; the authors observed a close relationship between the NIR spectral peaks and the mechanical properties of the wood. Eom *et al.* measured the surface moisture content of yellow poplar in real-time using a NIR technique. Moreover, NIR has been used by several investigators to detect wood surface defects [4][5], as well as to classify the species and origins of the wood specimens [6][7].

In this study, a fast and non-destructive testing method for measuring the compressive strength of *Fraxinus mandshurica* (parallel to the wood grain) was developed using near-infrared spectroscopy. First, a standard normal variable transformation combined with the Savitzky-Golay convolution smoothing algorithm was used to filter the collected NIR absorption spectra. Then, uninformative variables elimination (UVE) and genetic algorithm (GA) analyses were utilized on the recorded spectra to identify specific NIR wavelengths that correlated with the compressive strength of *Fraxinus mandshurica.* Finally, a calibration and a prediction model for the compressive strength (*i.e*., modulus of rupture (MOR) and the modulus of elasticity (MOE)) were developed using a partial least squares (PLS) regression algorithm. Through these analyses and evaluations of the models, it was deduced that there is a close correlation

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