Relationship between Anatomical Properties and Modulus of Rupture (MOR) of *Larix kaempferi* Carr

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ABSTRACT

*Larix kaempferi* is a tree with a major economic impact and is processed in large quantity every year in Korea. This study was carried out to collect basic data for the reasonable use of *Larix kaempferi* and to investigate the relation between anatomical properties and modulus of rupture (MOR) for heartwood and sapwood. As the length of earlywood tracheid and the radial wall thickness of earlywood tracheid and latewood tracheid increased, the modulus of rupture (MOR) increased, but decreased with increasing microfibril angle. Statistical analysis by the stepwise regression technique shows that the main factors affecting the modulus of rupture (MOR) of heartwood are the microfibril angle and the radial wall thickness of latewood tracheid, while those affecting MOR of sapwood are the length of earlywood tracheid and the microfibril angle.

Key words - *Larix kaempferi* Carr., Modulus of rupture, Anatomical property

I. INTRODUCTION

*Larix kaempferi*, introduced from Japan in 1904 and mainly planted in central south Korea, now provides major economic benefit. The tree is used for various purposes such as building interior materials, civil engineering materials, and flooring boards, and is produced in large quantity every year. The production of the tree is reaching 386,596m$^3$. And the growing stock is 55 million m$^3$ in 2010 (KFS, 2010). Because wood is an anisotropic material consisting of various cell tissues, variation is very diverse, not only between different kinds of tree but also within the same species and even within an individual specimen. Therefore, the basic properties need to be studied in order to gain an understanding of the wood properties. The factors affecting the strength of wood can be classified into internal factors, such as the kind of cell, structure of cell wall, direction of grain, moisture content, specific gravity and width of annual ring, and external factors, such as the form and size of a specimen, temperature and loading method (Bodig & Jayne, 1982; Kollmann & Cote, 1968). Particularly, it is known that anatomical factors exert many effects on mechanical properties. The microfibril angle existing in the middle lamella of the secondary wall of cells has also been reported to have a large effect on the mechanical and physical properties of wood (Bendtsen, 1978; Grossman & Wold, 1971; Kucera & Bariska, 1982; Meylan & Probine, 1968; Salmen & Ruvo, 1985) and it was an important factor determining the compression strength parallel to the grain and the modulus of elasticity (Taylor et al. 1992). Despite its large production, previous studies of *Larix kaempferi* had been confined to physical, anatomical, or mechanical properties, and only a few attempts have been made to study the synthetic interrelation. Thus, the present study of *Larix kaempferi* was conducted to acquire basic data for its reasonable use and to clarify the relation with the modulus of rupture (MOR) according to the anatomical properties by heartwood

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and sapwood, and earlywood and latewood.

II. EXPERIMENTAL

2.1 Samples

Fifteen straight larches from Jeollabuk-do, KOREA were used in this study (average D.D.H. 26cm, height 15.5m)

2.2 Specimens preparation for modulus of rupture (MOR)

Specimens sized 20(R) x 20(T) x 320(L)mm were made in accordance with KS F 2208(2004), in the region of the diameter breast height of exploited material timber. Forty samples were prepared to get the MOR data, respectively. These specimens were treated by humidification in a constant temperature and humidity chamber (temperature 20±1℃, humidity 65±5%) and reached an equilibrium moisture content of 12%, after which they were used for modulus of rupture (MOR) measurement.

2.3 Specimens preparation for optical microscopy

After the strength test, the specimens, exhibited strength differences despite the same physical properties such as the specific gravity and moisture content, were sorted out. The specimens of about 15 x 15 x 15mm were selected, left in water for 24 hours at the room temperature, and softened them in an autoclave for 30 minutes. The softened specimens were cut into three sections (radial, transverse, tangential) of 15-20µm in thickness with a sliding microtome, and then dyed with safranine. Next, they were wet in xylene after being dehydrated with an alcohol series and filled with Canada balsam, and permanent sliders were made. In addition, 2-3mm-thick, 15mm-long specimens were fabricated from the specimens used in making the three sections, placed into Schultze liquid for dissociation and dyed with safranine, after which temporary slides were made.

2.4 Measuring method

The tree ring widths, latewood percentage, and specific gravity of the specimens extracted from the neighboring part of the rupture were measured. After the specimens were humidified in a constant temperature and humidity chamber, MORs of those were measured in accordance with KS F 2206 (1980) by using a universal testing machine. The modulus of rupture (MOR) was calculated using the following formula:

\[
\text{Modulus of rupture (MOR) (MPa)} = \frac{3PL}{2BH^2}
\]

\[
P: \text{load, } L: \text{length of span, } B: \text{width, } H: \text{height}
\]

From the dissociated specimens, temporary slides of heartwood and sapwood, earlywood and latewood were made and enlarged 100 times under an optical microscope. The length of 100 randomly chosen tracheids was measured. In the cross section of the permanent slides, the width and radial walls of the tangential and radial directions of heartwood and sapwood, earlywood and latewood were enlarged 400 times, and the width and thickness of 100 randomly chosen tracheids were measured. In the tangential section of the permanent slides, the height of 100 randomly chosen rays was measured. After the radial sections cut with a microtome were dried, they were coated with a 200Å-thick gold layer and photographed with scanning electron microscopy (SEM) at an accelerating voltage of 10-15kV. The tilt angle of the microfibrils was determined by measuring the angle between the tracheid axis and the microfibril angle.

2.5 Statistical analysis

Stepwise regression technique was used for the statistical analysis to determine the impact factors of each anatomical property on the modulus of rupture (MOR).

III. RESULTS and DISCUSSIONS

3.1 Modulus of rupture (MOR) according to cell dimension