Digest of Doctoral thesis

Development of a method for estimating moisture content in green wood using vibrational properties

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It has been known that the moisture content (MC) of green logs and lumbers have large variation from individual to individual, especially some species including sugi which could have high heartwood MC. It is important to know the MC of green wood because it enables efficient usage of wood by fine tuning of the drying schedule and grading by air-dried density before drying. The purpose of this study is to develop a new method of MC estimation of the green wood with the MC above FSP, and to investigate the accuracy and precision of this method.

In Chapter 1, the literatures were reviewed. It became clear that it would be difficult to non-destructively determine the MC with accuracy when the MC was well above the fiber saturation point (FSP), as in green wood, since some proposed indices of MC were influenced both by MC and by mechanical property variation. On the other hand, it was found that the correlation between specific dynamic Young's modulus (E/ρ) and loss tangent (tan δ) in wood encompasses most of mechanical property variation of wood. Therefore, the purpose of this research was set to develop a new method for MC estimation in the range above FSP using this correlation.

In Chapter 2, the MC estimation equation was theoretically derived using this correlation. It was known that E/ρ decreases with increase of MC due to increase of apparent density increase though Young's modulus (E) and tan δ are constant above FSP. Therefore, the intercept of the regression line of the correlation decreases with increasing MC while the slope of it is constant. From the intercept, MC estimation equation was derived. From the equation, it was clear that this method requires the regression line at FSP, E/ρ and tan δ of target specimen. In addition, the calculation method of vibrational properties was also explained.

In Chapter 3, it was confirmed whether the correlation was true of air-dried or green lumber with defects, and the correlation coincides with previous studies or not. From the experiment using air-dried and green lumbers with defects such as core, knot and grain slope, defects don't seem to be affected to the correlation. On the other hand, it was revealed that there are some differences in the correlation between green specimens and air-dried and moisture-conditioned specimens from previous researches. Moreover, there were species dependency found in green specimens, which was not reported by air-dried specimens. It was suggested that these differences were caused by the difference in tan δ between green specimens and moisture-conditioned specimens.

In Chapter 4, MC of total of 85 logs of three species, sugi, hinoki and todomatsu were estimated. For the estimation, each regression line of the correlation measured from green small specimens of each specie in Chapter 3, and E/ρ and tan δ of logs from flexural vibration. The standard deviation in the estimation was ±15.7% except for 25.9% synthetic error. The synthetic error was considered to be caused by the difference in tan δ between small specimens and logs due to the difference in their supporting system. Moreover, the estimation accuracy largely decreases when the same regression line was used to all species without considering species dependency.

In Chapter 5, the cause of difference between tan δ from longitudinal vibration and that from flexural vibration, which was observed vibration test of 35 sugi logs was investigated. It was clarified that tan δ from longitudinal vibration was mostly larger than that from flexural vibration, and there was little correlation between them. On the other hand, it was found that the difference between them have positive correlation with apparent density difference between sapwood and heartwood due to moisture content difference. In order to clarify the influence of apparent density difference on longitudinal vibration, the longitudinal vibrational equation of cylindrical model with apparent density difference was solved. It was confirmed that shear strain energy increase with the decrease of apparent density difference by calculating the strain energies occurred at axial and shear deformation in longitudinal vibration. By assuming E/G and tan δ_S/tan δ_A from previous studies and calculating the rate of increase of tan δ with apparent density difference, it was appeared that the rate of increase of tan δ measured from sugi logs and calculated tan δ increase rate was well coincide with each other. Therefore, it was proposed that the tan δ from longitudinal vibration was strongly affected by apparent density difference between sapwood and heartwood.

In Chapter 6, it was shown by 35 sugi logs that the heartwood moisture content correlated to estimated moisture content using longitudinal vibrational properties by the proposed method. As shown in Chapter 5, tan δ from longitudinal vibration increase with increase of moisture content difference between sapwood and heartwood. When larger tan δ value was introduced into proposed estimation equation, estimated moisture content decrease. On the other hand, when there is difference between sapwood MC and heartwood MC, heartwood MC is smaller than average MC. Therefore, it was explained that estimated MC from longitudinal vibration have higher correlation with heartwood MC than average MC. Especially, in 29 sugi logs excluded logs with sapwood MC below 120% which were thought to start to dry, the coefficient of determination R^2 was 0.78, which suggested a possibility of highly accurate estimation of heartwood MC.