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A Simple Wood Quality Evaluation Technique using γ-Ray Attenuation in Some Tropical Hardwoods

ABSTRAK

Kertas ini melaporkan suatu teknik mudah untuk menentukan kualiti fizik bagi sebahagian kayu tropika. Pekali pengecilan linear sinar gama bagi lima spesis kayu telah diukur. Keputusan menunjukkan bahawa terdapat hubungan linear di antara pekali pengecilan dan ketumpatan kayu. Kajian ini dapat menunjukkan suatu kaedah mudah penilaian tak musnah (PTM) kualiti kayu berdasarkan pencirian fiziknya.

ABSTRACT

This paper reports a simple technique to evaluate the physical quality of some tropical woods. The gamma ray attenuation coefficients of five wood species were measured and the results show that there is a linear relationship between the attenuation coefficient and density of woods. This study could be used to demonstrate a simple non-destructive evaluation (NDE) of wood quality based on physical characteristics.

INTRODUCTION

In any manufacturing, fabrication or production process quality is achieved through commitment, planning and performance. Quality assurance would provide adequate confidence that products satisfy specified requirements through quality control, surveillance and audit (Zirnhelt 1990). However, in heterogenous materials that are subjected to age, climate and soils such as wood, quality assurance is associated more with species, grain sizes, fibre orientation and moisture content. Wood density is therefore dependent upon these parameters. Measuring wood density or, in a qualitative sense, the density gradient is very useful in the quality evaluation of forest products. The results can be used in estimating physical and mechanical properties, such as hardness, porosity, bending strength and stiffness, nail- and screw-holding strength, etc.

Wood density may be measured using several techniques such as gravimetric method and X-ray densitometer. Their drawbacks have been discussed elsewhere, for example Laufenberg (1986). Another method is using γ-ray attenuation techniques (Laufenberg 1986; Moschler and Dougal 1988). The nondestructive quality of this measurement allows the sample to be investigated before using it as a final product without damaging the part being tested. The principle used is to pass γ radiation through an object and the attenuated intensity of radiation beam is measured by a radiation detector. The attenuated intensity in a good geometry experiment can be described by the Lambert Equation $I = I_o\, exp(-\mu x)$ where I is radiation intensity after attenuation (counts/s), I_o is unattenuated radiation intensity (counts/s), μ is the linear attenuation coefficient (cm^{-1}) and x is the absorber thickness (cm). Since the beam intensity attenuation is due to the interaction of photons with electrons of atoms of the object the attenuation coefficient is therefore dependent upon atomic number of the atoms and energy of the photons, i.e. the linear attenuation coefficient is a function of the atomic number, Z, and energy, E, or $\mu(Z,E)$ (Elias *et al.* 1986, 1990a).

A scintillation counting system commonly applied in this technique has the disadvantages of having poor counting efficiency, is relatively expensive and requires some knowledge of electronic signal processing techniques. However, when the scintillation counter is not available gas-filled detectors such as G–M tubes and proportional counters could also be used. They are known to have ~100% counting efficiency. The electronic circuitry of a G–M tube is often built inside a scaler, so its usage does not require a knowledge of electronics, which is favourable to most wood technologists. In pursuing our main objective to design a simple nondestructive evaluation (NDE) system for quality evaluation of forest products (Elias *et al.* 1990b), we first investigated the basic principles of measurement using instruments commonly known to many scientists. This paper describes a simple technique to evaluate quality based on γ-ray attenuation coefficients of some tropical hardwoods using a G–M counter.

MATERIALS AND METHODS

Oven-dried wood samples were machined into equal-sized blocks of rectangular shape approximately 4 x 2 x 2 cm and weighed. The specimens were carefully examined for uniform appearance of the grain and straightness of fibres before cutting. Five samples were prepared for each species and each block has at right angles, smooth and parallel surfaces. The volume of the samples for each block was determined by multiplying their average thickness x width x length. For each sample the thickness, width and length were measured at several points. The density of the woods was then calculated in the usual manner. The overall uncertainty of the wood density is indicated in Table 1 and was due to volume determination of the wood only.

The linear attenuation coefficients for each of the wood species were measured separately by a transmission method. The ^{241}Am and ^{57}Co radioactive sources which emit low energy photons at energies 59.5 keV and 122 keV respectively were used. The activity for ^{241}Am and ^{57}Co sources was 7.39×10^9 and 6.61×10^6 becquerels respectively. A collimated γ-ray beam was allowed to pass through the samples perpendicular to the grain direction and the attenuated beam intensity was then measured at five different thicknesses from 2 cm to 10 cm. For each thickness, at least five series of counts were recorded from a scaler to obtain the average count. In order to determine the operational voltage of the G–M tube the counts at various applied voltages were first measured and a plateau curve was drawn. From the curve the applied voltage was set at 600 volts throughout the experiment corresponding to the constant count rate as registered by the scaler. A background count was established by counting radiation beam intensity of the environmental radiation while closing the shutter of the source holder. The counting was done several times during and after the experiment to ensure no abnormality in the counts of the background due to gas amplification in the counter. When there was no sample between the source and the detector the count was taken as the unattenuated radiation intensity.

RESULTS AND DISCUSSION

The species and oven-dry volume densities of the woods used in this experiment are shown in Table 1. Also shown are the hardness classification and colour of the samples which were taken from a booklet on common commercial timbers of Peninsular Malaysia of the Forest Research Institute of Malaysia (FRIM 1990). The results show that there is a consistent relationship between the density and physical quality of classification of hardness of the woods. The density increases with an increase in the hardness. For heavy hardwoods the density is higher than that of the medium hardwoods. Note that in the commercial timbers of Peninsular Malaysia, Cengal and Tembusu are classified as heavy hardwoods, Kapur is a medium hardwood, while Sepetir and Acacia are light hardwoods (FRIM 1990). Also included in this study is Pine, which has been classified as a softwood as indicated in the table.

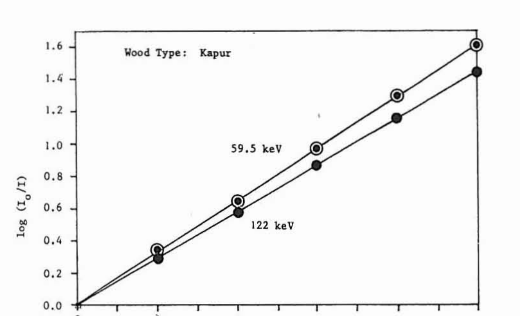

Fig. 1: Ratio of unattenuated and attenuated radiation beam counts against wood thickness for kapur (Dryobalanops aromatica) at γ- ray energies 59.5 keV and 122 keV.

Fig. 1 shows the curves of the ratio of count of the radiation beam, $\log(I_o/I)$ versus wood thickness, for two γ-ray energies, for Kapur. The gradient gives the linear attenuation coefficient of the wood. At the lower γ-ray energy the linear attenuation coefficient is higher than that of the higher energy. Samples from other wood species produce graphs

TABLE 1
Oven-dry volume density and classification of some tropical hardwoods used in this study

Local Name (species)	Density (kg m^{-3})	Class	Remarks (colour)
Cengal (*Neobalanocarpus heimii*)	947±12	Heavy hardwood	Yellow-brown
Tembusu (*Fagraea fragrans*)	857±16	Heavy hardwood	Light yellow
Kapur (*Dryobalanops aromatica*)	715±20	Medium hardwood	Rose-red
Sepetir (*Sindora velutina*)	687±22	Light hardwood	Golden-brown
Acacia (*Acacia mangium*)	579±16	Light hardwood	Yellow-brown
Pine (*Pinus caribaea*)	530±18	Softwood	Creamy-white

of a similar pattern but with different gradients. *Fig. 2* shows the γ-ray linear attenuation coefficient of the woods plotted against the density. The results show that the attenuation coefficient increases linearly with an increase in wood density. The attenuation coefficient of heavy hardwoods is higher

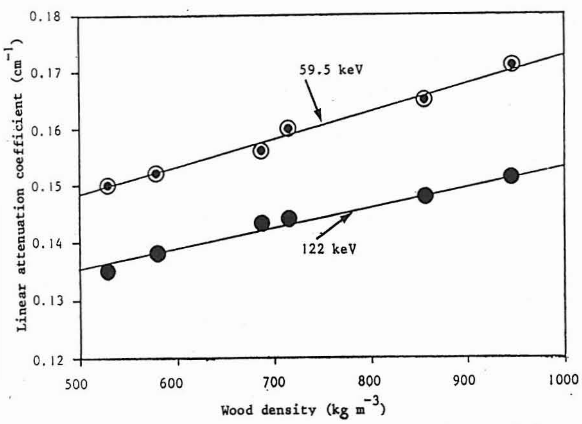

Fig. 2: Linear relationship beteween γ-ray attenuation coefficient and density of some tropical hardwoods at energies 59.5 keV and 122 keV.

than that of medium and light hardwoods. Our results are in agreement with previous results of Moschler and Dougal (1988) who measured the attenuation coefficients for some temperate woods of densities from about 350 to 800 kg m^{-3} and obtained the values of μ from about 0.05 to 0.16 cm^{-1} using ^{241}Am source. Nevertheless, the differences of less than 5% compared with our results are expected considering the fact that their equipment and radiation beam geometry were different from the present work. The results indicate that wood quality can be based on the γ-ray attenuation characteristics. A simple non-destructive evaluation technique could be developed to evaluate the quality of wood products based on the γ-ray attenuation coefficients which can be made faster, are non-invasive and offer better resolution than the traditional cutting and weighing method of density determination.

The results also show that the attenuation coefficient at energy 59.5 keV is higher than that of the 122 keV energy, in line with expectations. This means that a better characterization of wood quality is achieved at lower energy than that of the higher γ-ray energy. Nevertheless, at very low γ-ray energies the variation of the attenuation coefficient within the same wood species was observed by some researchers (Olson and Arganbright 1981). Some trace elements have a large elemental attenuation coefficient in low energy range. This could be overcome by not using radiation of very low energy, such as 6 keV photons from ^{55}Fe source. Moisture present in wood also increases the attenuation coefficient (Loos 1961) and thus, the moisture content of the wood must be determined prior to any attenuation coefficient measurements.

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ELIAS SAION, ZAINAL ABIDIN SULAIMAN,
PUVANASVARI SUBRAMANIAM,
MOHD YUSOF SULAIMAN
and MOHD HAMAMI SAHARI[1]

Department of Physics
Faculty of Science and Environmental Studies
Universiti Pertanian Malaysia
43400 UPM Serdang, Selangor Darul Ehsan,
Malaysia.

[1]*Department of Forest Products*
Faculty of Foresty
Universiti Pertanian Malaysia
43400 UPM Serdang, Selangor Darul Ehsan,
Malaysia.

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