A STUDY ON RELATIONSHIP BETWEEN THE DENSITY, HARDNESS AND THE SPECIES OF MALAYSIAN WOODS USING ULTRASONIC METHOD

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UNIVERSITI MALAYSIA TERENGGANU

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A STUDY ON RELATIONSHIP BETWEEN THE DENSITY, HARDNESS AND THE SPECIES OF MALAYSIAN WOODS USING ULTRASONIC METHOD

By
Ong Moon Ping

A proposal submitted in partial fulfillment of the
requirement of the award of the degree of
Bachelor of Applied Science
(Physics, Electronics and Instrumentation)

DEPARTMENT OF PHYSICAL SCIENCES
FACULTY OF SCIENCE AND TECHNOLOGY
UNIVERSITY MALAYSIA TERANGGANU
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Adalah ini diakui dan disahkan bahawa laporan penyelidikan bertajuk:.A study on relationship between the density, hardness and the species of Malaysian woods using ultrasonic method oleh Ong Moon Ping no. matrik: UK13419 telah diperiksa dan semua pembetulan yang disarankan telah dilakukan. Laporan ini dikemukakan kepada Jabatan Sains Fizik sebagai memenuhi sebahagian daripada keperluan memperolehi Ijazah Sarjana Muda Sains Gunaan (Fizik Elektronik & Instrumentasi), Fakulti Sains dan Teknologi, UMT.

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DECLARATION

I hereby declare that this thesis entitled a study on relationship between the density, hardness and the species of Malaysian woods using ultrasonic method is the result of my own research except as cited in the references.

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A STUDY ON RELATIONSHIP BETWEEN THE DENSITY, HARDNESS AND THE SPECIES OF MALAYSIAN WOODS USING ULTRASONIC METHOD

ABSTRACT

Since wood is a renewable resources and Malaysia is one of the most forested countries in the world. Among tropical forest countries, Malaysia supplies 80% of the tropical sawn timber to international trade. Nowadays, ultrasonic method in determining the species of Malaysian wood is not so popular in Malaysia. There are a lot of studies and research on wood had been carried out such as microwave, x-ray scanning method and ultrasonic method. Previous research showed that many of researchers using ultrasonic methods to investigate the properties of wood. This research was done using the ultrasonic method to determine the species of Malaysian wood. The species of wood is obtained by using ultrasonic diffractometer with the frequency above 20 kHz. There are five species of wood chosen in this research, which are Seraya Kitan, Merawan, Balau, Nyatoh and Chengal. The density, hardness and the reflection of the ultrasonic wave were affected by the moisture content of each species of wood. The moisture content of each species of wood is dried up using oven at the temperature of 105°C. The rectangular wooden block size is chosen because the moisture content of the wood samples was easily to dry up due to the larger surface of the wood samples. The acoustic wave propagation phenomena in wood are related to the microstructure of the wood. The ultrasonic signal received can be determine the species of wood. The relationship between density, hardness and each species of wood is distinguished. As the density and hardness of the wood increased, the reflection of the ultrasonic wave is decreased.

KAJIAN TERHADAP HUBUNGAN ANTARA KETUMPATAN, KEKERASAN DAN SPESIES BAGI KAYU-KAYAN MALAYSIA DENGAN MENGGUNAKAN KAEDAH ULTRASONIK

ABSTRAK

Sejak kayu ialah satu sumber yang boleh diperbaharui dan Malaysia adalah satu daripada negara yang terbanyak berhutan dalam dunia. Antara negara hutan tropika, Malaysia membekalkan 80% daripada kayu tropika terhadap perdagangan antarabangsa. Dalam masa sekarang ini, kaedah ultrasonik dalam menentukan spesies kayu-kayan Malaysia bukan begitu popular di Malaysia. Terdapat banyak pengajian dan penyelidikan pada kayu telah dijalankan seperti gelombang mikro, kaedah x-ray dan kaedah ultrasonic. Kajian yang sebelumnya telah menunjukkan kebanyakan para pengkaji menggunakan kaedah-kaedah ultrasonik untuk menyiasat sifat-sifat kayu. Penyelidikan ini dibuat dengan menggunakan kaedah ultrasonik untuk menentukan spesies kayu Malaysia. Spesies kayu dapat diperolehi dengan menggunakan ultrasonik difraktometer dengan frekuensi 20 kHz ke atas. Lima spesis kayu dipilih dalam penyelidikan ini, iaitu Seraya Kitan, Merawan, Balau, Nyatoh dan Chengal. Kandungan lembapan dalam kayu akan menjejaskan ketumpatan, kekerasan dan pantulan gelombang ultrasonik. Kandungan lembapan setiap spesies kayu dikeringkan dengan menggunakan ketuhar pada suhu 105°C. Blok kayu dipilih kerana permukaan kayu lebih besar dan kandungan lembapan dalam kayu lebih mudah untuk dikeringkan. Fenomena perambatan gelombang akustik dalam kayu adalah berhubungan untuk mikrostruktur kayu. Isyarat ultrasonik yang diterima boleh menentukan spesies kayu. Hubungan antara ketumpatan, kekerasan dan setiap spesies kayu dapat dikaji. Sekiranya ketumpatan dan kekerasan kayu bertambah, pantulan bagi gelombang ultrasonik akan berkurang.

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CHAPTER 1

INTRODUCTION

Malaysia, roughly the size of Norway, has a landmass of 32.86 million hectares, of which almost 60% which representing 19.25 million hectares is covered with natural forests. Malaysia's forests consist of complex ecosystems rich and varied in flora and fauna. Malaysian hardwoods have been used in a wide variety of industrial and domestic applications for many decades, both in Malaysia and around the world. While 2,500 different tree species are to be found in the tropical rainforests of Malaysia, 406 species are harvested for commercial use. Malaysian timbers are particularly suitable and widely used for flooring, building and construction, furniture, joinery, plywood/veneer, railway sleepers, paneling, and partitioning.

1.1 Categories of Malaysian Timbers

Malaysian timbers can be divided into three main categories: heavy hardwoods, medium hardwoods and light hardwoods.

1.1.1 Heavy Hardwoods

These are timbers with densities of 800 to 1,120 kg per cubic meter at 15% moisture content. They are naturally durable, containing substances which repel wood-destroying agents. They can safely be used without preservative treatment in all climates. Main uses are in heavy construction and flooring, railway sleepers, door and window frames. Species include Balau and Chengal.

1.1.2 Medium Hardwoods

These are timbers with a density of 720 to 880 kg per cubic meter at 15% moisture content. Some of these timbers are heavy and strong enough to be classified as "heavy hardwoods", but under tropical conditions they lack natural durability unless properly treated with preservatives. In temperate climates, which are less conducive to wood-destroying agents, they are naturally durable. Uses include construction, parquet flooring, plywood/veneer, paneling, windows, doors and frames. Species include Keruing, Meranti and Merawan (Malaysian Timber Council's Fact Sheet).

1.1.3 Light Hardwoods

These are timbers with a density of 400 to 720 kg per cubic meter and at 15% moisture content. They are "generally utility" timbers, but are also excellent for high class joinery work, cabinet making, furniture and decorative paneling. Species include Bintagor, Machang, Meranti, Nyatoh and Ramin (Malaysian Timber Council's Fact Sheet).

Wood is a material which is light, strong and easily worked. It is a natural material with a variability which adds greatly to its charm and beauty. It is also a complex natural material, both anisotropic and inhomogeneous in construction. It is generally modeled as an orthorhombic solid having three mutually perpendicular axes of symmetry giving rise to nine independent elastic constants. Each individual species has its own characteristic structures and consequent range of variation of elastic constant. These arise from the natural growth origins of the material. The elastic properties of wood can be shown to be closely linked to its cellular structure.

1.2 Wood Defects

Wood is far from a stable, consistent material. One of the biggest challenges of woodworking is learning to work within the constraints of a wood's properties. There are ten types of common wood defects:

1.2.1 Blue Stain

Blue Stain is a bluish gray discoloration on the woods surface. This feature is most common in woods like Holly, Pine, and Sycamore. It caused by mold that grows in warm and moist area, usually poorly ventilated.

1.2.2 Bow

Bow is a curve along the face of a board that usually runs from end to end. It caused by improper storage. It also caused by usually moisture evaporation from one side and not the other.

1.2.3 Checks or splits

Checks are breaks at the end of a board that run along the grain. Checks and splits are usually restricted to the end of a board. It caused by rapid drying.

1.2.4 Crook

Crook is warping along the edge from one end to the other. This is most common in wood that was cut from the center of the tree near the pith. It can be caused by improper drying and storage or the presence of reaction wood.

1.2.5 Cup

Cup is warping along the face of a board from edge to edge. This defect is most common of plain-sawn lumber. This defect can be caused when one board face dries at a faster rate than the other.

1.2.6 Dead or loose knot

Dead or loose knot is a dark, usually loose knot. This is caused by a dead branch that was not fully integrated into the tree before it was cut down.

1.2.7 Gum, Sap or pitch

Gum, sap or pitch is a accumulations of a resinous liquid on the surface or in pockets below the surface of wood. It caused by injury to the tree.

1.2.8 Machine burn

Machine burn is a dark streak along the face of a board. It usually caused by planer blades that are dull or spun on a part of the board for too long.

1.2.9 Ring check

Ring checks are breaks in the wood along the annual growth rings. It can be caused by improper drying or damage during transport.

1.2.10 Tiger knot

A know which is tightly integrated into the surrounding wood. This was once a branch that was incorporated into the tree as its girth increased.

1.2.11 Twist

Twist is a warping in lumber where the ends twist in opposite directions. It can be caused by growing conditions, uneven drying or the presence of reaction wood.

1.2.12 Wormholes

It is a small hole in the wood. This is caused by insects boring through the wood (WoodZone Woodworking Retail Store, 2008).

1.3 Ultrasonic Diffractometer

Ultrasound is cyclic sound pressure with a frequency greater than the upper limit of human hearing. Although this limit varies from person to person, it is approximately 20 kilohertz in healthy, young adults and thus, 20 kHz serves as a useful lower limit in describing ultrasound. The production of ultrasound is used in many different fields, typically to penetrate a medium and measure the reflection signature or supply focused energy. The reflection signature can reveal details about the inner structure of the medium.

The passage of ultrasonic waves through an anisotropic inhomogeneous material such as wood involves complex interactions between the physical vibrations of the ultrasound and the elastic response of the wood. The ultrasonic signal, which meets a defect in its way, would be partly reflected and will be received by the transmitter, while the reduced signal by the receiver. The proportion of these two signals can be used to investigate the internal defect (Tanasoiu et al, 2002). The many species of wood have subtly different elastic responses. Using ultrasonic diffraction machine is to investigate the types and defects of the woods.

1.4 Objectives

i. To determine the relationship between the density, hardness and the ultrasonic waveform in Malaysian woods.
ii. To determine the species of wood using ultrasonic method.
iii. To determine the inner and surface defect of woods using metallurgical microscope.

1.5 Research Significant

Nowadays, the ultrasonic method is seldom used in determining the species of wood in Malaysia. Ultrasonic method is more portable and convenient in determining the species of Malaysian woods compared to others methods such as x-ray scanning method and microwave method which had to be done in the laboratory. Ultrasonic method is non-destructive method in testing the wood samples proving that this method is more suitable in determining the species of wood.

1.6 Problem Statement

The use of ultrasonic method for determining the species of wood has its limitation itself. The main limitation is the measured values of one species of wood will always overlapped with the measured values of another species of wood if both wood samples has similarly density and hardness properties. The moisture content in the wood samples is changing in different weather. The intensity of ultrasonic waveform to propagate the wood sample is always influenced by the moisture content of the wood itself.

CHAPTER 2

LITERATURE REVIEW

Over the years the forest products industry has recognize the importance of wood make products. Many researches are being found on the wood and forest products. Since some of the methods had limitations itself, therefore to find the characteristics of wood was considered difficult.

2.1 Neural Network Analysis of Ultrasonic Signals

The example of one related studied is using the neural network analysis of ultrasonic signals to classify traces from species which had overlapping velocity values as well as overlapping received signal amplitudes. Clearly the ultrasound signal carries more information than that which can be obtained by measuring velocity and attenuation of the signal (Jordan et al., 1998).

2.2 Ultrasonic Testing for Nondestructive Technique of Standing Trees

The earliest method was to take an increment core from the tree, (which is considered non-damaging for its life) and to develop different nondestructive technique for the study of main physical characteristics of wood (Bucur, 2004). Many studies have been carried out on the propagation of ultrasound in wood. The majority of these studies focus on measuring the group velocity or relative attenuation in the material to estimate a physical parameter such as an elastic constant. Material waves which have passed through a particular species of wood may be expected to show the influence of the species through they have travelled. The range of measured values of wave velocity and attenuation for one species often overlaps with the measured values from other species. This implies that identifying the species of wood from ultrasonic waveform is a difficult task (Jordan et al., 1998).

2.3 Image Segmentation Algorithms Applied to Wood Defect Detection

Image segmentation is a key stage in the detection of defects in images of wood surfaces. While there are many segmentation algorithms, they can be broadly divided into two categories based on whether they use discontinuities or similarities in the image data. Each algorithm can also be categorized based on other factors such as whether it uses colour or grayscale data and is a local or global operator. While this presents a wide variety of approaches for segmenting images of features on wood surfaces, it also makes it difficult to select the most appropriate techniques. This paper presents the results obtained from using a variety of algorithms for wood surface feature detection and defines several measures used for examining algorithm performance. A region-based, similarity algorithm that was a combination of clustering and region-growing techniques exhibited the best overall performance. This was particularly true for defects that are subtle, meaning they blend in with other natural features on wood surfaces that are not considered defects. Examples include blue stain, pitch streaks, and wane. The clustering with region growing algorithm improved the detection accuracy of pitch streaks by over 20 percentage points compared to the next best algorithm. However, if subtle defects are not of interest, the edge detection algorithms performed as well as the region growing algorithm but with slightly better clearwood detection accuracies (Brunner et al., 2003).

2.4 Microwave

It is possible to determine properties of wood using microwave scanning techniques. Compared to ultrasonic method used in the research with previous research, the microwave method was to verify the measured values from a microwave imaging sensor to find the relationship between the density, attenuation and the moisture content in the wood sample. The attenuation and phase shift of an electromagnetic wave transmitted through birch wood were measured and compared with theoretical calculated values. The density distribution of the test piece was determined by computer tomography scanning. The result showed good correspondence between measured and theoretical values. The proportion of noise was higher at low moisture content due to lower attenuation. There is more noise in attenuation measurement than in measurement of phase shift. A reason for this could be that wood is an inhomogeneous material in which reflections and scattering affect attenuation more than phase shift. The microwave scanner has to be calibrated to a known dielectric to quantify the error in the measurement. (Hannson et al., 2005).

2.5 X-Ray Scanning Method

X-ray scanning methods are based upon the attenuation of a radiation beam passing through a material. X-ray scanning has been used to detect decay, knots, checks, pitch pockets, and honeycomb in wood. Methods that utilize x-ray scanning are capable of producing fast and high quality images of defects in wood. X-ray computed microtomography (microCT), being the high resolution variant of the medical CT scanner, overcomes such limitations. A series of non-invasive views through the sample (i.e., radiographic projections recorded from different viewing angles) are reconstructed mathematically into transverse two-dimensional (2-D) cross-sections with micrometer resolution. Moreover, X-ray microCT also provides a means to study the three-dimensional (3-D) internal microstructure of the sample. In combination with adequate software, automatic image processing of the 2-D and the 3-D images can be performed in limited time. The purpose of the paper is to demonstrate that microCT can also be successfully applied within the scope of wood anatomical research.

It is tested whether transverse cross-sections obtained with this novel technique can be used for quantifying wood anatomical characteristics instead of optical micrographs of stained thin sections. Self-developed software was thereby used to analyse the microCT images in order to automatically determine the inner vessel diameter, the transverse cross-sectional surface area of the vessels, the vessel density and the porosity. Particular attention was paid to the correct performance and accuracy of this new software. As a case study, samples of stem wood for a young beech and a young oak tree were analysed for differences in vessel anatomy. It is known that beech has a diffuse-porous wood matrix, while oak has ring-porous wood. For this purpose, the performance of X-ray microCT was evaluated against use of optical micrographs obtained by conventional microtomy. The potential of microCT for 3-D renderings of xylem microstructure was also evaluated (Steppe et al., 2004).

2.6 Relationship between Density and Ultrasonic Velocity in Brazilian Tropical Woods

The velocity of sound in wood is influenced by species, moisture content, temperature and anatomical direction. The latter is due to the fact that the propagation velocity in a solid depends on its elastic properties and its density. Such differences can vary depending on whether the species studied are softwood or hardwood and also according to the soil and climate conditions. Density is one of the parameters most widely used to evaluate mechanical properties of wood and it is an important factor that affects the velocity of an ultrasonic wave. The manner in which the propagation of the ultrasonic wave is affected by the structure of the material results in parameters that can lead to the characterization of the material. Several studies have demonstrated

CHAPTER 3

METHODOLOGY

This is a research that requires the Malaysian wood as the sample for studying the characterization of the wood itself. The Ultrasonic diffractometer and metallurgical microscope methods will be applied to test the wood sample for analysis.

3.1 Collection and sample preparation

There are five species of wood will be chosen for this study. The wood species are Seraya Kitan, Nyatoh, Balau, Chengal and Merawan. The wood samples are selected from the stocks of a wood processing factory in Kuala Terengganu and are high quality wood. The wood samples are then kept in the dry place. The wood samples are then cut into several sizes using wood sawing machine. Different sizes of the wood samples are used in the different experiment.

3.2 Dried the wooden block using oven

The wooden blocks were weighted using triple beam balance before heated. The wooden blocks were then put on a sheet of aluminum foil and placed into the oven. The wooden blocks were heated up to 100°C to dry up the moisture content. The wooden blocks were heated up every 2 hours and the weight had been recorded. The good relationship between the velocity of sound and mechanical properties of wood. It should also be noted that the micro structural characteristics of hardwoods are more anisotropic and complex relative to softwoods and thus favor the dissipation of ultrasonic wave. Researchers conducted studies on the relationship between ultrasonic velocity and density of wood. These results showed different relationships between ultrasonic velocity and density as follows: velocity increases with increased density; velocity is not affected by density and finally it decreases with increased density. (Fabiana et al., 2006)

The above review lists methods where major research effort has been directed to locate and identify features in wood. Every method have its limitations, ultrasound method will be the most suitable method in characterizing the species of wood. Ultrasonic method is considered as non-destructive method.

steps were repeated until the constant weight of the wooden blocks is obtained. The moisture content of the wooden block had to be heated up until in a dry condition due to the moisture content of each species are not in the same condition. The density of the wooden blocks increased with moisture content which affected the reflection of the ultrasonic wave. The volume is calculated by multiplying the length, width and height of the wooden blocks.

Table 3.1: Weight of the wooden block before heated and after heated for several hours at the temperature of 105°C

Species	Weight (with moisture content) (g)	Weight (after heated up for 1.5 hours) (g)	Weight (after heated up for 3 hours) (g)	Weight (after heated up for 4.5 hours) (g)	Weight (after heated up for 6 hours) (g)	Weight (after heated up for 7.5 hours) (g)
Merawan						
Chengal						
Nyatoh						
Seraya Kitan						
Balau						

The wooden block is heated up to 105°C to make sure the moisture content inside the wood was dried. The maximum temperature for the moisture content to dry is at around temperature of 100°C, therefore the oven used is set at 105°C. After the samples were heated up to a constant weight, the samples were taken out and calculate the density.

Table 3.2: Volume, weight and density of the wooden block

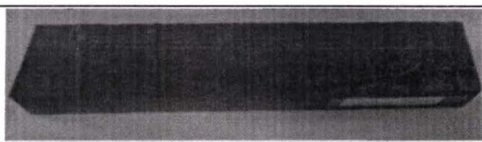
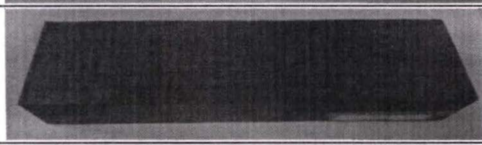
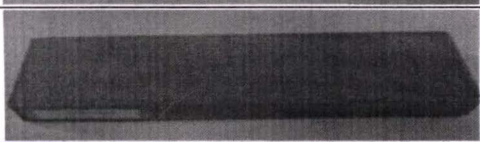
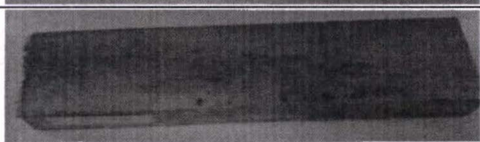
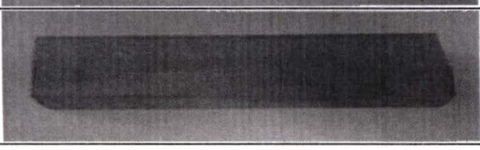
Species	Volume (cm^3)	Weight (In dry condition) (g)	Density with moisture content (g/cm^3)	Density (In dry condition) (g/cm^3)	Density (In dry condition) (kg/m^3)
Merawan					
Chengal					
Nyatoh					
Seraya Kitan					
Balau					

The Table 3.2 showed the volume, weight of wood samples before heated and after heated and density of wood before heated and after heated. The length, width and height of the wood is measured. The weight of the wood is measured using triple beam balance.

3.3 Ultrasonic Diffractometer

The wood sample of each species are been tested using ultrasonic diffractometer. The wood samples of each species were cut into 5cm x 2.5cm x 20cm. The wood samples were heated and dried up using oven to obtain the constant weight. The receiver and the transmitter of the ultrasonic diffractometer are set to fix at the position. The wood sample is then put on the middle of the transmitter and the receiver. The distance between the wood sample and the transmitter are almost equally with the distance of the receiver and the wood sample. The ultrasonic waves were produced form the source and then propagate through the wood samples. The result is recorded using software and a graph obtained. The steps are repeated with another species of the wood sample

Table 3.3: The size of the samples used in ultrasonic experiment

Sample	Species	Size of the sample
	Seraya Kitan	5cm x 2.5cm x 20cm
	Nyatoh	5cm x 2.5cm x 20cm
	Chengal	5cm x 2.5cm x 20cm
	Merawan	5cm x 2.5cm x 20cm
	Balau	5cm x 2.5cm x 20cm

The wooden block was chosen in this experiment because the wooden blocks were well-processed from the wood factory, which is the moisture content of each species can be considered as in the same quantity. Compared using standing tree as a sample, the moisture content would influence reflection of the ultrasonic wave. The moisture content of the wooden block was easily to dry up using oven due to the larger surface compared to standing trees.

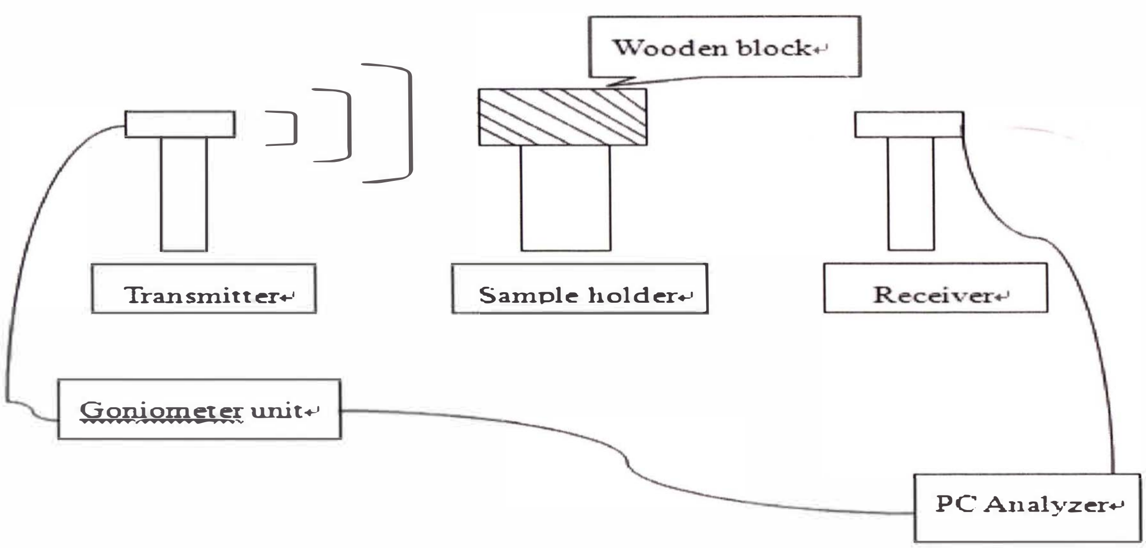
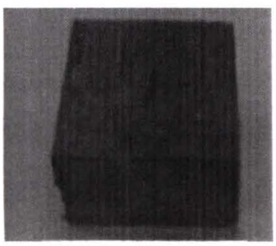
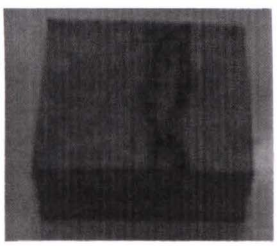
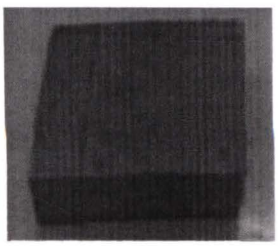
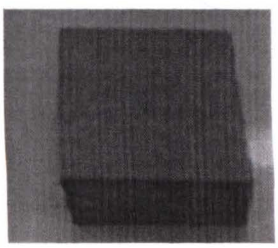


Figure 3.1 Ultrasonic Diffractometer

3.4 Metallurgical Microscope

The wood sample of each species is cut into 5cm x 2.5cm x 5cm. The Metallurgical Microscope is switched on and interfaced to computer. The wood sample placed on the specimen stage. The Eyepiece On/Off pin is the push in. The lowest objective (10x) is been used followed by the highest objectives (50x). The coarse focus adjusted slowly until a clear image of the sample can be seen form the eyepiece. Fine focus is used to get a shaper image of the sample after course focus had been adjusted. The Motic Images Plus 2.0 software is used and the computer is on. Motic MCCamera used to capture the sample image on the computer screen. The wood sample is then saved in the provider folder.

Table 3.4: Preparation of the wood samples in metallurgical microscope experiment

Sample	Species	Size of the sample
	Seraya Kitan	5cm x 2.5cm x 5cm
	Merawan	5cm x 2.5cm x 5cm
	Chengal	5cm x 2.5cm x 5cm
	Balau	5cm x 2.5cm x 5cm

The wood samples were cut into 5cm x 2.5cm x 5cm since the size of the specimen stage is considered as very small. The metallurgical microscope is used to determine the surfaces of the wood samples using different magnification. The highest resolution of metallurgical microscope is 50X which is suitable to determine the surfaces of wood samples. This method is used to focus and study on surface of different species of wood.

CHAPTER 4

RESULTS AND ANALYSIS

The wood samples were heated up at temperature of 105°C to constant weight which considered as no moisture content inside the samples.

4.1 The calculation of constant weight and density of wood samples

Table 4.1: Weight of the wooden block before heated and after heated for several hours at the temperature of 105°C after the experiment

species	Weight (with moisture content)	Weight (after heated up for 1.5 hours)	Weight (after heated up for 3 hours)	Weight (after heated up for 4.5 hours)	Weight (after heated up for 6 hours)	Weight (after heated up for 7.5 hours)
Merawan	27.1g	24.3g	23.8g	23.7g	23.5g	23.5g
Chengal	29.1g	27.3g	26.7g	26.4g	26.2g	26.2g
Nyatoh	395.4g	385.4g	381.1g	377.7g	376.9g	376.9g
Seraya Kitan	42.8g	40.1g	39.0g	38.6g	38.5g	38.5g
Balau	32.8g	31.1	30.4g	30.1g	30.0g	30.0g

The constant weight of wooden blocks was obtained after 7.5 hours. The weight is measured using triple beam balance.

Table 4.2: Calculation on volume, weight and density calculated of the wooden block

Species	Volume (cm^3)	Weight (In dry condition) (g)	Density with moisture content (g/cm^3)	Density (In dry condition) (g/cm^3)	Density (In dry condition) (kg/m^3)
Merawan	32.02	23.5	0.8463	0.7339	733.9
Chengal	31.00	26.2	0.9387	0.8452	845.2
Nyatoh	586.18	376.9	0.6745	0.6430	643.0
Seraya Kitan	37.88	38.5	1.1299	1.0164	1016.4
Balau	28.68	30.0	1.1437	1.0460	1046.0

The volume was calculated by multiplying the length, width and height of the wooden blocks. The density was calculated by dividing the constant weight (after heated for 7.5 hours) with volume of the wooden block. The results showed that Balau has highest density compared to other wood samples. The density of Seraya Kitan is nearly same as Balau, which is second highest, followed by Chengal, Merawan and Nyatoh has the lowest density compared to others wood samples.

4.2 The intensity of ultrasonic wave reflected by the wood samples using ultrasonic method

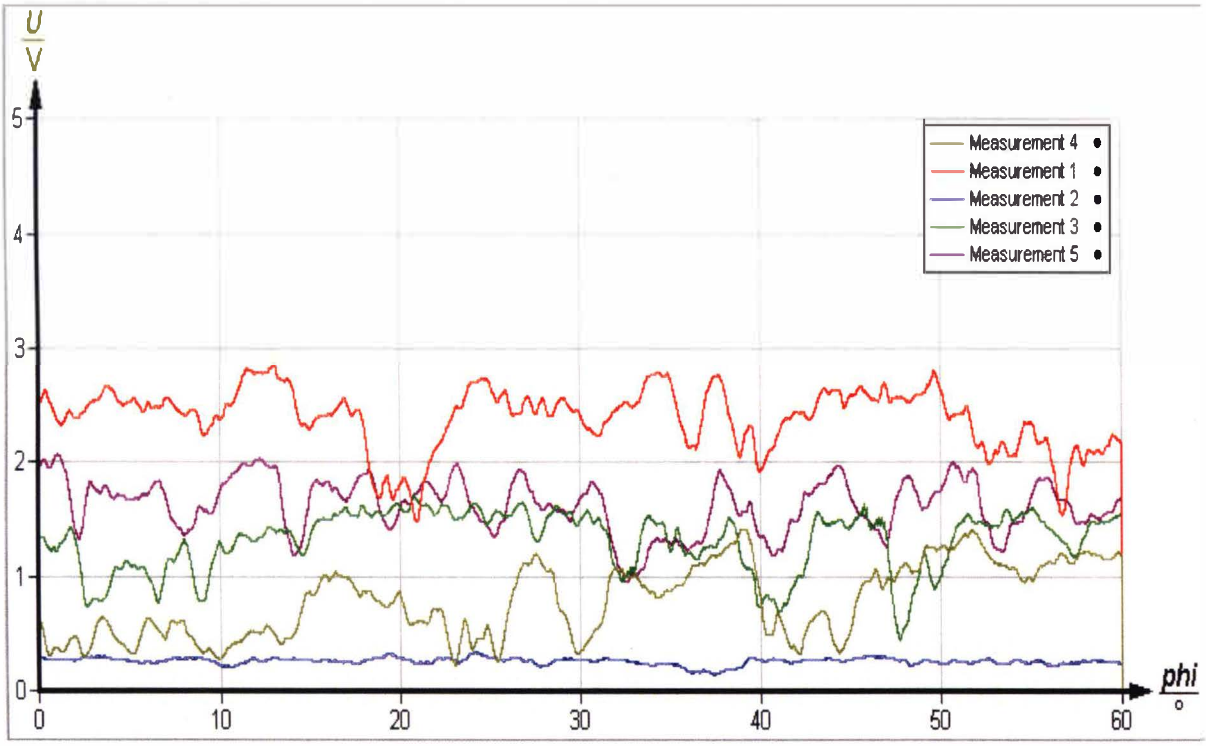


Figure 4.1: All wood samples been plotted in a graph

Measurement 1 (red line) = Seraya Kitan
Measurement 2 (blue line) = Nyatoh
Measurement 3 (green line) = Chengal
Measurement 4 (light green line) = Merawan
Measurement 5 (purple line) = Balau

Refer to the Figure 4.1, one of the species of the wood samples which is Seraya Kitan showed the highest amplitude, followed by Balau, Chengal, Merawan and Nyatoh showed the lowest amplitude compared to others samples. The Figure 4.1 showed that Nyatoh reflected the most ultrasonic wave since the receiver received a very small portion of wave. Seraya Kitan reflected the least wave as shown in the Figure 4.1.

4.3 Discussion and Analysis

The most frequently ultrasonic methods are the through transmission. According to Tanasoiu et al. (2002), the ultrasonic signal, which meets a defect in its way, would be partly reflected and will be received by the transmitter, while the reduced signal by the receiver. The proportion of these two signals can be used to investigate the internal defect. In this research, the defect of wood can not done due to the less wood sample, and need others instrument such as tomography to make comparison with ultrasonic method. Therefore, the inner and surface defects are ignored in this research. According to Bucur (2004), the acoustic wave propagation phenomena in wood are related to the microstructure of this material. An accurate estimation of the mechanical behavior of wood requires simultaneous views on structure and wave propagation phenomena. Clearly wave parameters are affected by the wood structure that acts as a filter. This interaction is high revealing of the anisotropy of the material. The transmission and reflection of the ultrasonic wave is related to the physical properties of wood itself.

Table 4.3: The species and densities of wood

Name	Botanical Name	Average Air-Dry Density (kg/m^3)	Density in dry condition (kg/m^3)
Seraya Kitan	Shorea kunstleri	785-1000	1016.4
Nyatoh	Spp. of Sapotaceae	400-1075	643.0
Chengal	Neobalanocarpus heimii	915-980	845.2
Merawan	Hopea spp.	495-980	733.9
Balau	Shorea spp.	850-1155	1046.0

(Malaysian Timber Council Fact Sheets)

The database of species, botanical name of the species and average air-dry density is referred to Malaysian Timber Council Fact Sheets while the density in dry condition of wood samples were calculated as shown in Table 4.2. The purpose of the average air-dry density is referred from Malaysian Timber Fact Sheets is as a reference and compared to density that had been done in the experiment. Referred the Table 4.2, clearly showed that the density of wood samples in dry condition is almost in the range of the average air-dry density that stated in Fact Sheets. In this research, the intensity of ultrasonic wave been reflected due to densities in wood had obtained. According to Fabiana and Almir (2006), the effect of density on the ultrasonic velocity in seven softwoods and 12 hardwoods was examined and reported that although ultrasonic velocity in the longitudinal direction was independent of density on the whole, it could be classified into three groups; in one group ultrasonic velocities increased with increased densities, in another it was independent of density, and in the third, it decreased with increasing densities.

From the previous research mentioned above, the density of wood species might be related to the ability of the wood reflect the ultrasonic wave itself. From the Figure 4.1 and Table 4.3, the purple line indicated as Balau, which has density of 1046.0 kg/m^3, reflected the second least ultrasonic wave, the receiver received a large portion of ultrasonic wave. The green line indicated as Chengal, which has density of 845.2kg/m^3 reflected a portion wave followed by Merawan, which indicated as light green line, which has density of 733.9 kg/m^3. Finally, the blue line indicated as Nyatoh, which has density of 643.0 kg/m^3. Nyatoh reflected the most ultrasonic wave. From the Figure 4.1, the effect of density on ultrasonic wave transmission through the wood, and the correlations between these parameters were examined. The result showed that when the density of wood is increased, the intensity of ultrasonic wave been reflected is decreased except for the Seraya Kitan.

Table 4.4: The species and hardness of wood

Species	Botanical Name	Hardness (kg)
Seraya Kitan	Shorea kunstleri	901
Nyatoh	Spp. of Sapotaceae	531
Chengal	Neobalanocarpus heimii	752
Merawan	Hopea spp.	648
Balau	Shorea spp.	747

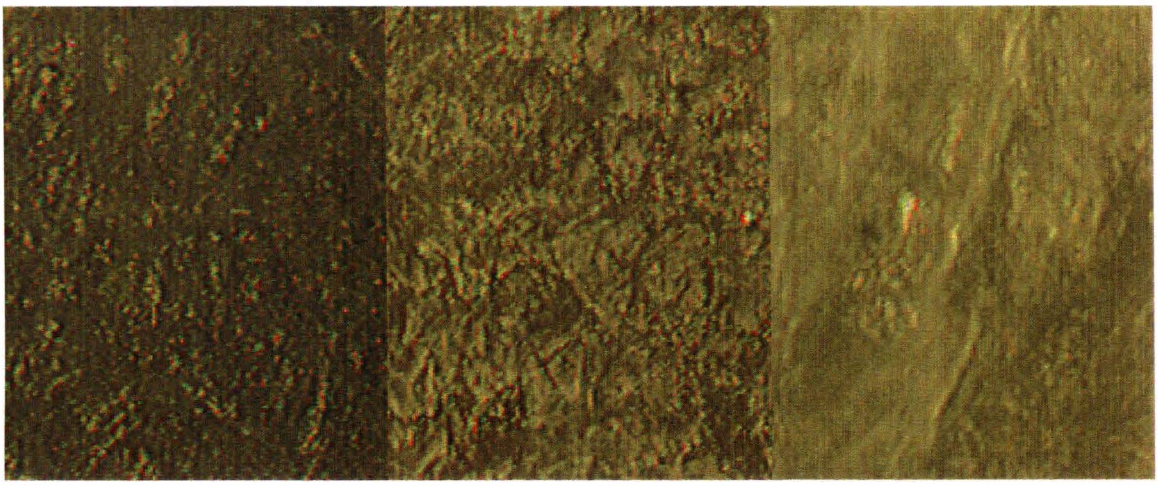
(Malaysian Timber Council Fact Sheets)

The hardness of the wood samples is referred to Malaysian Timber Fact Sheets. Referred to the Table 4.3, Seraya Kitan has average air-density of 1016.4kg/m^3, which almost same density as Balau (1046.0 kg/m^3), but this species reflected the least ultrasonic wave, since the receiver received a very small portion of wave. Referred to the Table 4.4, the hardness of the Seraya Kitan is 901kg. According to Bucur (2002), the acoustic wave propagation phenomena in wood are related to the microstructure of this material, and clearly wave parameters are affected by the wood structure that acts as a filter. The relationship between the hardness of the specimen and the intensity of the ultrasonic wave indicate as the hardness of the specimen increased, the ultrasonic wave tended to propagate through the specimen is increased.

Referred to the Figure 4.1, a portion of ultrasonic wave would be reflected due to different species of wood, there are different properties among them. Besides that, different species of wood have its microstructure itself. From Figure 4.1, the part of acoustic wave reflected were different using different types of wood. The relationship between the hardness and the ultrasonic wave been reflected is obtained.

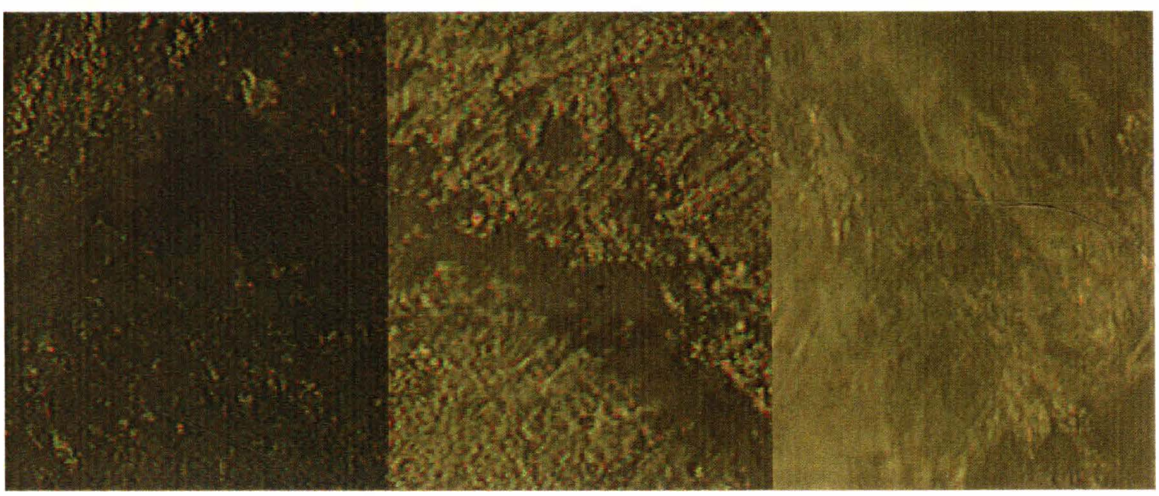
From the Figure 4.1, the result showed the purple line which indicated as Balau and the green line which indicated as Chengal overlapped although both species has different density in dry condition and hardness. Referred to the Table 4.3, the density of Balau in dry condition is much higher than Chengal, therefore the average amplitude of Balau is higher than Chengal even though the ultrasonic wave shown for both species in Figure 4.1 is overlapped. The light green line which indicated as Merawan showed there is a small portion of ultrasonic wave been received due to its softer compared to Balau and Chengal. For the all wood samples being tested, Nyatoh is the softest wood compared to the rest which reflected the most ultrasonic wave.

4.4 A study on surface of wood using metallurgical microscope



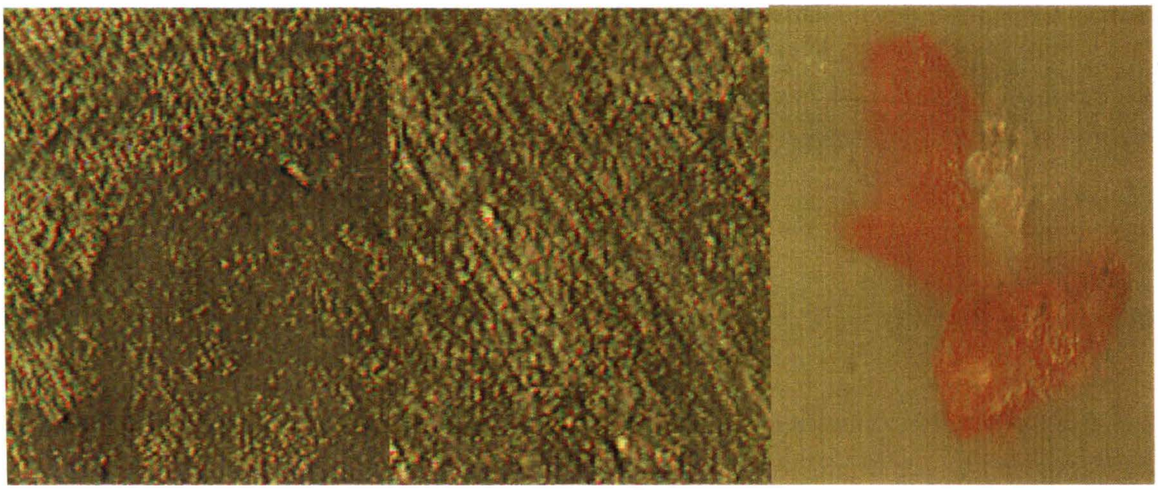
10x magnification 20x magnification 50x magnification

Figure 4.2: The images of Balau captured using metallurgical microscope



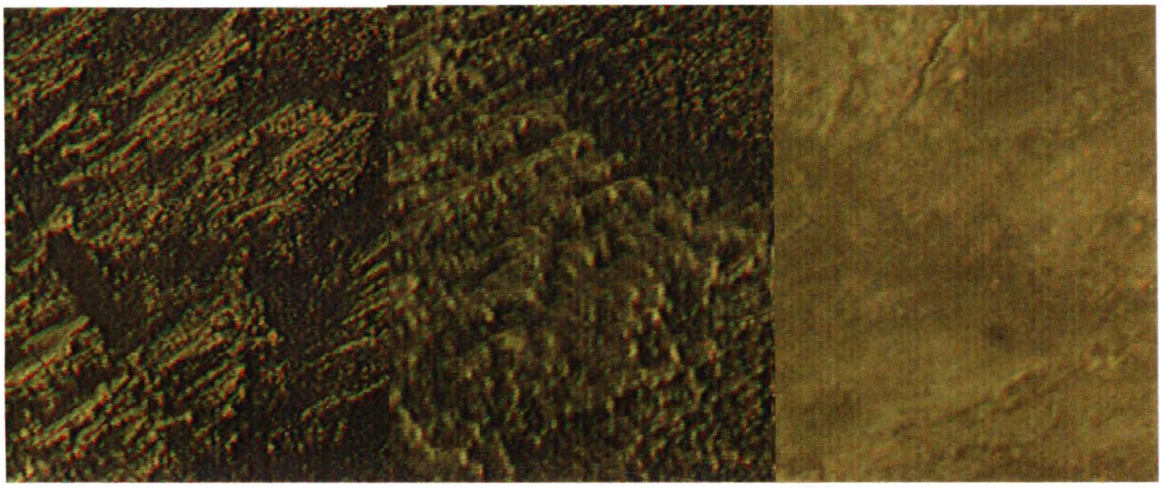
10x magnification 20x magnification 50x magnification

Figure 4.3: The images of Chengal captured using metallurgical microscope



10x magnification 20x magnification 50x magnification

Figure 4.4: The images of Merawan captured using metallurgical microscope



10x magnification 20x magnification 50x magnification

Figure 4.5: The images of Seraya Kitan captured using metallurgical microscope

4.4 Discussion and Analysis

Referred to the Figure 4.2, 4.3, 4.4 and 4.5, different species of wood consist of different surfaces and colours itself. The pictures of the specimens had been captured using Metallurgical Microscope. From the Figure 4.2, 4.3, 4.4, and 4.5, the species of wood were characterized by colour and the surfaces on the specimen. The surface defect of wood would not be determined by using metallurgical microscope. It is due to the crack, knots or nodes had been observed was too small and can consider as harmless to the wood itself.

CHAPTER 5

CONCLUSION & SUGGESTION

The species of wood is successfully determined using ultrasonic method. The reflection and transmission is always affected by the physical properties of wood.

5.1 Conclusion

The species of Malaysian wood had been determined using ultrasonic diffractometer. The species of wood is obtained by analyzing the correlation among the wood density, hardness and the intensity of ultrasonic wave been reflected. As the density of wood is increased, the intensity of the ultrasonic wave been reflected is decreased except for Seraya Kitan. Therefore the hardness and the density of wood had to be considered at a same time since the result showed the intensity of the ultrasonic wave is the least reflected by the Seraya Kitan when the wave propagate through the Seraya Kitan. While Nyatoh showed the most ultrasonic wave been reflected since its properties with low density and softer compared to the others sample.

The surface defect of wood unable to investigate using metallurgical microscope due to the wood sample was too small. The crack from the surface of wood captured by the camera can be ignore due to the crack is too tiny.

5.2 Suggestion

The microstructure of the wood are always affecting the transmission of ultrasonic wave propagate through the wood sample, therefore, some suggestion like others properties of wood should taking into account making more reliable result. For the further study, the moisture content of wood should consider. For commercialize purpose, ultrasonic method is a portable and non-destructive method in determining the species of wood when people working in a selected forest. To obtain more accurate result, the research should consider others properties such as tensile strength, radial and tangential shrinkages, and moisture content.

In investigating the surface defect of wood, the metallurgical microscope is not suitable since the defect found is too tiny and can considered as harmless to the wood itself. To investigate the surface and inner defects of wood, ultrasound tomography may be a more suitable method compared to microscope.

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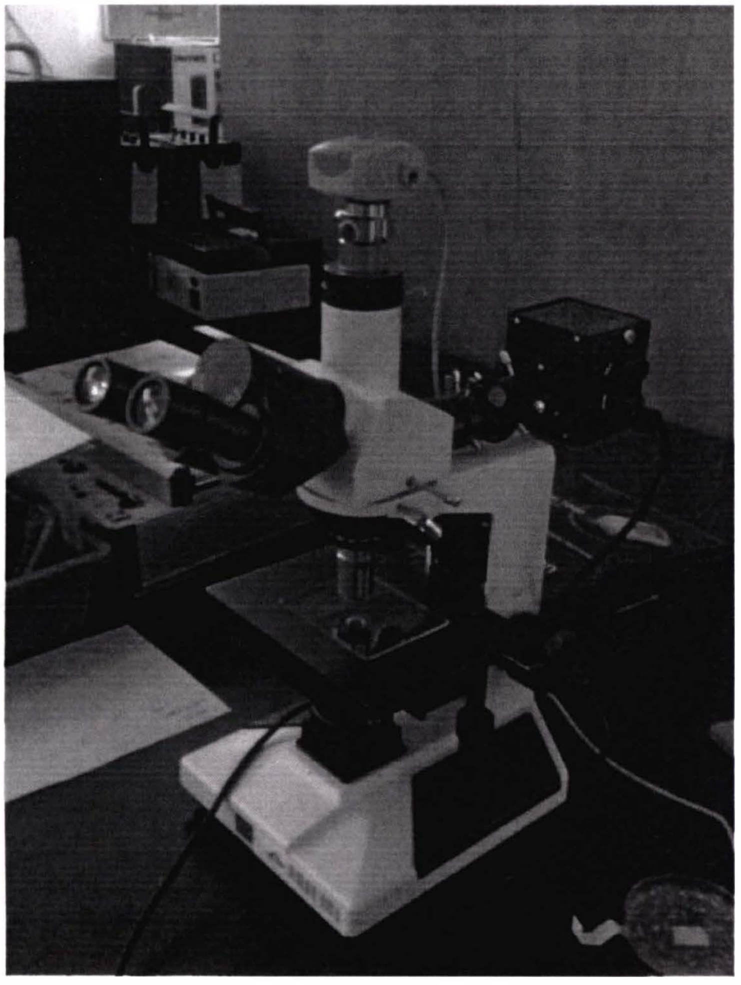

Figure 1: Metallurgical Microscope

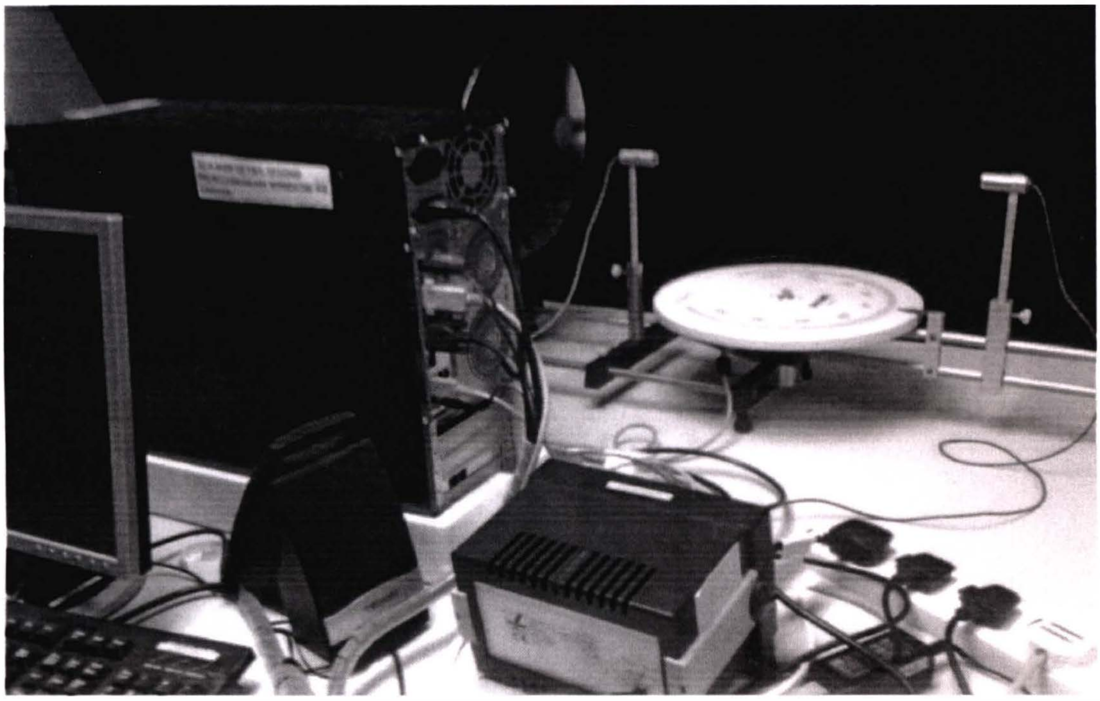

Figure 2: Ultrasonic Diffractometer

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A STUDY ON RELATIONSHIP BETWEEN THE DENSITY, HARDNESS AND THE SPECIE OF MALAYSIA WOODS USING ULTRASONIC METHOD - ONG MOON PING