DEVELOPMENT OF ULTRASONIC TECHNIQUE FOR DETECTION OF DECAY IN WOODEN CROSS-ARMS

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DEVELOPMENT OF ULTRASONIC TECHNIQUE FOR DETECTION OF DECAY IN WOODEN CROSS-ARMS

By
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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

May 2002
Dedicated to My Parent and Family Members......
Abstract of thesis presented to Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science.

DEVELOPMENT OF ULTRASONIC TECHNIQUE FOR DETECTION OF DECAY IN WOODEN CROSS-ARMS

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May 2002

Chairman : Professor Dr. Kaida bin Khalid

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A simple, economic, and accurate nondestructive measurement method has been developed to determine the quality of in-service wooden cross-arms. A wooden cross-arm is part of the pylon normally used to support high-power transmission line. The measurement system uses an ultrasonic pulse, 45kHz, to propagate from transmitter to receiver. The transit time of the pulse is the basic parameter. Investigations show that the transit time is dependent on the distance between two transducers and needs a continuum medium. Other factors such as density, moisture content, fiber direction, continuity of the medium, and sample thickness also influence the propagation of ultrasound. An investigation has been done to find out the optimum condition for detection methods. The optimum condition was determined through various experimental methods such as C-Method, Upper Method, Direct Method, Indirect Method, and Semi-Direct Method.

The investigation found that C-method is the best method to be used for wooden cross-arms decay detection. This method is able to detect the decay of the wood under the metal block, which is impossible by using microwave method. The transit times for
sound wood, old wood, and cracked wood fall under the ranges of 100µs to 200µs, 200µs to 500µs, and above 500µs respectively. Most of the measured results for cracked wood are above detection time limit of the device and the signal is normally very weak. The experimental results also showed that for moisture content ranging from about 10% to 30% in the wood, there is not much effect in the transit time. This range of moisture content corresponds to the moisture that can be absorbed by Chengal wood during rainy day. Most of the measurement of transit time is done in the L-L direction. It was found out that the velocity along the L-T direction is about 500ms\(^{-1}\). The propagation along this direction, which is parallel to the fiber direction, is 3 times higher than the T-R or R-R directions.

To complete the study, a prototype has been developed, which can be used for field-testing or maintenance work. This prototype is light, portable, easy to use, safe, and reliable.
Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PERBINAAN ULTRASONIK TEKNIK UNTUK PENGESANAN PEREPUTAN PADA PALANG LENGAN KAYU

Oleh

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Kajian mendapati bahawa Kaedah-C adalah kaedah yang terbaik untuk pengesanan kereputan palang lengan kayu. Kaedah ini dapat digunakan untuk mengesan kereputan
kayu dibawah blok logam yang tidak mungkin dapat dikesan menerusi gelombang mikro. Masa penghantaran bagi kayu sempurna, kayu lama dan kayu retak masing-masing adalah dalam lingkungan dari 100μs hingga 200μs, dari 200μs hingga 500μs dan melebihi 500μs. Kebanyakan hasil pengukuran bagi kayu retak adalah melebihi had masa pegesa nan peralatan dan isyaratnya sangat lemah. Keputusan kajian ini juga menunjukkan bahawa kandungan kelengasan dalam lingkungan dari 10% hingga 30% dalam kayu, kurang mempengaruhi masa penghantaran. Julat kelengasan ini adalah kelengasan yang diselang oleh kayu Chengal semasa hari hujan. Kebanyakan kajian bagi masa penghantaran adalah dalam arah L-L. Didapati bahawa sepanjang arah L-T julaju ultrasonik adalah dalam lingkungan 500ms⁻¹. Pemancaran sepanjang arah ini yang selari dengan arah serabut adalah 3 kali ganda lebih tinggi daripada arah T-T dan R-R.

Bagi melengkapkan kajian satu prototaip dibina untuk digunakan bagi pengujian di lapangan (field testing) atau kerja penyelengaraan.. Prototaip ini adalah ringan, mudah alih, mudah digunakan. selamat dan boleh dipercayai.
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I certify that an Examination Committee met on 7th May 2002 to conduct the final examination of Lai Sook Kean on her Master of Science thesis entitled “Detection of Decay in Wooden Cross-Arm using Ultrasonic Sensor” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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<td>BaTi</td>
<td>Barium Titanate</td>
</tr>
<tr>
<td>$\Gamma_{ik}$</td>
<td>Christoffel Tensor</td>
</tr>
<tr>
<td>C</td>
<td>Crack Wood</td>
</tr>
<tr>
<td>D%</td>
<td>Degradation Percentage</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Density, $\text{kgm}^{-3}$</td>
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<tr>
<td>$C_{ijkl}$</td>
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<tr>
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<td>Elasticity for Longitudinal</td>
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<tr>
<td>$C_{RR}$</td>
<td>Elasticity for Radial</td>
</tr>
<tr>
<td>$C_{TT}$</td>
<td>Elasticity for Tangential</td>
</tr>
<tr>
<td>EMC</td>
<td>Equilibrium Moisture Content</td>
</tr>
<tr>
<td>FSP</td>
<td>Fiber Saturation Point</td>
</tr>
<tr>
<td>$\delta_{ik}$</td>
<td>Kronecker Delta</td>
</tr>
<tr>
<td>PMN</td>
<td>Lead Metaniobate</td>
</tr>
<tr>
<td>PZT</td>
<td>Lead Zirconate Titanate</td>
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<tr>
<td>MOE</td>
<td>Modulus of Elasticity</td>
</tr>
<tr>
<td>MOR</td>
<td>Modulus of Rapture</td>
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<td>MC</td>
<td>Moisture Content</td>
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<td>O</td>
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\begin{itemize}
    \item $\lambda$ \hspace{1cm} Poisson’s Ratio
    \item $P_m$ \hspace{1cm} Polarization Vector
    \item $V$ \hspace{1cm} Pulse Velocity, ms\(^{-1}\)
    \item $S$ \hspace{1cm} Sound Wood
    \item $[\varepsilon_{ij}]$ \hspace{1cm} Strains Tensor
    \item $[\sigma_{ij}]$ \hspace{1cm} Stress Tensor
    \item TNB \hspace{1cm} Tenaga Nasional Berhad
    \item $t$ \hspace{1cm} Transit Time, $\mu$s
    \item $x$ \hspace{1cm} Length, cm
    \item $\mathbf{u}_j$ \hspace{1cm} Displacement
    \item $A_o$ \hspace{1cm} Amplitude of the Wave
    \item $P_i$ \hspace{1cm} Unit Displacement Polarization Vector
    \item $k_m$ \hspace{1cm} Wave Vector Component Along the $\chi_m$
    \item $\chi_m$ \hspace{1cm} Position Vector
    \item $n_k$ \hspace{1cm} Direction Cosines
    \item $\omega$ \hspace{1cm} Angular Frequency
\end{itemize}
CHAPTER I

GENERAL INTRODUCTION

Introduction

Wood can be considered as a biological substance, which is widely used in many industries due to its complex structure and durability. In a microscopic overview, the wood composite is formed in a discrete scale level to assure its high performance against different environmental conditions such as strong wind and heavy rain.

In Malaysia, wood poles and wooden cross-arms are used as line supports for power pylon towers. The design, the construction of transmission lines and wood poles for power line supports are done by Tenaga Nasional Berhad (TNB). The transmission lines are divided into three major categories: 500kV, 257kV, and 132kV, as shown in Figure 1.1. The End-Joint of a tower is constructed with a wooden cross-arm. For commercial plantations (the private sector), wood poles are used as power line supports, instead of the costly concrete or galvanized iron line supports now in use (Hussein, 1998).

The most popular uses of heavy hardwoods in this country are for heavy constructions such as wooden houses, railway sleepers, timber bridges, and power line poles based on the woods' natural durability. By far Chengal is the most popular hardwood fit for the above purposes.
Figure 1.1: Structures of Power Pylon Towers for 500kV, 237kV, and 132kV.
The hot and humid climate in tropical countries like Malaysia facilitates the growth of fungi and other destructive microorganisms in wooden structures. Thereby, deterioration of wooden structures occurs. It takes the forms of splits, cracks, and other defects that permit the entry of fungi into the cores of the poles, rendering them unsuitable for use as line supports. For wooden structures, this nature of degradation or deterioration can inhibit the performance of the entire structure.

Hence, wooden cross-arms inspection and maintenance are essential for the following reasons:

i) Safety to life and property: wooden cross-arms should be maintained above definite minimum strength requirements. The strength value of each species of wood is different from others. The minimum strength requirements according to species of wood have been chosen for intelligent applications of woods.

ii) Efficient service within the system: outages or service interruption due to pole failures should be kept to a minimum. For examples, mechanical damage may lead to a reduction in the useful life of a wooden cross-arm, and maintenance works that leave some holes after testing (quasi nondestructive method) the wooden quality condition may also lead to degradation of wood.
iii) economical operation: the number of wooden cross-arm replacements should not be excessive and the maximum useful life should be obtained from every wooden cross-arm.

Plate 1.1 shows a worker doing inspection for the end-joint of a power tower. The maintenance work is very dangerous. So, a simple method to be used for this purpose is essential. The most currently used nondestructive evaluation (NDE) methods to detect the wood defects are by vibration technique (traditional method), sonic stress wave technique, microwave technique, radiation (X-ray and gamma ray), visual inspection, and drill resistance (MC Master, 1982). As every technique has different advantages of its own for various wood defect detection condition, a simple, fast, safe, and accurate technique must be developed.

Plate 1.1: The End-Joint of a Power Tower. The worker is doing inspection for the Wooden Pole Quality Situation.