CLASSIFICATION OF STAINLESS STEEL AND MILD STEEL USING VIBRATION TECHNIQUE

INTAN MAISARAH BINTI ABD RAHIM

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Classification of Stainless Steel and Mild Steel Using Vibration Technique

by

Intan Maisarah binti Abd Rahim
(0831410259)

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School of Mechatronic Engineering
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UNIVERSITI MALAYSIA PERLIS

DECLARATION OF THESIS

Author's full name : Intan Maisarah binti Abd Rahim

Date of birth : 24 July 1985

Title : Classification of Stainless Steel and Mild Steel Using Vibration Technique

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Dengan nama Allah yang Maha Pemurah lagi Maha Penyayang.
To my beloved and supportive family,
my younger sisters,
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LIST OF ABBREVIATIONS

FRF	Frequency Response Function
NDT	Non-Destructive Testing
FFT	Fast Fourier Transform
NN	Neural Network
ANN	Artificial Neural Network
k-NN	*k*-Nearest Neighbor
LM	Levenberg-Marquardt
GUI	Graphical User Interface
UTM	Universal Testing Machine
DTS	Dynamic Touch Sensor
MLPNN	Multi Layer Perceptron Neural Network
ASTM	American Society for Testing and Materials

LIST OF SYMBOL

ω	Omega
∞	Infinity
k	Stiffness
m	Mass
ω_n	Natural frequency
ζ	Zeta - Damping ratio
c	Constant - Damping constant
c_c	Constant - Critical damping constant
η	Eta
δ	Delta
γ	Gamma
f	Frequency

Klasifikasi Metal Melalui Teknik Getaran

ABSTRAK

Pengeluaran bahan dalam industry mestilah memenuhi piawaian yang telah ditetapkan seperti piawaian oleh American Society for Testing and Materials (ASTM) International. Keperluan dan syarat untulk piawaian bahan ini amat penting terutama dalam sesetengah bidang yang kritikal seperti aero angkasa, kejuruteraan dan automotif. Kajian ini juga memperkenalkan pembangunan skim ujian tidak musnah keatas bahan dalam menentukan jenis sesuatu bahan. Pengkelasan sesuatu bahan amat berguna dalam pengesahan pasca produksi. Terdapat banyak kaedah telah dibangunkan untuk mencapai piawaian dalam produksi sesuatu bahan. Kaedah ujian terhadap sifat mekanikal sesuatu bahan menggunakan teknik getaran dan kaedah ini boleh menentukan frekuensi asli, nisbah redaman dan mod bentuk sesuatu struktur. Kaedah ujian terhadap bahan yang dilaksanakan untuk kajian ini adalah ujian paluan impak. Signal Fungsi Tindakbalas Frekuensi diperolehi dari ujian ini dan frekuensi asli untuk sesuatu bahan diekstrak dari Signal Fungsi Tindakbalas ini. Dalam kajian ini, ciri-ciri yang dipertimbangkan sebagai data masukan yang diperlukan untuk latihan algoritma adalah frekuensi asli untuk sesuatu bahan dan juga amplitudnya. Kemudian, data masukan yang diperolehi akan dikelaskan menggunakan algoritma Rangkaian Neural Buatan (ANN) dengan teknik Levenberg-Marquardt Backpropagation dan juga algoritma Jiran Terdekat *k* (*k*-NN). Setiap algoritma pengelasan akan menghasilkan kadar pengelasan yang berbeza bergantung kepada keupayaan data masukan yang dilatih. Keputusan dari skim pengelasan menunjukkan *k*-NN memberikan ketepatan sebanyak 99.69% dengan nilai $k = 3$. Sementara Levenberg-Marquardt Backpropagation memberi ketepatan kelas sebanyak 99.43%.

Classification of Stainless Steel and Mild Steel Using Vibration Technique

ABSTRACT

The production of material in industry must attain some standard such as the standard required by American Society for Testing and Materials (ASTM) International. The requirement of the material standard is important in some crucial field such as aerospace, engineering and automotive. This research presents a development of a material classification scheme with non-destructive testing on the material to classify the material type. The classification of the material can be useful in post-production verification. Many testing methods have been developed to reach the standard of the material production. The testing of the material mechanical properties using vibration technique could determine the natural frequencies, the damping ratio and mode shapes of the structure. The testing method chose to be implemented in this research is impact hammer testing. Frequency Response Function (FRF) signals obtained from the testing and natural frequencies of the materials are extracted from FRF signals. In this research, the features considered as the input data for the algorithm training are the natural frequencies of the material and its amplitude. Later, the input data obtained are classified using Artificial Neural Network (ANN) with Levenberg-Marquardt Backpropagation and *k*-Nearest Neighbor (*k*-NN). Each of the classifier produced a different classification rate depending on the performance of the training input data set. The result from the classification system shows that k-NN is giving the accuracy of 99.69% with the *k* value of 3. While, Levenberg-Marquardt Backpropagation is giving the best classification rate of 99.43%.

CHAPTER 1

INTRODUCTION

1.1 Project Background

The classification of the material can be useful in post-production verification process. In industry, there are some standards need to be achieved in order to release the production to the market place. One of the popular testing is the impact testing. The natural frequencies gained from the testing used to determine the durability and usefulness of the material. For example, mild steel always used as one of the construction materials such as concrete backbone. The toughness and durability of this material need to be verified as it stands a crucial part of the construction. Vibrations that happened in environment will contribute to the damage of the material. In order to overcome the vibration from external forces that happened in environment, the material need to have higher natural frequencies.

The advance in vision system has developed some researches in classifying the material using image processing. The classification of material using image processing technique developed by Caputo et al., (2010) focused on the materials that possess obvious apparent on the material's surface. It is challenging for some material as the surface appearance for some metal is almost similar even with different composition. However, the value of natural frequencies for the material is different depends on the parameter of the structure. In order to verify the suitable natural frequencies for the material tested, two specimens used for each material type. The data gained shows only

slight difference happened to the natural frequency and its amplitude values. Impact testing applied in this research to gain Frequency Response Function (FRF) signal for each of the material types. From FRF signal, three important modal parameters obtained which are natural frequencies and their amplitude, mode shape and also damping ratio. The natural frequencies and their amplitudes then used to differentiate the type of material using the classifying scheme developed.

With the improvement that could be made to the system, according to Neubauer (1991), the image processing could be used to detect damages happened to the structure. By using the natural frequencies and their amplitudes, the damages of the structure can also be detected. The difficult part in detecting the damages using the natural frequencies is in determining the location of the damages and how bad the damage is. However, the scope of this research is only to classifying the type of different material.

1.2 Scope of Research

The scope of this research is to implement the classification algorithms in classifying the material structure. Each of the material holds the different mechanical properties and thus, the difference in the properties can distinguish the material structure. The materials used in the research had different composition and thickness but the length and wide dimension is the same which is 400mm x 300mm. In this research, the features that had been investigated limited to the changes in the natural frequencies as the mechanical properties for the material changed. The impact testing used as the method in capturing the FRF signals that contain the information on the natural frequencies of the structure.

1.3 Problem Statement

This purpose of the research is to implement the non-destructive vibration testing in classifying the type of different materials. The material properties of the material are very important considering the various usage of the material in critical area such as aerospace, buildings and vehicles. In current practice, material properties are mostly determined manually which requires human skills and expertise such as Scanning Electron Microscope (SEM) technique. Recently, non-destructive testing is getting more attention in classifying the material properties in post-production processes. With regards of its advantages in reducing cost and waste during testing, the vibration testing with implementation of smart classification algorithm is benefiting in material identification problem. It offers faster and easier solution for real problem application. Listed below are the solutions for this research:

i. Selecting the accelerometer for vibration measurement is very critical. The important criteria include choosing the accelerometer with minimum weight as possible and with optimized bandwidth. The sensor with more weight eventually influences the acceleration and displacement of the structure.

ii. The fixed boundary condition for experimental setup needed more complicated mathematical solution. For this experiment, the free-free condition is used as this method is easily verifiable than the more complex mathematical solution for the fixed boundary condition.

iii. The FRF signals obtained from the experiment provide information such as natural frequency, damping ratio and mode shape. For classification process, it is enough using the natural frequency as the features for the system. This will decrease the computation resources that will improve the response of the system.

1.4 Objectives

The objectives of the research are described as below:

- To determine the FRF Signal from the experiment using Non-Destructive Testing (NDT) of vibration method for different material. The useful information then extracted from the FRF signal and used as features in the classifier algorithms.
- To implement classification algorithms to determine the types of material, either mild steel or stainless steel.
- To develop a Graphical User Interface (GUI) that helps to interface the users to classify different type of materials.

1.5 Expected Output

The expectation from this research is to develop a system that has the capability of classifying different type of the material. This can be accomplished by development of classification system using classifier algorithms which are ANN and *k*-NN. The system interfaced to the users using the GUI developed afterward.