Saya akui bahawa saya telah membaca karya ini dan pada pandangan saya karya ini Adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal (Struktur & Bahan)

Tandatangan : ....

Nama penyelia : PN. RAINAH BT. ISMAIL

Tarikh : MEI 2007

DYNAMIC CHARACTERAIZATION OF A TWO DIMENSIONAL FLEXIBLE PLATE STRUCTURE USING NEURAL NETWORK

MOHD AZAM BIN ROSLAN

Laporan ini diserahkan kepada Fakulti Kejuruteraan Mekanikal sebagai memenuhi
sebahagian daripada syarat penganugerahan
Ijazah Sarjana Muda Kejuruteraan Mekanikal (Struktur & Bahan)

Fakulti Kejeruteraan Mekanikal
Universiti Teknikal Malaysia Melaka

Mei 2007

"Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya jelaskan sumbernya"

Tandatangan : ....

Nama penulis : MOHD AZAM B. ROSLAN

Tarikh : MEI 2007

To my beloved family, mum and dad,
thank you for your 'doa', support and encouragement
that you have given in my life

Acknowledgment

First and foremost, ALHAMDULILLAH I'm grateful to ALLAH SWT on blessing in completing this project.

I would like to take this opportunity to thank my project supervisor, Pn. Rainah Bt. Ismail for her invaluable guidance, assistance and support throughout this work. Under her supervision, many aspects regarding on this project has been explored, and with knowledge, idea and support received from her, this thesis can be presented in the given time.

Finally, I would like to dedicate my gratitude to all my lecturers involved in teaching my course, thanks for the lesson that been delivered. Not forget to all my friends, course mate, and anyone that has provided whether an idea or support, directly or indirectly, that played a role towards in completing this work.

ABSTRACT

An investigation into the dynamic characterisation of a two dimensional (2D) flexible plate structure is presented. A thin aluminum, flat plate, with all edges clamped, is considered. A simulation algorithm characterising the dynamics behavior of the plate is developed through a descretisation of the governing partial differential equation formulation of the plate dynamics using finite different methods. The algorithm is implemented within the Matlab environment, and it allows application and sensing of a disturbance signal at any mesh point on the plate. The validation of the algorithm is presented in both the time and frequency domains. Investigations reveal that the measured parameters associated with the first five resonance modes of the system compare favorably with previously reported results. Multi-Layer Perceptron Neural Network (MLP-NN) is applied to the simulation algorithm and the first three modes of frequency is comparing with the theoretical value that developed earlier for the validation and acceptable level of the future work.

ABSTRAK

Penyiasatan tentang pencirian dinamik suatu struktur mudah lentur (2D) akan dibincangkan. Suatu plat aluminum dimana sifat-sifatnya ialah nipis, rata dan kesemua bucunya diikat dipertimbangkan. Suatu simulasi algoritma yang mencirikan sifat dinamik dibangunkan memlalui proses pengasingan formulasi persamaan pembezaan separa yang mengawal dinamik plat menggunakan kaedah pembezaan terhingga. Algoritma ini dilaksanakan dalam persekitaran Matlab dan ia membolehkan aplikasi dan pengesanan isyarat gangguan pada sebarang titik jaringan pada plat itu. Pengesahan algoritma ini ditunjukkan dalam domain masa dan frequensi. Kajian mendedahkan bahawa parameter yang diukur berkait rapat dengan 5 mode resonans yang terawal daripada sistem dibandingkan dengan kajian lepas. MLP-NN dilaksanakan terhadap algoritma simulasi. Frequensi daripada 3 mode terawal dibandingkan dengan nilai teori yang didapati daripada kajian awal untuk pengesahan dan pada satu tahap yang boleh diterima untuk kajian akan datang.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Pz	- external load
Qx and Q_y	- transverse shear force
M_x and M_y	- bending moments
Mxy and *Myx*	- twisting moments
qx + ..., *qy* + ..., *etc.*	- internal forces with increments
u, v, w	- displacement components
$\sigma_x, \sigma_y, \sigma_Z$	- stresses in plate
E	- modulus of elasticity
ν	- poisson's ratio
$\varepsilon_x, \varepsilon_y, \varepsilon_z$	- the strains in a plate
τ_{xy} and τ_{yx}	- in-plane shear stresses
γ	- shear strain
G	- shear modulus
χ	- *warping* of the plate
w	- Internal forces
h	- thickness of the plate
w	- lateral deflection in the z-direction
$D = \dfrac{Eh^3}{12(1-v^2)}$	- bending or *flexural rigidity* of the plate
$\nabla^2(\bullet) = \dfrac{\partial^2(\bullet)}{\partial x^2} + \dfrac{\partial^2(\bullet)}{\partial y^2}$	- two-dimensional Laplacian operator

m	- pivotal point
Δx, Δy	- indicated the distance between mesh lines in x and y direction
ξ	- points in the interval
ρ	- Mass density per unit area
$q = q(x,y)$	- Transverse external force, with dimensions of force per unit area
$\frac{\partial^2 w}{\partial t^2} =$	- Acceleration in the z direction
$D = \frac{Eh^3}{12(1-\upsilon^2)}$	- Flexural rigidity
Δx , Δy	- mesh width
k	- reference index
$W_{m,\,n,\,k+1}$	- the deflection of grid points m = 1, 2,….. *i* and n = 1, 2,….*j* at time step $k + 1$
$W_{m,\,n,\,k}$, $W_{m,\,n,\,k-1}$	- the corresponding deflections at time steps *k* and $k - 1$
t	- time
υ	- transverse shear force
$\partial m_{xy}/\partial y$ and $\partial m_{yx}/\partial_x$,	- additional shearing forces at the edge
D	- constant $(n+1)(m+1)x(n+1)(m+1)$ matrix that entries depend on physical dimensions and characteristics of the plate and the number of the sections the plate is divided into
E	- Time step Δt and mass per unit ρ of the plate
F	- $(n+1)(m+1)x1$ matrix and known as forcing matrix
I	- Second Moment of Inertia
q	- step input force with amplitude
$\lambda = \omega a^2(\sqrt{\rho / D})$	- parameters
$y = \Phi(\sum_i X_i W_i + W_0)$	- mathematical description of a neuron

$E(W) = \frac{1}{2}\sum_{i=1}^{m}(d_i - Y_i)^T(d_i - Y_i)$ - error function

LIST OF ABBREVIATIONS

FDM	- Finite Difference Method
BEM	- Boundary Element Method
FEM	- Finite Element Method
PDE	- Partial Difference Method
DSC	- Discrete Singular Convulation
NNs	- Neural Networks
MLP-NN	- Multi-Layer Perceptrons Neural Network
ENN	- Elman Neural Network
RBF-NN	- Radial Basis Function Neural Network
OSA	- One Step Ahead prediction

CHAPTER 1

INTRODUCTION

1.1 Overview

Plates and plate-type structures have gained special importance and notably increased applications in recent years. The large number of structural components in engineering structures can be classified as plates. Typical example that using the plates such in civil engineering structures, shipbuilding and aerospace. Plate also used in part of machineries and other mechanical devices.

Various analytical and numerical methods have been developed to investigate the vibration behavior of plates. The main objective is to ensure that the structure under investigation shall have an adequate safety factor against failure within reasonable economical bounds. Furthermore, the structure shall be serviceable when subjected to design loads. A part of serviceability can be achieved, for example, by imposing suitable limitations on deflections.

A variety of computational methods have been employed successfully for plate analysis such as Superposition method, Levy approach, point collocation method, Finite Difference Method (FDM), Boundary Element Method (BEM), Differential Quadrature (DQ) method, Rayleigh method, Ritz variational methods, Meshless methods to the Finite Strip method and the Finite Element Method (FEM). The widely used numerical techniques are Finite Difference Method (FDM) and Finite Element Method (FEM).

To obtain an accurate model of the plate structures in order to control the vibration of a plate efficiently is crucial; then FDM is used to obtain an efficient numerical method of solving the PDE formulation. This is because the FDM is simple, versatile, and suitable for computer and programmable desk calculator use, and the results in acceptable accuracy for most applications involving a uniform structure, such as plate considered here. These techniques also more suitable in the real-time application comparing with FEM and BEM.

The MATLAB software is used to implementation the algorithm and it allows application and sensing of a disturbance signal at any mesh point on the plate. Then, a MATLAB Finite Difference method (FDM) was developed to perform subsequent system identification algorithm simulations. System identification is extensively used as a fundamental requirement in many engineering and scientific applications. The objective this system is to find exact or approximate models of dynamics system based on observed inputs and outputs. Then, the neural network is applied into the numerical techniques in the MATLAB.

1.2 STATEMENT OF PROBLEMS

In studying a dynamic characterization of a two-dimensional flexible plate structure using Neural Network, there are several things need to understand to solve the problem. The flexible plates that focus on are an aluminum-type thin square plate. The length, width and thickness are discussed later in a next chapter. A thin square plate with all edges clamped is considered.

By using the finite difference method, a simulation algorithm characterizing the dynamic behavior of the plate is developed. The important aspect of the work is to implement this algorithm on the computer using the MATLAB software. The MATLAB software allows applications and sensing disturbance signal at any mesh point on the plate. The dynamic behavior characterization of the system in performance of the developed algorithm is assessed in comparison with previously reported results by using various other methods. Therefore, the data obtained from the first part of work will be used to develop the neural networks model by using MLP-NN.

CHAPTER 2

FLEXIBLE PLATE

2.1 Overview

Chapter 2 discuss about studies on flexible plate, general behavior of plate and the classical dynamic equation of plate. The topics of general behavior of plate include the meaning or the theory of a plate and the application of a plate in civil engineering, shipbuilding and aerospace industries. In the classical dynamic equation of a plate topic, show the relation to get the classical equation of a plate.

2.2 Studies on flexible plate

2.2.1 Solution of clamped rectangular plate problems

Taylor and Govindjee (2002), was present an efficient scheme for determining very accurate solutions to the clamped rectangular plate problem. The method used is based upon the classical double cosine series expansion and an exploitation of the

Sherman-Morrison-Woodbury formula. The classical method for this problem involves solving a system of (MN) x (MN) equations, if the cosine expansion involves M terms and N terms in the two plate axes directions. The proposal reduces the problem down to a system of well conditioned N x N equations (or M x M when M < N). Compared to the solution generated via Hencky's method, numerical solutions for rectangular plates with various side ratios are presented.

The solution of the clamped plate problem via the double cosine series method, had presented a method to efficiently compute. The technique of exploiting the Sherman-Morrison-Woodbury formula is at the heart of the technique and its successful execution further relies upon a scaling of the governing equations. While, for the particular problem at hand the method of Hencky (essentially a modified Levy method) results in a more satisfactory result, note that the reduction method developed can be employed for other similar problems using near- (but non-) orthogonal basis expansions.

2.2.2 DSC-RITZ Method for the free vibration analysis of Mindlin plates

Hou et al. (2005), introduced a novel method for the free vibration analysis of Mindlin plates. The proposed method takes the advantage of both the local bases of the discrete singular convolution (DSC) algorithm and the *pb*-2 Ritz boundary functions to arrive at a new approach, called DSC-Ritz method. Two basis functions are constructed by using DSC delta sequence kernels of the positive type. The energy functional of the Mindlin plate is represented by the newly constructed basis functions and is minimized under the Ritz variational principle. Extensive numerical experiments are considered by different combinations of boundary conditions of Mindlin plates of rectangular and triangular shapes. The performance of the proposed method is carefully validated by convergence analysis. The frequency parameters agree very well with those in the literature. Numerical experiments indicate that the proposed DSC-Ritz method is a very promising new method for vibration analysis of Mindlin plates.

Due to their findings, the key idea is to take the advantage of DSC local delta sequence kernels and the *pb*-2 Ritz boundary functions. Numerical experiments are conducted for rectangular plates and triangular plates with various combinations of simply supported, clamped and free edge conditions. Numerical results indicate that the proposed DSC-Ritz method is a simple approach for the vibration analysis of Mindlin plates. Comparing to previous DSC algorithm, which makes use of delta sequence kernels of Dirichlet type and the collocation formulation for differential equations, the present DSC-Ritz method employs delta sequence kernels of positive type and is relied on Ritz energy minimization principle (essentially the Galerkin formulation). Obviously, the philosophy of discrete approximations to the singular delta distribution, i.e. the universal reproducing kernel, underpins both DSC methods. Believe that these DSC methods are promising new approaches for structural analysis in general.

2.2.3 DSC Analysis of rectangular plates with non-uniform boundary conditions

Zhao and Wei (2005), introduced the Discrete Singular Convolution (DSC) for the vibration analysis of rectangular plates with non-uniform and combined boundary conditions. A systematic scheme is proposed for the treatment of boundary conditions required in the proposed approach. The validity of the DSC approach for plate vibration is tested by using a large number of numerical examples that have a combination of simply supported, clamped and transversely supported (with non-uniform elasticrotational restraint) edges.

As a conclusion, for the analytically solvable case of all-side simply supported boundary conditions, the DSC results are the most accurate yet available. In all other test problems, the DSC results are consistent with previous ones in the literature. The numerical results confirmed the promising nature of the present approach and the great potential it holds for plate analysis.

2.3 General behavior of Plate

Plate is synonyms to the cover, protect, shield, laminate, overlay, sheet, finish and electroplate. It is a straight, plane, two-dimensional structural components of which one dimension, referred to as thickness *h*, is much smaller than the other dimensions. Plates and plate-type structures have gained special importance and notably increased applications in recent years. The plate have many application as shown in **Figure 2.1** such as in civil engineering structures are floor and foundation slabs, lock-gates, thin retaining walls, bridge decks and slab-bridges. Plates are also indispensable in shipbuilding and aerospace industries. The wings and a large part of the fuselage of an aircraft, for example, consist of a slightly curved plate skin with an array of stiffened ribs. The hull of a ship, its deck and its superstructure are further examples of stiffened plate structures. In machineries and other mechanical devices, plates are also frequently parts.

In all structural analyses the engineer is forced, due to the complexity of any real structure, to replace the structure by a simplified analysis model equipped only with those important parameters that mostly influence its static or dynamic response to loads. In plate analysis such idealizations concern (Szilard, 2004):

1) The geometry of the plates and its supports,

2) The behavior of the material used and,

3) The type of loads and their way of application.