

**Vibration Control and Genetic Algorithm Based  
Design Optimization on Self-sensing Active  
Constrained Layer Damped Rotating Plates**

by

**Chong Ian Ian**



**MSc in Electromechanical Engineering**

**2011**



**Faculty of Science and Technology  
University of Macau**

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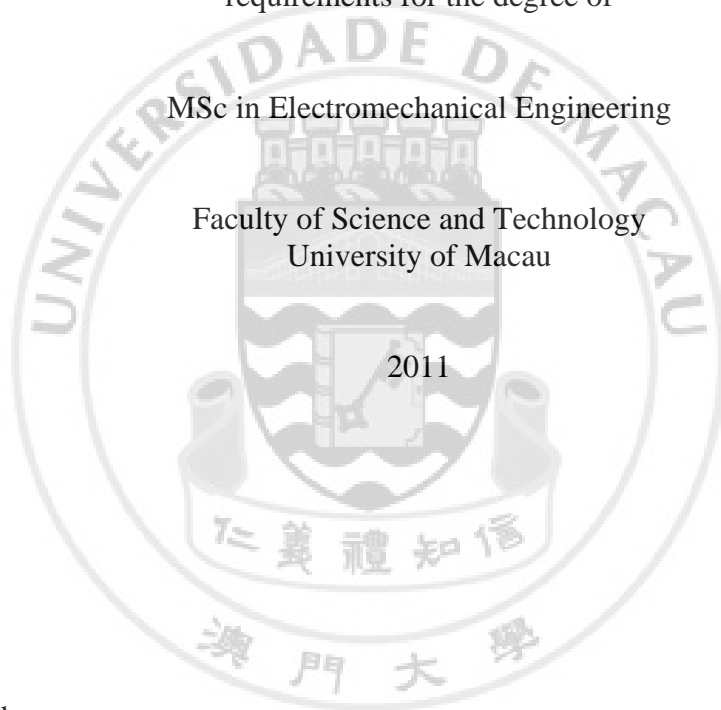
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Approved by \_\_\_\_\_

Supervisor

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Co-Supervisor

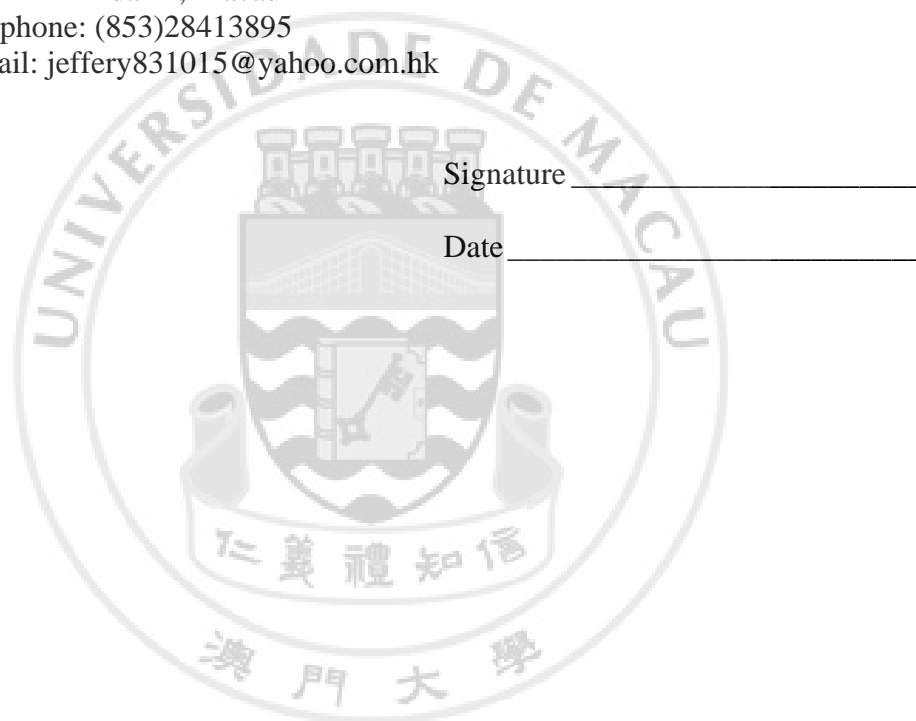
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Address: EST. Marginal Do Hipodromo No. 51 EDF. Iau Tim BL-1, 15  
Andar E, Macau  
Telephone: (853)28413895  
E-mail: jeffery831015@yahoo.com.hk



University of Macau

Abstract

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Thesis Supervisor: Prof. Wong Pak Kin (Chief Supervisor)  
Dr. Zheng Chao Xie (Co-supervisor)

Department of Electromechanical Engineering, Faculty of Science and Technology

This thesis investigates the vibration of a rotating constrained layer damped plate system. Although currently, most existing research utilizes rotating structures as modeled beams, this work however, models rotating structures as plates with constrained layer damping. Through the models investigated, this thesis develops a single layer plate finite element model for a rotating structure to improve in both accuracy and versatility.

Concurrently, existing research shows that the damping of the active constrained layer can provide more damping than the damping of the passive constrained layer. Therefore, in this work the constraining layer is made of piezoelectric material and thus, will work as both the self-sensing sensor and the actuator. In addition, a proportional control strategy is implemented to effectively control the damping in the rotating plate; parametric study is also conducted to explore the impact of some design parameters on structure's modal characteristics.

Furthermore, due to a large number of design variables in the complex model incorporating visco-elastic damping, this work examines the application of genetic algorithm (GA) in optimizing the first two resonance amplitudes of the driving point mobility at the center of the rotating plate. A genetic algorithm is applied to simultaneously determine several design parameters which maximize an objective

function. Compared with a typical gradient search approach Quasi-Newton method, GA can be more efficient and effective in finding the optimum configuration with the highest objective function value in the numerical example.



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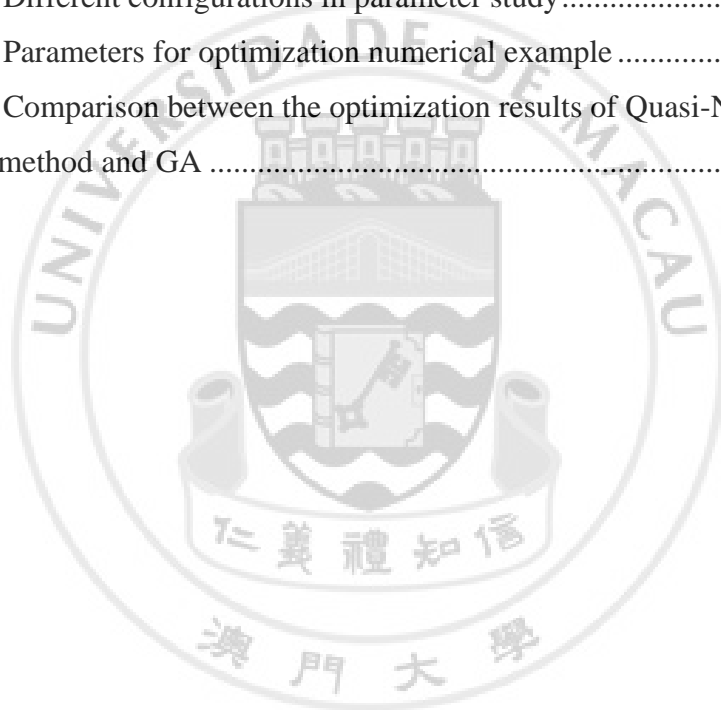
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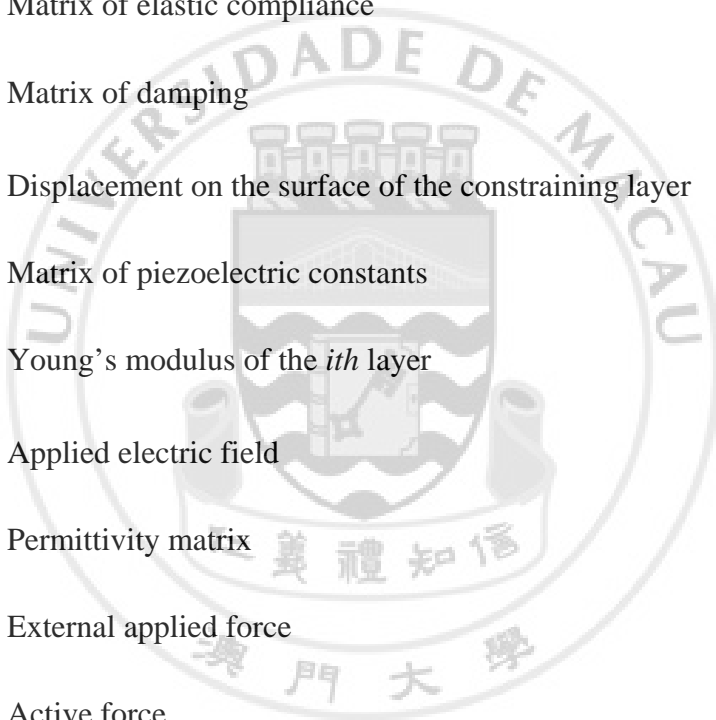


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## LIST OF ABBREVIATIONS



$A$	Transformation matrix between two coordinate systems
$B$	Matrix to decompose structural displacement
$b_i$	Shape functions for transverse displacement
$C$	Matrix of elastic compliance
$[C]$	Matrix of damping
$D$	Displacement on the surface of the constraining layer
$d$	Matrix of piezoelectric constants
$E_i$	Young's modulus of the $i$ th layer
$E$	Applied electric field
$e$	Permittivity matrix
$F$	External applied force
$F_c$	Active force
$f$	Additional stiffness matrix
$G_i$	Shear modulus of the $i$ th layer
$H_i$	Thickness of the $i$ th layer
$I_i$	Moment of inertia of the $i$ th layer

$K_1$	Elastic strain stiffness
$K_p$	Proportional gain
$[K]$	Linear stiffness matrix
$[K]_p$	Stiffness matrix due to proportional control
$L_i$	Width of plate
$[M]$	Mass matrix
$N$	Shape function matrix
$n$	Total number of degrees of freedom
$n_i$	Shape functions for longitudinal displacement
$q$	Whole plate finite element with three layers
$q_i$	Displacement vector of the $i$ th layer
$R$	Objective function
$R_1$	Peak responses for the first resonant frequencies
$R_2$	Peak responses for the second resonant frequencies
$RP$	Stiffening matrix
$RPM$	Rotational speed
$T_i$	Kinetic energy of the $i$ th layer
$TR_i$	Map matrix of the $i$ th layer

$u_i$	Longitudinal displacement at the contacting surfaces of the $i$ th layer
$V_a$	Control voltage
$V_i$	Strain energy of the $i$ th layer in the rotating plate
$V_s$	Sensor output voltage
$v$	Volume of plate
$v_i$	Longitudinal displacement at the contacting surfaces of the $i$ th layer
$w$	Transverse displacement for all layers
$z$	Transverse coordinate
$\bar{z}$	Transverse coordinate at the mid-plane of constraining layer
$\omega$	Angular velocity of rotating plate
$\theta$	Angle between the coordinate system $o-xyz$ and $O-XYZ$
$\rho_i$	Density of the $i$ th layer
$\sigma$	Stress
$\varepsilon$	Strain

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