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

by

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Abstract

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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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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 *ith* 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 *ith* layer
H_i	Thickness of the *ith* layer
I_i	Moment of inertia of the *ith* 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 *ith* 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 *ith* layer
TR_i	Map matrix of the *ith* layer

u_i	Longitudinal displacement at the contacting surfaces of the *ith* layer
V_a	Control voltage
V_i	Strain energy of the *ith* layer in the rotating plate
V_s	Sensor output voltage
v	Volume of plate
v_i	Longitudinal displacement at the contacting surfaces of the *ith* layer
w	Transverse displacement for all layers
z	Transverse coordinate
$\bar{z}$	Transverse coordinate at the mid-plane of constraining layer
ω	Angular velocity of rotating plate
θ	Angle between the coordinate system ***o-xyz*** and ***O-XYZ***
ρ_i	Density of the *ith* layer
σ	Stress
ε	Strain

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