# Optimum Design of a Tuneable Vibration Absorber with Variable Position to Suppress Vibration of a Cantilever Plate

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Tuneable vibration absorbers (TVAs) are used as semi-active controllers to reduce the undesirable vibrations in applications such as electrical transmission lines, machining processes, gas turbines, engines, and bridges. In this paper, the application of a TVA to suppress vibration of a cantilever plate is presented. The TVA, including mass, spring, and damper elements, is attached to the cantilever plate under harmonic excitation. In addition, the effect of the spring mass is considered in this analysis, which cannot be neglected in the small-scale problems. After the formulation of the problem, the optimum specifications of the absorber, including the spring stiffness and its position, are determined using an algorithm based on mode summation method. Using a numerical algorithm, the spring stiffness of the absorber and its best position are found for different values of excitation force position and frequency.

## 1. INTRODUCTION

Thin plates as the components of thin-walled structures are used in many engineering fields such as manufacturing processes, underwater vessels and structures, vehicles, missiles and aircrafts, medical equipments, and modern housing. Due to the extensive application of the plates and the importance of their vibration control, many investigations have been done. A review of the free vibration of isotropic rectangular plates with point supports is an early work in this area.[1] Using the Rayleigh-Schimdt technique, plate vibration with one term including two adjunct edges support and a point support at the opposite corner, has been researched.[2] The Rayleigh-Ritz method with orthogonal polynomial approximation functions has been used to analyze free flexural vibration of thin isotropic plates.[3]

For the safety design of a structure, generally modelled as uniform shells or plates, its dynamic analysis is of great importance. In practice, more realistic models are applied for structures with added mass and constraints. In this area, tuneable vibration absorber design to suppress vibration of a cantilever beam,[4] vibration characteristics of a cantilever plate with attached spring-mass system,[5] the effect of added lumped or distributed mass on natural frequency of cantilever and simply supported plates,[6,7] and forced vibration of a thin plate with attached discrete dynamic absorbers have been studied.[8] Also, finite element formulation for vibration sensing and control analysis of plates,[9] and estimation of natural frequencies by generation algorithm in neural network have been investigated.[10]

Many passive and active control approaches have been taken to suppress the vibration of plates. Using additional control load,[11] pre-stressed shape memory alloy (SMA) wires embedded in sleeves attached to the surface of the plate and SMA wires supporting the plate at strategically selected points,[12] passive piezoelectric-resistor elements,[13] and tuneable vibration absorbers[4] are some examples of passive control technique. Using active constrained layer damping (ACLD) for laminated thin composite plates,[14] uniformly distributed piezoelectric actuators,[15] piezoelectric patches including sensors and actuators,[16] active vibration absorbers,[17] and optimum determination of piezoelectric actuators and sensors locations,[18] are some methods done in active control approach.

In this paper, a dynamic system containing a TVA applied on a rectangular clamped plate is considered. The plate is under harmonic excitation force, and its frequency and position can be changed. The formulation is derived with the TVA comprising mass, spring, and damper elements. Since the spring mass cannot be ignored in small-scale dynamic systems, the formulation is modified and its effect is considered. To minimize the plate deflection, optimum values of the absorber parameters including the spring stiffness and its position are determined using an algorithm based on mode summation. Unlike the previous works, the vibration of the plate is suppressed through the simple and inexpensive design of a tunable vibration absorber. In this analysis, the best position of the TVA and its spring stiffness is found for various positions and frequencies of the excitation. As the force is moving along the plate, the TVA is moved along a specific determined path such that the plate vibration is minimized.

## 2. VIBRATION CHARACTERISTICS OF A CANTILEVER PLATE

A uniform rectangular plate over the domain $D$ defined by $0 < x < L_1$ and $0 < y < L_2$ and clamped in $x = 0$ is considered. Using the extended Hamilton's principle,[19] and assuming the plate deflection $w(x, y, t)$ as $w = WF^*$, in which $W$ depends on the spatial coordinates and $F^*$ is a time-dependent harmonic function of frequency $\omega$, leads to

$$\nabla^4 W(x,y) - \tilde{\beta}^4 W(x,y) = \frac{f}{D_E},$$
$$\tilde{\beta}^4 = \frac{\rho\omega^2}{D_E}, \qquad x, y \text{ in } D, \tag{1}$$