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Active Vibration Control of a Flexible Beam Structure using Chaotic Fractal Search algorithm

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Abstract

The performance of lightweight and flexible systems such as beam, plate and shell structures are vulnerable to excessive vibration level. Thus, many vibration control techniques have been developed in the past two decades in order to overcome this problem. In this paper, the development of active vibration control to suppress the unwanted vibration from a flexible beam structure is presented. The objective of this work was to evaluate the performance of chaos-enhanced Stochastic Fractal Search (CFS) optimization algorithm in modeling and vibration control of flexible beam system. Parametric modeling of the system was developed using auto-regressive exogenous (ARX) model structure based on the input-output data from previous experimental finding. The first two resonance frequencies of flexible beam structure was found at 3.418 Hz and 21 Hz. The accuracy of generated flexible beam model was validated using correlation and system stability tests. A PID controller incorporated with CFS optimization algorithm was employed to attenuate the unwanted vibration from the flexible beam system. Based on the proposed method, about 83.95% of the initial vibration disturbance successfully been suppressed with the mean-squared error value of 1.5178×10^{-4} been achieved. In conclusion, the simulation study indicates that the CFS algorithm possess capability to extract an adequate and stable model of the flexible beam structure, hence a better performance of control strategy can be achieved.

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Keywords: active vibration control; chaotic fractal search; flexible structure; fuzzy logic; PID controller

1. Introduction

Vibration is an element which exists in many mechanical systems. It happen when a body oscillated about an equilibrium point due to intentionally or unintentionally movement. Excessive vibration level in a flexible system can lead to long term damage and decrease the system performance. Therefore, many vibration control techniques either passive or active were proposed in order to attenuate the vibration level from disturbing the flexible structure system. In active vibration control, a new force signal (with similar magnitude but in opposite direction to disturbance force signal) is introduced to cancel out the disturbance force signal.

The studies in active vibration control have become more exciting with the recent advance in bio-inspired metaheuristic algorithms. The emergence of new metaheuristics can assist in solving system identification and controller design problems with fast and reliable results. This paper presents an investigation on dynamic modeling and controller design of the active vibration control for a flexible beam system. A novel enhanced Stochastic Fractal Search (SFS) optimization algorithm with chaos is employed to search for optimal parameters in parametric modeling and controller design of the system [1].

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2. Active Vibration Control of Flexible Beam Structure

Previously, many active vibration control methods for flexible structures have been developed. Mat Darus et al. [2] experimentally investigated the implementation of active force control (AFC) method to suppress disturbance vibration from a flexible plate system. The experimental results indicated a better vibration attenuation performance in comparison to high gain controller. A new approach of PID controller tuning via evolutionary algorithm to attenuate vibration of a flexible beam system have been presented by Saad et al. [3]. Parametric model identification was employed to obtain the system dynamic model. Two optimization algorithms which are Genetic Algorithm (GA) and Differential Evolution (DE) were used to tune the PID controller parameters. The experimental study found that PID controller tuned by DE and GA gave a better transient response than using Ziegler-Nichols method. Figure 1 shows the experimental setup of active vibration control for flexible beam system which adapted from [3].

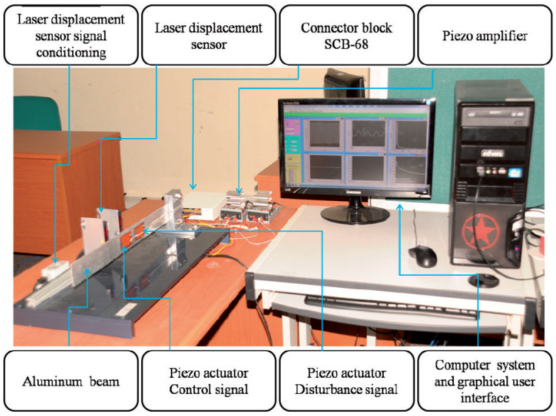

Fig. 1. Experimental setup [3]

In this study, the input-output data from the previous experimental finding is utilized to generate an adequate model of the dynamic system via system identification with the help of chaos-enhanced SFS algorithm (CFS).Figure 2 shows the normalized input-output data of the flexible plate system. A pseudo-random binary signal (PRBS) signal was selected to excite the flexible beam system due to its capability to excite all the dynamic modes within frequency range of interest [4]. The sampling rate of 1 kHz was employed.

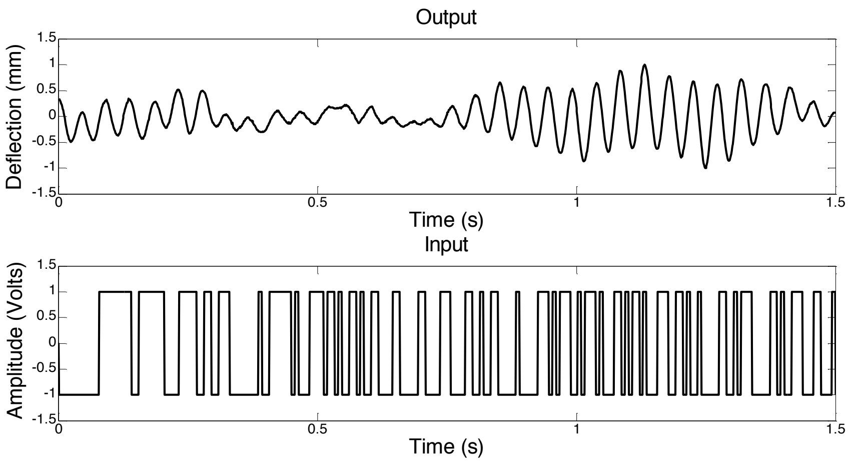

Fig. 2. Input output of flexible beam system