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Identification of pseudo-natural frequencies in a beam-moving mass system with periodic passages †

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Abstract

The response of a linear time-invariant (LTI) system to harmonic input generates a harmonic output with constant frequency but varying magnitude and phase. Many structural dynamic systems have been modeled as linear time-varying periodic (LTP) systems. Previous studies have reported that the response of an LTP system to an exponential input establishes an infinite number of frequencies. These studies have presented a new, exponentially modulated periodic signal space and a corresponding harmonic transfer function as useful tools in the operational modal analysis of LTP systems. In consideration of this new approach, this study mainly identifies the frequencies of a typical LTP system, such as a beam that is subject to the intermittent passage of moving masses. Upon obtaining the harmonic transfer function for the beam-moving mass system, conventional frequency domain methods for LTI systems are used to derive the frequency characteristics of the LTP system from the system response. These methods include the peak-picking method. As expected in an LTP system, an infinite number of pseudo-natural frequencies resonate in the beam-moving mass system.

Keywords: Beam-moving mass system; Harmonic transfer function; Linear time-periodic systems; Modulated periodic signal space; Operational modal analysis

1. Introduction

According to Ewins [1], a primary assumption for the applicability of experimental modal analysis is that the structure must remain time invariant, that is, the parameters to be determined should be constant. Identification techniques for linear time-invariant (LTI) systems have been developed by many researchers, including Andersen and Brincker [2], Fu and Hua [3], Brincker et al. [4], and Peeters and Ventura [5]. However, identification and modeling techniques for systems with time-varying parameters remain under investigation and development. The time-varying characteristics of an in-operation system correspond to valuable information for machine monitoring and diagnosis. Thus, Mathelin and Lozanob [6] and Bonato et al. [7] explored the benefits of determining the time-varying behavior of in-operation systems. These researchers established an effective modeling technique to extract the exact specifications of these systems.

Solving problems under ambient excitations is inherently difficult when traditional modal analysis methods are used; however, these methods can be regarded as a base for generating techniques to identify the traits of systems with time-varying characteristics. Numerous techniques have been proposed for the identification of linear time-varying (LTV) systems in either time or time-frequency domain, including those developed by Liu [8], Bellizzi et al. [9], Xu et al. [10], and Zhang et al. [11]. Liu and Kujath [12] adopted a new method that considers the time history of a linear time varying-periodic (LTP) system in time domain to determine some of the modal parameters of systems. These researchers employed a subspace-based algorithm that uses a multitude of force responses to identify the successive discrete transition matrices of LTP systems. This method is among of the few developed for LTP systems in time domain. Allen [13] presented a frequency-domain approach for intuitively characterizing an LTP system according to the methodology, as well as algorithms based on LTI systems. In fact, this method develops pre- and post-processing techniques to modify measured data and to extract pseudo frequency using conventional LTI methods. Han et al. [14] theoretically analyzed the natural frequencies of a spur—gear—pair system as a time-variant system on the basis of Floquet theory. The influences of the periodically time-varying parameters of mesh stiffness, including sideband frequency and contact ratio, on natural system frequencies in the stable and unstable regions were illustrated in detail. In 2010, Allen et al. [15] applied Wereley's [16] signal space definition to determine the modal parameters of a wind turbine

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