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Assessment of the phase synchronization effect in modal testing during operation*

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Abstract: The impact-synchronous modal analysis (ISMA), which uses impact-synchronous time averaging (ISTA), allows modal testing to be performed during operation. ISTA is effective in filtering out the non-synchronous cyclic load component, its harmonics, and noises. However, it was found that at operating speeds that coincide with the natural modes, ISMA would require a high number of impacts to determine the dynamic characteristics of the system. This finding has subsequently reduced the effectiveness and practicality of ISMA. Preservation of signatures during ISTA depends on the consistency of their phase angles on every time block but not necessarily on their frequencies. Thus, the effect of phase angles with respect to impact is seen to be a very important parameter when performing ISMA on structures with dominant periodic responses due to cyclic load and ambient excitation. The responses from unaccounted forces that contain even the same frequency as that contained in the response due to impact are diminished with the least number of impacts when the phase of the periodic responses is not consistent with the impact signature for every impact applied. The assessment showed that a small number of averages are sufficient to eliminate the non-synchronous components with 98.48% improvement on simulation and 95.22% improvement on experimental modal testing when the phase angles with respect to impact are not consistent for every impact applied.

Key words: Experimental modal analysis; Vibration; Impact-synchronous modal analysis (ISMA); Impact-synchronous time averaging (ISTA); Modal testing; Phase synchronization
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1 Introduction

Modal analysis is used in investigating the dynamic behavior of systems. This study enables an enhanced understanding and identification of the root cause of the vibration phenomena encountered in engineering by describing a system with its modal parameters, namely the natural frequencies, natural damping, and natural modes (Rossmann, 1999; Wang *et al.*, 2010a). These three parameters comprehensively define the dynamic characteristics of a system. Currently, there are two techniques used to extract these parameters, i.e., the classical experimental modal analysis (EMA) and operational modal analysis (OMA).

EMA has attracted attention and grown rapidly in popularity since the advent of the digital fast Fourier transform (FFT) analyzer in the early 1970s. In the modal data acquisition stage of EMA, the responses of a linear, time-invariant system are measured along with a known excitation, often out of its

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