A Multi-View Optical Technique to Obtain Mode Shapes of Structures

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A Multi-View Optical Technique to Obtain Mode Shapes of Structures

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Abstract

The vibration characteristics of a structure are conventionally obtained by exciting the structure using an impact hammer or a mechanical shaker and measuring the response using accelerometers. However, using accelerometers for vibration measurement may induce mass loading effects and does not provide the full-field response of the structure. Also, sometimes it is challenging to excite measurement points in all the three x, y and z directions using an impact hammer and obtaining the 3D mode shapes becomes nearly impossible. Digital Image Correlation (DIC) has provided a solution to these problems because it provides the full-field response of the structure, is a non-contacting technique, and does not induce any mass loading effects. However, the DIC technique (similar to other optical methods) is limited by the field of view of the cameras and can only measure the response on the parts of the structure that cameras have a line of sight. Thus, this technique cannot be used to obtain the mode shapes of large and complex structures. In this paper, we have proposed and validated a new approach to obtain a uniform scaling factor that enables us to stitch the mode shapes from different views of cameras. This technique enables us to extract the mode shapes of complex structures using only a single pair of cameras. To show the merit of the proposed technique, the mode shapes of a fender are extracted using this optical based technique. The fender is excited with a known force using an impact hammer. A pair of high-speed cameras is used to measure the response of the structure limited to its field of view. The mode shape of every field of view is then obtained based on the excitation force and measured response using the digital signal processing theory. Further, the mode shapes of individual fields of view are stitched using a minimum of three reference points in the region common to the adjacent field of view to obtain the mode shapes of the entire structure. The proposed approach expands the applications of digital image correlation technique in the field of structural dynamics and enables us to extract mode shapes of a complex structure using this optical technique.

Keywords: Digital image correlation, computer vision, mode shape, structural dynamics, photogrammetry, vibration, measurement techniques, fender, automotive structure

1. Introduction

Recently, lightweight materials (e.g., aluminum, plastic, carbon fiber, composite, and high-strength steel) are increasingly used in automotive body structure and aerospace industry to reduce fuel consumption while maintaining or even improving safety and performance. Because most structural vibrations in cars are radiated by the body panels [1], particular care must be paid in the modeling of these lightweight structures. Thus, accurate models of these structures are required for dynamic and vibration analyses. There have been many efforts in the area of validating analytical results using experimental results for these structures. In conventional Experimental Modal Analysis (EMA), a structure is excited with a known force using an impact hammer or a shaker, and the response at a few discrete points are recorded using accelerometers to obtain the natural frequency and mode shapes of the structure. However, there are