823. Finite element model updating of micromachined torsion structures using experimental eigendata

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Abstract. In this paper, the dynamic characteristics including natural frequencies and mode shapes of a cross-shaped torsion structure, fabricated by a micromachining process, are measured by using two full-field and non-contact experimental techniques: Electronic Speckle Pattern Interferometry and Stroboscopic Interferometry. In addition, the finite element method is also applied to analyze the microstructure. Since the mechanical properties of a microstructure are usually not accurately known and neither is its depth dimension, it is very likely that the measured and the predicted results show a significant inconsistency. This research performs a finite element model updating procedure to determine a set of much more reliable values for the mechanical properties and the thickness of the torsion structure. The result is a refined finite element model capable of accurately predicting the dynamic behaviors of the micromachined device and suitable for further design modification studies. Two updating cases both show significant improvements in frequency prediction. With the inclusion of the thickness parameter, the second case reduces the frequency differences from over 17 % to under 0.4 %.

Keywords: torsion structure, micromachined structure, finite element model updating, ESPI, SI.

1. Introduction

The functional performance of micromachined torsion structures, widely utilized in projection televisions and optical switches, is critically dictated by their dynamic characteristics including the natural frequencies and mode shapes. During the process of design and development of a Micro-Electro-Mechanical-System (MEMS) structure, there is always a concern that the actual behavior of a manufactured device is significantly different from the simulation result of the counterpart virtual model. If this deviation is substantial, the consequence might be catastrophic. The finite element method (FEM) has been commonly employed to simulate the static and dynamic behavior of microstructures, e.g. [1, 2]. Applying FEM to analyze a microstructure requires mechanical and geometrical properties, such as the Young's modulus and Poisson's ratio of the material used and the thickness of the structure, as input parameters. A small error in one input parameter can produce large deviations from the true structural responses. To obtain a more accurate and reliable finite element (FE) model, the FE model updating technique can be implemented to fine tune the model based on measured data [3-5]. For dynamic characteristics measurement of MEMS devices, Electronic Speckle Pattern Interferometry (ESPI) and Stroboscopic Interferometry (SI), which both are full-field and non-contact experimental techniques, play two important roles. ESPI and SI methods employ optical and image processing techniques and analysis software to extract the resonance frequencies of microstructures and their three dimensional mode shapes. Holographic interferometry [6], the underlining principle used by ESPI and SI, is a procedure for recording and analyzing the brightness and darkness, colors, and phases of two interfering light beams, one reflected from the test object and the other forming the reference. Holographic interferometry has been extensively applied to various engineering applications, including measurements of temperature field [7], three dimensional deformation [8], and structural dynamics measurement in nano-scale [9, 10].