DEVELOPMENT OF A COMB-DRIVE´S FAILURES IDENTIFICATION METHODOLOGY

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ABSTRACT

Many MEMS fabrication processes have been developed since the study of these devices began in the 60´s. We also know that, defects are used to be generated in such processes. A harmonic analysis, using a finite elements program, may be used to simulate MEMS structures, generating, as results, a signature with specific information that allows identifying the defect. We look for the development of a failure identification methodology based on the comparison between signatures of perfect and damaged structures. In this work, we present a failure identification methodology for a comb-drive, associating failures, signatures and change of vibration modes.

1. INTRODUCTION

Micro-Electro-Mechanical-Systems (MEMS) [1] are transduction devices whose functional principles relate mechanical and electrical domains (e.g. displacement and voltage). One of these devices is the comb-drive, composed by two pairs of combs, a static (fixed) pair and a mobile pair, each comb having a number of very slim fingers, as shown in Fig.1.1 (that shows only the mobile pair). The mobile pair of combs is connected to a mobile structure composed by folded spring elastic beams, which allows the displacement in the same direction as the electrical excitation. The fixed comb is located close to the mobile comb and their fingers are interleaved. A voltage (ddp) is applied between the mobile and fixed parts, in order to provide capacitive effects between the combs. It is between the closest combs that occurs the conversion from electrical signal to displacement and contrariwise. The comb-drive may work as a sensor, an actuator, or a frequency mechanical filter, being this last function the most relevant for this work.

The dimensions in MEMS are used to be of the order of micrometers (μm), what difficults not only the experimental analysis but also the fabrication process. Up to now, many different techniques were developed to manufacture these devices, but they are not free of defects. Because of reliability and quality control subjects, it is necessary to develop a failure identification methodology. This work presents a failure testing methodology for comb-drives, based on harmonic analysis.

2. RELATED WORK

2.1. Manufacturing Process

There are different techniques used for MEMS fabrication. The most common are those based on deposition of different materials layers patterning and etching. The most important material used in comb-drive fabrication is the poly-silicon, which has the required mechanical and electrical properties.

2.2. Failures characterization

The failures that come from the manufacturing process [2] are changes in the structure such as mass excess, attachment of mobile parts and, as a consequence, the collapse of the structure. The failure may occur in layers deposition or layers etching phases. Other common failures are beam breaking, mass subtraction because of deposition mistakes or broken parts, total or partial (friction) attachment of mobile parts.

2.3. Simulation

The failures were simulated in a finite elements software (Ansys), using a bi-dimensional comb-drive structure in plan stress state. The dimensions of the simulated structure do not match the real device, but we want just to analyze the effects of the failure on the behavior of the device. It is also important to say that none electrical behavior was considered in this work. The failures were simulated and studied one by one and the effects of more than one failure, simultaneously, were not considered. The structure was submitted to a harmonic analysis. A pre-determined displacement was applied with a certain frequency and we got as a result the displacement amplification. A frequency range from 100 KHz to 1 MHz was considered, and we got a displacement *vs.* frequency plot that we called the structure signature.

This analysis was first made with a perfect structure and than, in a damaged one. The signatures were compared and we could relate the signature changes with the type of failure. We also observed the changes in the vibration modes, Fig.2.1-2.2.

3. RESULTS

3.1. Intact comb-drive

The perfect structure presented a signature, with two peaks corresponding to the first and second natural oscillation frequencies which are associated to the first and second vibration modes; being this first mode the needed one. (Figs.3.1-3.2.)

3.2. Finger breaking (mass decrease) defect

The finger breaking corresponded to a mass decrease, and the broken finger's position didn't affect the results (not considering electrical effects). The first vibration mode did not change, and a mass decrease causes, by the equation 3.1, an increase on vibration frequencies, shifting the signature curve to the right.

$$\omega_{\mathrm{n}} = \sqrt{\frac{K}{M}} \qquad (3.1)$$

3.3. Mass addition defect

The mass addition to the fingers causes only a decrease of vibration frequencies, shifting the signature curve to the left. The first vibration mode did not change greatly.

3.4. Total or partial finger attachment defect

In both cases, the first vibration frequency increases strongly, because of the appearing of a new anchor. The vibration mode changes from fully translational to partially rotational. (Fig.3.2.)

3.5. Spring beam breaking defect

In these cases, we observed that the first vibration frequency becomes slightly lower. The higher order natural vibration frequencies are greatly modified, being even possible to identify which beam was broken. The vibration mode also changes, getting partially rotational. (Fig.3.1.)

4. REFERENCES

[1] Stephen D. Centuria . "Microsystem Design"Microsystem Design. Kluwer Academia Publishers. (2001)

[2] A, KOLPEKWAR, c, Kellen, R Blanton, "MEMS Fault Model Generation using CARAMEL, Internacional test conference IEEE, (1998)

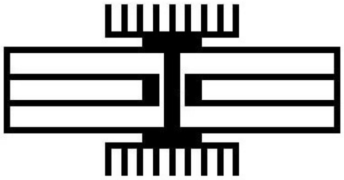

Fig. 1.1 Mobile comb's intact structure

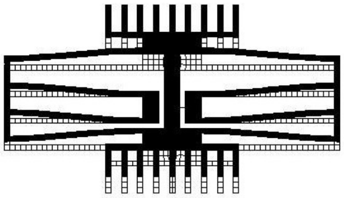

Fig. 2.1 Intact comb first vibration mode

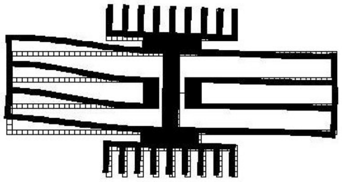

Fig. 2.2 Fixed finger defect first vibration mode

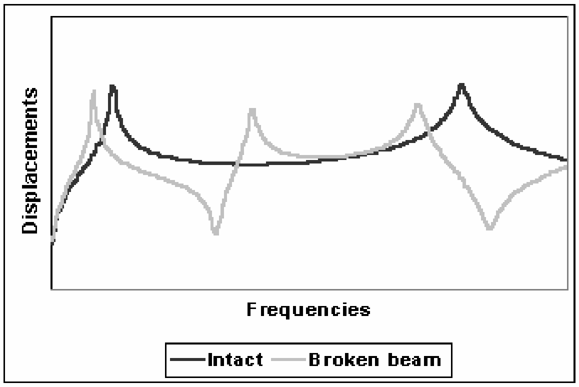

Fig.3.1 Signatures of intact comb-drive (darkest line) and spring broken beam comb-drive.

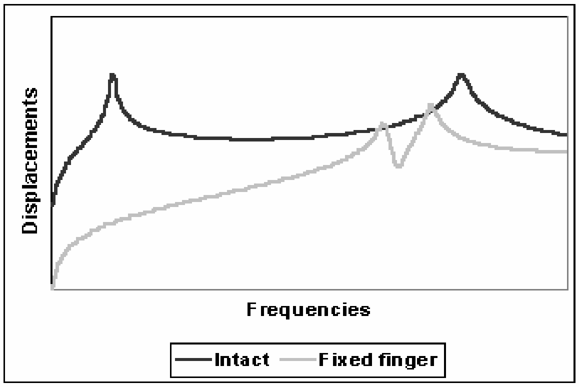

Fig.3.2 Signatures of intact comb-drive (darkest line) and fixed finger comb-drive.