Mechanical Caracterization of a Comb-Drive Structure to Applications in Accelerometers and Electromechanical Filters

Savio Franzner, Jakson Manfredini Vassoler
franzner@yahoo.com
jaksonmv@bol.com.br

Universidade Federal do Rio Grande do Sul - UFRGS
Departamento de Engenharia Mecânica - DEMEC

Abstract

This work intends to study the mechanical behavior of a comb-drive, typical structure used in micro-mechanism with the objective to work as sensor/actuators or mechanical filters. The understanding of the structural behavior of these kinds of devices will assist in the design and instruments projects that use them. For that was realized a finite elements model of the comb-drive structure and made three kinds of analyses (determination of modes and natural frequencies and determination of the system gain function for an input and an output established and direct analyze in time using an implicit method of integration).

1 Introduction

The motivation that led to the development of microsystems is very similar to that motivated the development of CIs: miniaturization, manufacture cost reduction in large amount, project flexibility, performance, reproduction, reliability, besides of the possible integration with electronic circuits.

The growing interest of researchers and industries for microsystems in the last years is easily explained by the great spectrum of application in the most different areas as telecommunications, medicine, motorist, process control and industrial automation that definitely see in these micro-mechanism a way to develop sensors and actuators for applications before limited by the size of the devices. The micro-system project, in the world context, is one of the markets more attractive for the new generation of engineers with capability in control, electronic and mechanics.

The micro-systems could be defined as compost miniaturized systems by three fundamental blocks: the communication block with the exterior environment(sensor/actuator), the analog interface block for acquiring/transmission and amplification of the sensors/actuators signals and the intelligent control block of the data storage systems and interface with computational systems.

Inside this vision, it will be studied the part of the actuators/sensors, through the specific study of the comb-drive structure for application in micro-accelerometers using an own technology for the building of micro-structures.

More information about mechanical and electronic aspects of this mechanisms can be found in Nandim [1], Senturia [3]

1.1 Basic Structures of the Comb-Drive

Comb-drive is one of the structures more known and used in micro-machines due to your operation somewhat simple and efficient. Basically, comb-drive is formed by a whole of fixed fingers and another by moving fingers. The two wholes are electrically isolated each other.

Your structure very useful can be used as many actuators as sensors. In the case of actuators, an applied tension in the fixed fingers causes a displacement in the moving part due to the electrostatic force. This concept is used in various micro-actuators.

In the case of the utilization of comb-drive as micro-sensors, the whole of fixed and moving fingers forms capacitors that, with the aid of an external force in the moving fingers suffer a displacement and as a result the variation of yours capacitances. This variation is used to detect any value.

As example of this kind of application can quote the building of micro-accelerometers and the electro-mechanical filters formed by various comb-drive structures connected in series.

The objective of this work is to show the advances realized in the mechanical behavior of comb-drive with the purpose to become easier the design of these kinds of sensors.

In the section two show the characteristics of the used model to realize the mechanical characterization and the kinds of analysis that are being made. In the section three show some results and the partial conclusions obtained in the work.

2 Description of the Numeric Model

It was built a numeric model of a comb-drive using a finite element system (Ansys 5.6[2]), available in CESUP-UFRGS using shells and beams as elements. In the table 1 is shown the mains characteristics used to the building of the model specifying the material properties and the elements type used.

Element	Shell	beam
Element type	Shell 63	Beam 4
Young's modulus(N/m^2)	202E9	202E9
Density(Kg/m^3)	2330	2330
Poisson's ratio	0.278	0.278

Table 1 – Material properties of the comb-drive analyzed.

About the model was realized the following analyses:

a) Determination of modes and natural frequencies;
b) Determination of the system gain function in the frequency's field defining the input as an horizontal displacement in the base and the output as a displacement in a extreme of a comb-drive's comb;
c) Determination of the system response in time subjecting the same to an impulsive excitation in the base, measuring the response in the extreme of one of the comb-drive.

The system study with these three kinds of analyses allowed to understand better the mechanical behavior of the system studied.

3 Preliminaries Results

As preliminaries results show in the figure 1 a view with the configuration of the vibration's first mode of the structure in analysis. In the figure 2 show the response in terms of the displacement obtained in the extreme of a comb due to an harmonic excitation in the base, changing the frequency of the harmonic excitation. In Figure 3 shows the first mode obtained to a filter consisting of two comb-drives joined in series. In figure 4 shows the response obtained carrying out an harmonic analyse subjecting the structure to an harmonic for seen displacement in the base of one of the components, measuring the response in the extreme of one of the combs. In figure 5 shows the same graphic that in figure 4, but in logarithm scale. Finally in figure 6 shows the variation in time of the horizontal displacement in one of the extremes of the filter component when subjected to an impulsive excitation in the base.

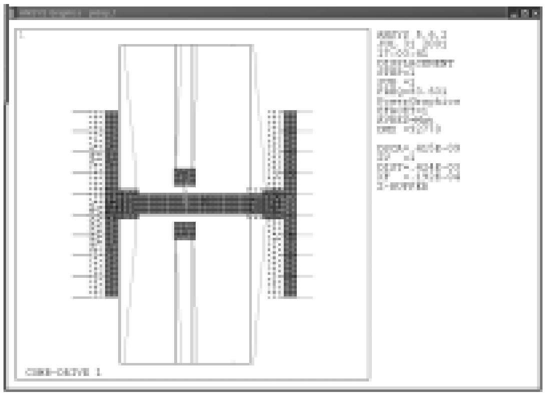

Figure 1 - First mode of vibration in 83.631 Hz.

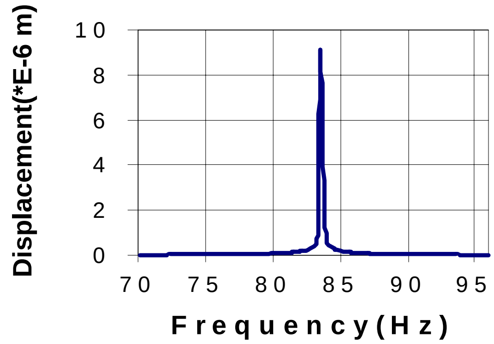

Figure 2 – Graphic of displacement measured in the extreme of one of the combs when applied an excitation harmonic in your base.

Notice that with the frequency of 83 Hz results in a displacement more accentuated due to the harmonic force acts in the same direction of the natural frequency.

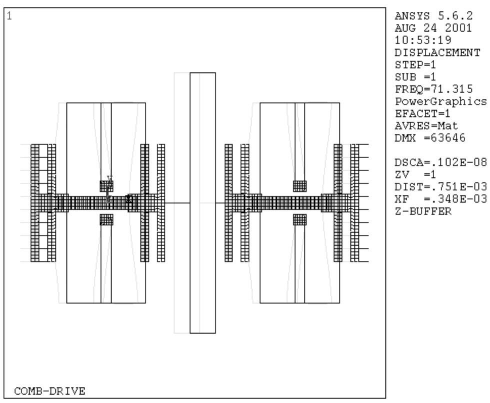

Figure 3 - First mode of vibration in 71.315 Hz.

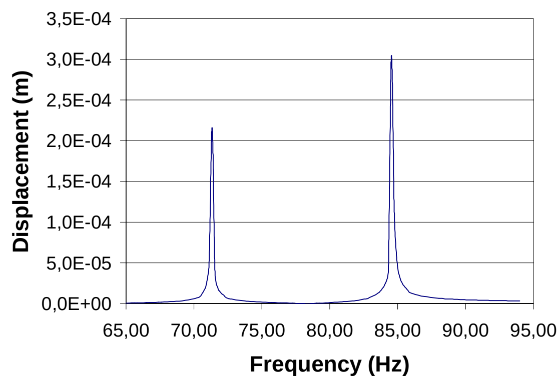

Figure 4 - Graphic of displacement in the extreme of the filter when applied an harmonic force in the base, measuring the response in one of the extremes of the comb.

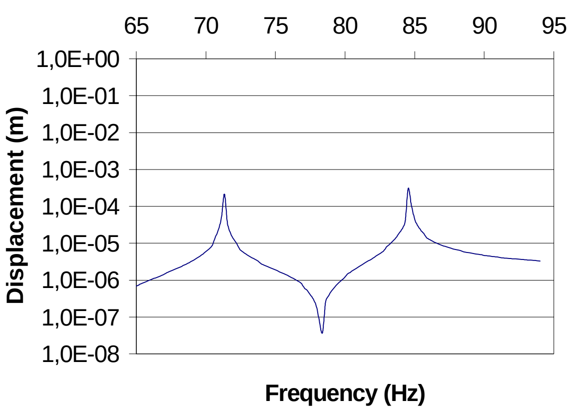

Figure 5 - Graphic of displacement in the extreme of the filter when applied an harmonic force in the base of the components measuring the response in one of the extremes of the comb, in logarithm scale.

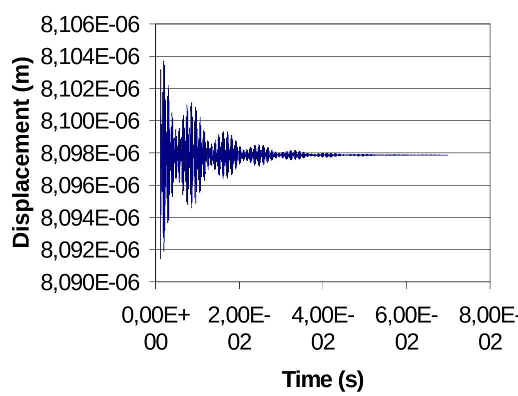

Figure 6 - Graphic of variation of the displacement in the extreme of the filters components comb excited with an impulse in the base of one of your components.

4 Preliminaries Conclusions

In this work was made a numeric model of a comb-drive with the objective to understand your mechanical operation and about the preliminaries results obtained is possible to conclude that:

- A mechanical numeric model of a comb-drive using the finite element methods will allow to know better the mechanical characteristics and assist in the design of the same.

- The utilization of many kinds of analyses (determination of modes and frequencies, harmonic and transient analyses), permitted to obtain coherent results each other;

The continuation of this work will consist from developed mechanical model on realizing a parametric study that allows to obtain simple formulas which can be incorporated to a project program that include the electronic characteristics of the sensor to be projected. This kind of work is recommended in Senturia [3]. This mechanical models will be able to be used to determine the locating and damage magnitude from variation of the dynamics parameters of the structure on.

References

[1] Nadim Maluf, “An Introduction to Microelectromechanical Systems Engineering”, p. 249, Boston, London, Artech House,2000.
[2] Ansys 5.6, “Ansys’ Guides Help”, 2001.
[3] Stephen D. Senturia, "Microsystem Design", Massachusetts Institute of Technology, p. 689, Kluwer Academic Publishers, 2000.