Construction and Characterization of an Ultrasonic Array Using Different Backing Materials to Evaluate Crosstalk

Israel Sánchez Domínguez^{1,2} and Pedro Acevedo Contla²

1. Polytechnic University of Madrid, School of Industrial Engineering, Madrid 28001, Spain

2. National Autonomous University of Mexico, Institute of Research in Applied Mathematics and Systems, Mexico City 04510, Mexico

Received: March 05, 2013 / Accepted: April 02, 2013 / Published: August 25, 2013.

Abstract: The construction and characterization of an ultrasonic array using different backing materials are presented. In the construction of these arrays PZT piezoelectric elements are used as sensors. The objective of this paper is to evaluate the propagation of crosstalk in different materials to find an optimum material to be used in the construction of the array. Rexolite, copper and brass were the materials used in this work due to their ideal propagation characteristics and taking into account the geometry and dimensions of the array, these three different materials were studied to verify which one of them offered the best option to determine the propagation of the phenomenon of crosstalk. Simulations made using a finite elements software (COMSOL) showed that the various modes of response of the array can be determined, and using frequency generators, drivers and digital oscilloscopes is possible to validate the simulations presented in this work.

Key words: Ultrasonic array, backing, crosstalk, simulation, finite elements method (FEM).

1. Introduction

The construction and characterization of a matrix array using piezoelectric elements is described, and the matrix array was used to evaluate the phenomenon of crosstalk. The performance of ultrasonic arrays is established by the shape and materials used in its construction. However, the functionality also is affected by factors derived from the shape and the materials used, a primary factor is the phenomenon known as crosstalk. Crosstalk is a phenomenon that is generated in arrays of piezoelectric elements; this produces an unwanted interaction between the piezoelectric elements of the matrix, causing parasite radiation (in the lateral mode). The distance between elements is a key factor in this phenomenon since this distance sets the coupling capacitance between

elements; other factors are the electrical connections as well as the electromagnetic emission.

The dimensions of the elements, their position and the vibration modes of the piezoelectric materials cause different intensities of crosstalk [1-2]. Fig. 1 shows the types of crosstalk that can be caused in an array of piezoelectric elements.

An array is a set of piezoelectric elements arranged in different geometries and with different numbers of elements with a (λ) separation between them which is calculated from the following equation:

$$\lambda = \frac{c}{f} \quad (1)$$

where, c is ultrasonic velocity in the propagation medium; f is frequency.

Fig. 2 shows the different types of arrays that can be constructed using piezoelectric elements, where it is possible to observe that the distance between them is an important factor since to place a large number of

Corresponding author: Israel Sánchez Domínguez, Ph.D. student, UPM. E-mail: israel.sanchez@iimas.unam.mx.

Fig. 1 various modes of coupling between array elements that contribute to the formation of “cross-talk” (a) Mechanical “cross-talk”: propagation of acoustic waves through the support elements and the material that fills the gap between them; (b) Electrical “cross-talk”: power through capacitive coupling between elements and electrical connections as well as electromagnetic emission.

Fig. 2 Types of arrays.

Elements, the distance between them should be minimal [1].

2. Materials and Methods

The construction and characterization of the array was made in three stages, firstly, the simulation using the finite elements method (FEM) [3, 4] followed by the construction of the matrix of piezoelectric elements, in this stage three different types of materials (Rexolite, copper and brass) were considered, which were used as backing and basis for the matrix [5-6]. The dimensions of the matrix can be seen in the following diagram (Fig. 3), which shows an array of 2×3 elements. Finally, once the matrix was constructed using piezoelectric elements, the crosstalk that was generated in this matrix was measured, to carry out this measurement we used the set up shown in Fig. 4, where the measurement was performed on each one of the arrays [7].

3. Results and Discussion

Fig. 5 shows the three arrays constructed using different materials (Rexolite, copper and brass) to verify whether the material influences the propagation of crosstalk. The arrays have the dimensions shown in Fig. 3.

Fig. 6 shows the experimental set up indicating how the measurements were performed, here only a part of all the measurements are presented, however these measurements are valid to show that the experiment was successful showing the presence of crosstalk.

From the measurements obtained we can say that the presence of crosstalk is mainly due to lateral vibration mode and is undoubtedly the cause of the phenomenon of crosstalk. The graphics below show that is possible to observe the presence of crosstalk as well as the way in which it propagates. However, it should be noted that when using Rexolite as backing material, there is a strong attenuation in the propagated energy in the side mode, this is because the Rexolite is an excellent acoustic coupler, however, it is a perfect attenuator and insulating material when it transmits energy to the contiguous elements.

Fig. 7 shows the excitation pulse of the ceramics. This pulse was the same for all the experiments and all the arrays employed.

Fig. 3 Diagram of the 2×3 piezoelectric elements array.

Fig. 4 Diagram of the crosstalk measurement in the piezoelectric elements arrays.

Fig. 5 Constructed arrays to measure crosstalk using different materials, (a) brass (b) copper and (c) rexolite.

Fig. 6 Experiment for measuring crosstalk, the pulser, the oscilloscope and the arrays are shown in the figure at the hand right side a zoom of the arrays is shown in the figure at the hand left side.

Fig. 7 Excitation pulse to measure crosstalk in the arrays of piezoelectric elements.

Fig. 8 shows two of the measurements made using the copper array, the positions shown are point 1 and 4, this because point 1 is the nearest distance and point 4 is the most distant distance.

Fig. 9 shows two of the measurements carried out in the brass array.

Fig. 10 shows two of the measurements carried out in the Rexolite array. In this case it can be seen an attenuation in the signal, implying that Rexolite is a material that attenuates the propagation signal that radiates all the elements in its lateral vibration mode.

Based on the results obtained in the measurement using Rexolite, a measurement in each of the ceramics of the array was made, founding that all the ceramics were radiating. Fig. 11 shows the radiation form of the ceramics in the Rexolite array.

4. Conclusions

From the results obtained it is possible to conclude that Crosstalk is present in all matrix arrays and in all cases can be seen that the material of the array influences the propagation of crosstalk, independently of the separation between the piezoelectric elements. Rexolite is a material which presents acoustic characteristics similar to water, however in this case it was found that it is capable of attenuate the vibration form in the lateral mode; it allows that the elements

Fig. 8 Crosstalk measured at 2 different points of the copper array of piezoelectric elements, (a) position 1, nearest point between elements and (b) most distant point.

Fig. 9 Crosstalk measured at 2 different points of the brass array of piezoelectric elements, (a) position 1, nearest point between elements and (b) most distant point.

Fig. 10 Crosstalk measured at 2 different points of the Rexolite array of piezoelectric elements, (a) position 1, nearest point between elements and (b) most distant point.

vibrate correctly in the array, but does not allow the propagation in the lateral mode. The other materials used in the experiments gave interesting results, where

the presence of the crosstalk phenomenon is present and based on these results it is worth to continue this research line.

Fig. 11 Vibration of one of the ceramics in the array with backing of Rexolite.

Acknowledgments

The authors thank DGAPA- PAPIIT-1N109513 for their support; also to AlβAN Office grant number IO4D00029MX.

References

[1] I.S. Domínguez, Metodología para la Evaluación del

cross-talk en Transductores Ultrasónicos Matriciales, MSc. These, Universidade Federal do Rio de Janeiro, 2003.

- [2] I.S. Domínguez, M.A. von Kruger, Methodology for evaluating the cross-talk matrix transducers, in: XVIII Brazilian Congress of Biomedical Engineering, Sao Jose dos Campos, SP, Brasil, 2002, pp. 224-227.
- [3] I. Sánchez, J. Contreras, P. Acevedo, M. Fuentes, Finite Element Simulation Using A Type Ultrasonic Transducer Array for Medical Applications, SOMI XXIII, Instrumentation Congress, Xalapa, Veracruz, México, October 2008, memories CD.
- [4] Manual COMSOL Multiphysics® 3.3: Manual Structural Mechanics Module, Version 3.3, 2006, pp. 323-346.
- [5] I. Sánchez, P. Acevedo, J. Contreras, Simulation and characterization of an ultrasonic transducer as the acoustic coupling using Rexolite, in: 29th Annual Meeting International Conference on Materials, Surface and Vacuum, San Luis Potosi, México, 2009.
- [6] Rexolite® Information, <http://www.rexolite.com/>.
- [7] P. Gori, N. Lambertini, F. Montero De Espinosa, A. Iula, M. Pappalardo, Influence of the inter-element coupling on ultrasound array radiation patterns, *Journal of Computational Acoustics* 9 (3) (2001) 773-778.