Experimental Characterization of A Piezoelectric Transducer Array Taking into Account Crosstalk Phenomenon

Abdelmajid Bybi[1,*], Driss Khouili[2], Christian Granger[3], Mohammed Garoum[1], Ahmed Mzerd[4], Anne-Christine Hladky-Hennion[3]

[1]Mohammed V University in Rabat, High School of Technology in Sale, MEAT, Sale, Morocco

[2]Mohammed V University in Rabat, High School of Technology in Sale, LASTIMI, Sale, Morocco

[3]ISEN Department, IEMN, UMR CNRS 8520, Lille, France

[4]Mohammed V University in Rabat, Faculty of Science, STCE, Energy Research Center, Rabat, Morocco

Received 29 May 2019; received in revised form 20 July 2019; accepted 06 August 2019

Abstract

Ultrasonic transducer arrays are generally composed of several piezoelectric elements arranged in 1D or 2D ways. Crosstalk is an undesirable phenomenon decreasing the performance of these devices. It generates parasitic displacements at the elements' radiating surfaces, which changes the directivity of the array. Furthermore, the transducer's displacement plays a critical role in terms of the focal area and transferred intensities. The objective of this paper is to characterize a piezoelectric array composed of seven-elements made of PZ 27 ceramic experimentally. It investigates the effects of the crosstalk phenomenon on the array's performance in particular. The results have shown that the array's elements vibrate mainly in thickness mode, but the displacement is not uniform along their length due to the contribution of a parasitic length mode. Moreover, the major parasitic displacements are obtained on the neighboring passive elements: about -7.3 dB, -11 dB, and -12 dB, on the first, the second, and the third elements, respectively.

Keywords: ultrasonic transducer arrays, displacement measurement, directivity pattern, crosstalk

References

[1] J. Lee, J. Y. Moon, and J. Chang, "A 35 MHz/105 MHz dual-element focused transducer for intravascular ultrasound tissue imaging using the third harmonic," Sensors, vol. 18, no.7, pp. 2290, July 2018.

[2] R. H. Silverman, "Focused ultrasound in ophthalmology," Clinical Ophthalmology, vol. 10, pp. 1865-1875, September 2016.

[3] S. Ovel, Sonography exam review: physics, abdomen, obstetrics and gynecology, 2nd ed. Elsevier Health Sciences, 2013.

[4] J. Y. Zhang, W. J. Xu, J. Carlier, X. M. Ji, S. Queste, B. Nongaillard, and Y. P. Huang, "Numerical and experimental investigation of kerf depth effect on high-frequency phased array transducer," Ultrasonics, vol. 52, no. 2, pp. 223-229, February 2012.

[5] W. Wang, S. W. Or, Q. Yue, Y. Zhang, J. Jiao, B. Ren, D. Lin, C. M. Leung, X. Zhao, and H. Luo, "Cylindrically shaped ultrasonic linear array fabricated using PIMNT/epoxy 1-3 piezoelectric composite," Sensors and Actuators A: Physical, vol. 192, pp. 69-75, 2013.

[6] A. Bezanson, R. Adamson, and J. A. Brown, "Fabrication and performance of a miniaturized 64-element high-frequency endoscopic phased array," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 61, no. 1, pp. 33-43, January 2014.

* Corresponding author. E-mail address: abdelmajid_bybi@hotmail.fr

Tel: +212-6-39668291; Fax: +212-5-37881564

[7] R. Chen, N. E. Cabrera-Munoz, K. H. Lam, H. S. Hsu, F. Zheng, Q. Zhou, and K. K. Shung, "PMN-PT single-crystal high-frequency kerfless phased array," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 61, no. 6, pp. 1033-1041, June 2014.
[8] A. Abrar, D. Zhang, B. Su, T. W. Button, K. J. Kirk, and S. Cochran, "1-3 connectivity piezoelectric ceramic-polymer composite transducers made with viscous polymer processing for high frequency ultrasound," Ultrasonics, vol. 42, no. 1-9, pp. 479-484, April 2004.
[9] J. M. Cannata, J. A. Williams, Q. Zhou, T. A. Ritter, and K. K. Shung, "Development of a 35-MHz piezo-composite ultrasound array for medical imaging," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 53, no. 1, pp. 224-236, January 2006.
[10] H. R. Chabok, J. M. Cannata, H. H. Kim, J. Williams, J. Park, and K. K. Shung, "A high-frequency annular-array transducer using an interdigital bonded 1-3 composite," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 58, no. 1, pp. 206-214, January 2011.
[11] Q. Zhang, P. A. Lewin, and P. E. Bloomfield, "Variable-frequency multilayer PVDF transducers for ultrasound imaging," Proc. International Society for Optics and Photonics, Medical Imaging 1997: Ultrasonic transducer engineering, April 1997, vol. 3037, pp. 2-12.
[12] K. Brenner, A. S. Ergun, K. Firouzi, M. F. Rasmussen, Q. Stedman, and B. Khuri-Yakub, "Advances in capacitive micromachined ultrasonic transducers," Micromachines, vol. 10, no. 2, pp. 152, February 2019.
[13] B. C. Lee, A. Nikoozadeh, K. K. Park, and B. T. Khuri-Yakub, "High-efficiency output pressure performance using capacitive micromachined ultrasonic transducers with substrate-embedded springs," Sensors, vol. 18, no. 8, pp. E2520, August 2018.
[14] J. H. Jang, C. Chang, M. F. Rasmussen, K. Brenner, and Q. Stedman, "Dual-mode capacitive micromachined ultrasonic transducer arrays for high intensity focused ultrasound and imaging," The Journal of the Acoustical Society of America, vol. 144, no. 3, pp. 1698-1698, September 2018.
[15] A. Bybi, O. Mouhat, M. Garoum, H. Drissi, and S. Grondel, "One-dimensional equivalent circuit for ultrasonic transducer arrays," Applied Acoustics, vol. 156, pp. 246-257, 2019.
[16] S. Pyo and Y. Roh, "Analysis of the crosstalk in an underwater planar array transducer by the equivalent circuit method," Japanese Journal of Applied Physics, vol. 56, no. 7S1, pp. 07JG01-1-07JG01-6, June 2017.
[17] C. Ishihara, T. Ikedaa, and H. Masuzawaa, "Higher-frame-rate ultrasound imaging with reduced cross-talk by combining a synthetic aperture and spatial coded excitation," Proc. International Society for Optics and Photonics, Medical Imaging, Ultrasonic Imaging and Tomography, April 2016, vol. 9790, pp. 97901Z-1-97901Z-7.
[18] L. Tong, Q. He, A. Ortega, A. Ramalli, P. Tortoli, J. Luo, and J. D'hooge, "Coded excitation for crosstalk suppression in multi-line transmit beamforming: simulation study and experimental validation," Applied Sciences, vol. 9, no. 3, pp. 486, January 2019.
[19] F. P. Branca, F. Bini, F. Marinozzi, and A. Grandoni, "Optimum choice of acoustic properties of filling materials using optical measurement," IEEE Ultrasonics Symposium (IUS), August, 2004, vol. 3, pp. 1663-1665.
[20] W. Lee and Y. Roh, "Optimal design of a piezoelectric 2D array transducer to minimize the cross talk between active elements," IEEE Ultrasonics Symposium (IUS), September, 2009, pp. 2738-2741.
[21] H. J. Fang, Y. Chen C. M. Wong, W. B. Qiu, H. L. W. Chan, J. Y. Dai, Q. Li, and Q. F. Yan, "Anodic aluminum oxide-epoxy composite acoustic matching layers for ultrasonic transducer application," Ultrasonics, vol. 70, pp. 29-33, August, 2016.
[22] M. H. Amini, T. W. Coyle and, T. Sinclair, "Porous ceramics as backing element for high-temperature transducers," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 62, no. 2, pp. 360-372, February, 2015.
[23] S. M. Ji, J. H. Sung, C. Y. Park, and J. S. Jeong, "Phase-canceled backing structure for lightweight ultrasonic transducer," Sensors and Actuators A: Physical, vol. 260, pp. 161-168, 2017.
[24] M. Celmer, K. J. Opielinski, and M. Dopierała, "Structural model of standard ultrasonic transducer array developed for FEM analysis of mechanical crosstalk," Ultrasonics, vol. 83, pp. 114-119, February, 2018.
[25] K. J. Opielinski, M. Celmer, and R. Bolejko, "Crosstalk Effect in Medical Ultrasound Tomography Imaging," Joint Conference - Acoustics, September 2018, pp. 1-6.
[26] A. Bybi, S. Grondel, J. Assaad, A. C. Hladky -Hennion, C. Granger, and M. Rguiti, "Reducing crosstalk in array structures by controlling the excitation voltage of individual elements: a feasibility study," Ultrasonics, vol. 53, no. 6, pp. 1135-1140, August 2013.
[27] A. Bybi, C. Granger, S. Grondel, A. C. Hladky -Hennion, and J. Assaad, "Electrical method for crosstalk cancellation in transducer arrays," NDT E International, vol. 62, pp. 115-121, March 2014.
[28] S. Zhou and J. A. Hossack, "Reducing inter-element acoustic crosstalk in capacitive micromachined ultrasound transducers," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 54, no. 6, pp. 1217-1228, June 2007.

[29] A. Bybi, S. Grondel, A. Mzerd, C. Granger, M. Garoum, and J. Assaad, "Investigation of cross-coupling in piezoelectric transducer arrays and correction," International Journal of Engineering and Technology Innovation, vol. 9, no. 4, pp. 287-301, October 2019.

[30] K. C. T. Nguyen, L. H. Le, M. D. Sacchi, L. Q. Huynh, and E. Lou, "Adaptive noise cancellation in the intercept times-slowness domain for eliminating ultrasonic crosstalk in a transducer array," Proc. 5th International Conference on Biomedical Engineering in Vietnam, Springer, August 2015, vol. 46, pp. 32-35.

[31] D. M. Mills and S. W. Smith, "Multi-layered PZT/polymer composites to increase signal-to-noise ratio and resolution for medical ultrasound transducers. II. Thick film technology," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 49, no. 7, pp. 1005-1014, August 2002.

[32] T. Lilliehorn and S. Johansson, "Fabrication of multilayer 2D ultrasonic transducer micoarrays by green machining," Journal of Micromechanics and Microengineering, vol. 14, no. 5, pp. 702-709, March 2004.

[33] D. M. Mills and S. W. Smith, "Multi-layered PZT/polymer composites to increase signal-to-noise ratio and resolution for medical ultrasound transducers," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 46, no. 4, pp. 961-971, July 1999.

[34] P. Anastasiadis, A. Mohammadabadi, M. J. Fishman, J. A. Smith, B. A. Nguyen, D. S. Hersh, and V. Frenkel, "Design, characterization and evaluation of a laser-guided focused ultrasound system for preclinical investigations," Biomedical Engineering OnLine, vol. 18, no. 1, pp. 36, March 2019.

[35] D. S. Hersh, P. Anastasiadis, A. Mohammadabadi, B. A. Nguyen, S. Guo, J. A. Winkles, A. J. Kim, R. Gullapalli, A. Keller, V. Frenkel, and G. F. Woodworth, "MR-guided transcranial focused ultrasound safely enhances interstitial dispersion of large polymeric nanoparticles in the living brain," PloS one, vol. 13, no. 2, pp. e0192240, Febreuary 2018.

[36] J. Assaad, J. N. Decarpigny, C. Bruneel, and B. Nongaillard, "Electromechanical coupling coefficients and far-field radiation patterns of lithium niobate bars (Y-cut) used in high-frequency acoustical imaging and nondestructive testing," The Journal of the Acoustical Society of America, vol. 94, no. 5, pp. 2969-2978, November 1993.

[37] N. El Atlas, A. Bybi, H. Drissi, and A. C. Hladky -Hennion, "Finite element modeling of a piezoelectric slender bar transducer equipped with a multilayer backing for medical imaging applications," Proc. 3rd International Conference on Electrical and Information Technologies (ICEIT), November 2017.

[38] J. Assaad, J. N. Decarpigny, C. Bruneel, R. Bossut, and B. Hamonic, "Application of the finite element method to two-dimensional radiation problems," The Journal of the Acoustical Society of America, vol. 94, no. 1, pp. 562-573, July 1993.

Copyright© by the authors. Licensee TAETI, Taiwan. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY-NC) license (https://creativecommons.org/licenses/by-nc/4.0/).