Piezopolymer Interdigital Transducers for a Structural Health Monitoring System

L. Capineri, A. Bulletti, M. Calzolai, and D. Francesconi

1 PPTs Fabrication Characteristics

The flexible piezopolymer transducers made with thin 100 μm PVDF film were proposed by the authors in previous works [1–3].

The proposed technology uses an array of transducers which can be designed to excite particular types of ultrasonic Lamb waves in laminate materials (metallic or composite). The finger to finger distance of interdigital electrode patterns determines the central wavelength of the transducer (λ) and then the corresponding Lamb waves mode. The piezoelectric polymer film can operate in a range of temperature (−80 to +60 °C) that is broader than that of ceramic transducers. Furthermore, the high mechanical compliance makes it adaptable to curved surfaces. A laser-based microfabrication design process can be tuned for efficient excitation and reception of selected Lamb waves. This property depends on the characteristics of laminate material and defect types. In our case we adopted 8 mm finger distance and four pairs of electrodes (see Fig. 1). Permanently glued on the vessel surface, a series of PZTs (Acellent Technologies, Inc., Sunnyvale, CA) used during previous tests is still present.

The piezopolymer interdigital transducers have been characterized at low temperature (−80 °C) and high temperature (+60 °C) showing no significant change of behavior, confirming that they can operate in the temperature range required for space application. Also levels of driving voltages and excitation burst frequency have been selected depending on the monitored medium. Because of the lower

L. Capineri (✉) • A. Bulletti • M. Calzolai
Department of Information Engineering, University of Florence,
Via S. Marta 3, 50139 Florence, Italy
e-mail: lorenzo.capineri@unifi.it

D. Francesconi
Thales Alenia Space Italia S.p.A, Strada Antica di Collegno 253, 10146 Torino, Italy

C. Di Natale et al. (eds.), *Sensors and Microsystems: Proceedings of the 17th National Conference, Brescia, Italy, 5-7 February 2013*, Lecture Notes in Electrical Engineering 268,
DOI 10.1007/978-3-319-00684-0_2, © Springer International Publishing Switzerland 2014

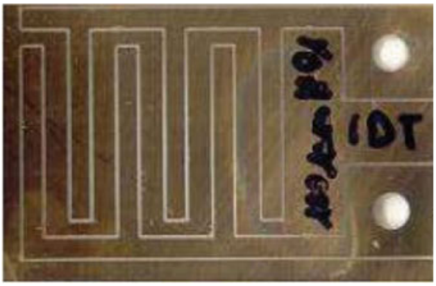

Fig. 1 The fabricated interdigital PPT made with thin 100 μm-thick PVDF film with $\lambda = 8$ mm. The two holes ($\phi = 2$ mm) are used for cables connection. Dimensions 26 mm × 37 mm

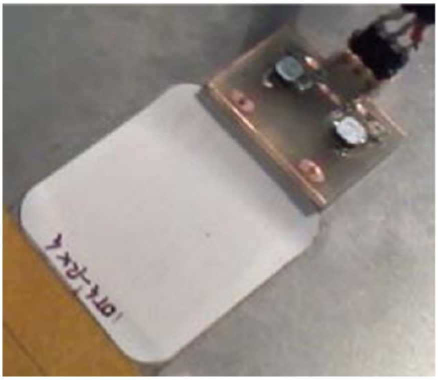

Fig. 2 Interdigital PPT with protective adhesive cover and the matching network designed. Implementation of the Piezopolymer Transducers Network

Fig. 3 Programmable acquisition system for active SHM on COPV with interdigital PPTs network

efficiency of PVDF with respect to PZT, higher voltages are necessary to drive the IDT transducers starting from low-voltage (±12 V) integrated driven circuit. Voltages up to 150 Vpp are obtained by designed matching networks (see Fig. 2).

All operations have been carried out with the scope of testing a piezopolymer transducers (PPTs) network applied on the surface of a scaled model of a carbon composite overwrapped pressurized vessel (COPV) to proof its efficiency for the localization of artificially induced damages on the COPV surface (see Fig. 3).

PPTs network has been designed for the wavelength $\lambda = 8$ mm, assembled on matching network designed connected to the receiving electronics. Adhesion of the sensors to the COPV surface is assured by smoothing with sandpaper and then degreasing with isopropyl alcohol the vessel surface. Then 8 PPTs (4 for the transmission Tx and 4 for the detection Rx) are installed on the vessel surface to investigate a portion of the cylindrical surface.

The chosen configuration (4+4 PPTs at 180 mm of distance spread along 180 mm depending on the defect characteristic and dimension) allows the acquisition of data along the paths between all possible pairs of transmitting and receiving transducers with a good signal-noise ratio.

2 Experimental Tests

A developed electronic system is programmed for the selection of multiple couples of pitch and catch PPTs and for the acquisition of relevant data. Front-end electronics has been designed and optimized for high signal-to-noise ratio taking into account the low power space requirements. The system includes also dedicated software that is developed to process off-line signals up to 8×8 different pairs of transducers for detecting both the damaged area and the size of the damage. The developed software interface controls the experiment and evaluates a damage index (DI) both in no damaged and damaged conditions and finally shows a colored scale image connected to the levels of probability of the presence of the damage.

Algorithm development for damaged area detection includes:

- The definition of signal paths from transmitter to the receiver
- The definition of excitation signal parameters
- The definition of artificially induced damages (drops of gel of 3 cm^2 size)
- The definition of Matlab routine managing the acquired signals of different paths before the DI calculation
- The calculation of DI based on the difference of both shape and amplitude of two acquired signals across the same path in undamaged and damaged conditions

Different artificial defects have been detected successfully by signal processing with the developed laboratory system: defects with area of about 3 cm^2 made by an ultrasonic gel drop on the surface of COPV have been detected successfully by using two arrays of four transmitters and four receivers placed at a distance of 180 mm. The antisymmetric A_0 mode at 220 kHz has been used to scan the area. The damage index image is shown in Fig. 4 corresponding to 1 for no defect and 0 for strong defect (no signals received).

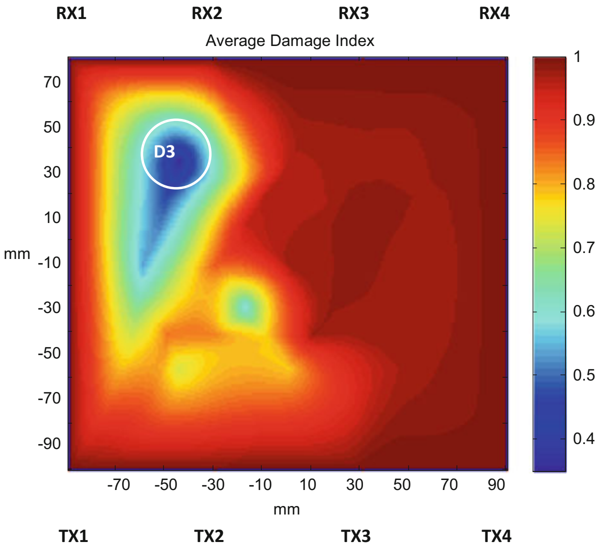

Fig. 4 Image of damage index distribution of the investigation area on COPV with defect D3 with real position ($x = -45°$; $y = +45°$)

References

1. L. Capineri, A. Gallai, L. Masotti, M. Materassi, "Design criteria and manufacturing technology of Piezo-polymer transducer arrays for acoustic guided waves detection", Ultrasonics Symposium, 2002. Proceedings. 2002 IEEE, Volume: 1, 8–11 Oct. 2002, pp. 857–860
2. F. Bellan, A. Bulletti, L. Capineri, L. Masotti, G. G. Yaralioglu, F. Levent Degertekin, B. T. Khuri-Yakub, "A new design and manufacturing process for embedded Lamb waves interdigital transducers based on piezopolymer film", Sensors and Actuators A 123–124 (2005) 379–387
3. F. Bellan, A. Bulletti, L. Capineri, A. Cassigoli, L. Masotti, O. Occhiolini, F. Guasti,, E. Rosi, "Review of non destructive testing techniques for composites materials and new applications ", Proceedings of The 10th Italian Conference on Sensors and Microsystems, Firenze, Italy, 15–17 February, 2005, World Scientific Publ. Pte. Ltd., Singapore Co., pp. 618–623