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Dual point contact imaging of scattered ultrasonic waves in piezoelectric materials

A. Habib[1], V. Agarwal[2], B. S. Ahluwalia[1], F. Melandsø[1], and A. Shelke[2]

[1]Department of Physics and Technology, UiT The Arctic University of Norway, Norway
[2]Department of Civil Engineering, Indian Institute of Technology Guwahati, Assam 781039, India

1. Introduction

Lead Zirconate Titanate $Pb(Zr_xTi_{1-x})O_3$ (PZT) ceramics are a class of piezoelectric material that are increasingly used in many application such as electromechanical devices, medical imaging, sensor, and actuators. It has a high piezoelectric coefficient and a high dielectric constant (typically 1700) [1-3]. Due to their unique ferroelectric and electromechanical properties, PZT ceramics are commonly used in generation and detection of guided waves and bulk waves [4]. These ceramics are also increasingly used in excitation and detection of lamb waves in aircraft integrated structures for structural health monitoring and nondestructive testing (NDT) [5, 6]. PZT ceramics are manufactured from piezoelectric sintered materials which exhibit both isotropic (in x, y direction) and inhomogeneous behavior depending on manufacturing procedures. Inhomogeneity is inherently induced in PZT ceramics during sintering and compaction processes. The main objective of this paper is to introduce a new technique for visualizing the scattering and attenuation of bulk waves in PZT ceramics employing point contact excitation and detection method. A steel sphere with a diameter of 2.57 mm was employed in order to excite the acoustic waves on PZT ceramics. On the receiving side a similar types of steel sphere have used to receive the excited signal.

The main advantage of such methods is; a wide band excitation and detection can be achieved in the absence of mechanical, geometrical and electrical resonances. The dynamical forces applied on the surface of the sample by mechanical contact are sufficient for an effective acoustic coupling without surface distortion or damages. The method introduced here is independent from any type of coupling media or photo-lithography procedure. A similar method already been employed for determining the surface acoustic waves velocity on $LiNbO_3$ crystal, scattering and attenuation of surface acoustic waves due to surface flaws on the surface of the crystal, and bulk wave velocity in PTZ ceramics [7-11]

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e-mail: anowarul.habib@uit.no

2. Experiments and Results

Figure 1 represents the excitation and detection setup for dual point contact. A similar scanning system has been used before for ultrasonic field measurements [12].

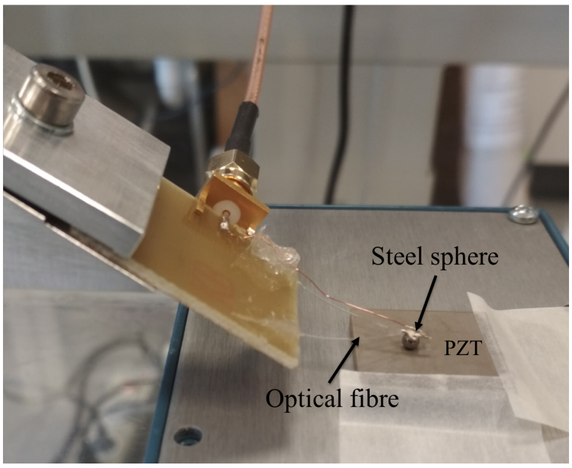

Fig. 1: Optical image of dual point contact excitation and detection

A PZT with 20 × 20 mm^2 dimensions with 3 mm thick was chemically etched using ferric chloride solution, in order to remove the conducting silver (Ag) from the both sides. After etching the Ag from the both sides, the PZT was cleaned with distilled water and dried with nitrogen. A fiber optical cable was glued on a holder in a such a fashion that it can form a triangle shape. On the tip of the triangle, a steel sphere was fixed with epoxy glue. The steel sphere was connected with a copper wire for excitation. All these components include an arbitrary function generator for generating the excitation pulse. Later on, the excited was amplified with a radio frequency (RF) amplifier and delivered to the steel sphere which was gently in contact with piezoelectric ceramics. A Dirac delta pulse (width 75 ns) form was delivered for excitation in both healthy and damage state. The excited signal on the surface of PZT ceramics was received and amplified with a current amplifier. On the receiver side a similar steel sphere was used for picking up the excited signal which was amplified with am current amplifier and delivered for recoding the transient signal and displayed for further processing.

A scanning area on the PTZ ceramics were set to 10 mm in both direction for healthy and damage state. Scanning step size were set to 50 µm in x and y directions.

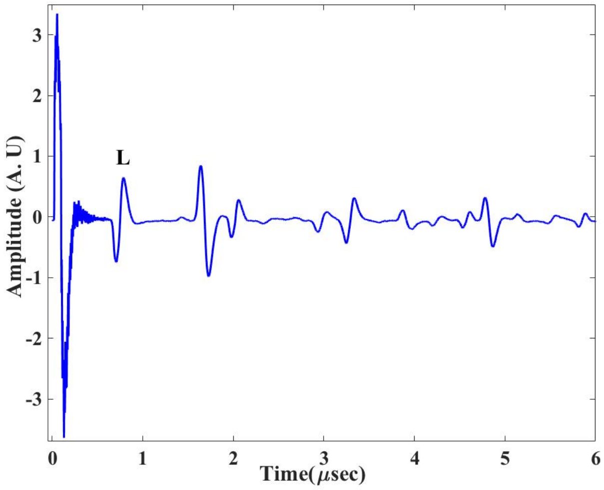

Fig 2: Transient signal amplitude recorded with a steel sphere, act as a receiving electrode positioned on the opposite side of the PZT ceramics

Fig. 2 corresponds to the time domain signal which was recorded using point contact excitation and detection method. In fig 2, the 1st signal indicated the excitation signal which occurs at 0.056 µs and the 2nd signal which marked L represents the first longitudinal waves signal. The first longitudinal waves arrive at 0.67 µs. Later, recorded peaks correspond different wave packet arrives at different times which can be mentioned such as the reflected and mode converted signal e.g. longitudinal and surface skimming longitudinal waves in PZT ceramics.

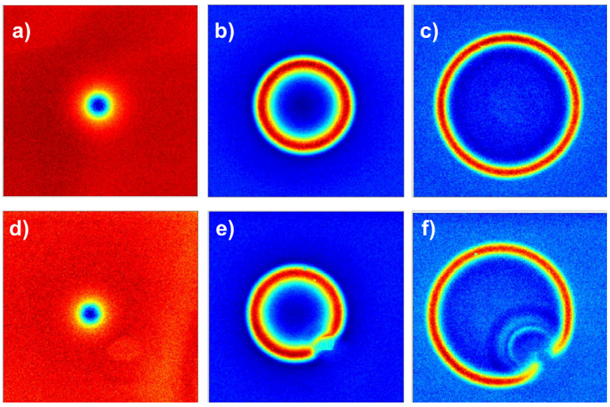

Fig 3: a), b), and c) represents the images recorded at different times in healthy state. Fig. d), e), and f) represents damage state. Image sizes in both cases are 10×10 mm^2.

In fig. 3 a), b), and c) corresponds to the successively image at different time for healthy state. An artificial defect was inserted on the PZT ceramics in order to visualize the scattering and attenuation on the propagated ultrasonic waves due to defect. Fig. 3 d), e), and f) demonstrate a sequential image at different times for damage state. For healthy and damage state corresponded images recorded at 1.12 µs, 6.74 µs, and 9.23 µs, respectively. In figure 3a) to c) it significant that ultrasonic longitudinal waves were generated on the PZT ceramics and propagated out ward. From the fig. 3 f) it is clearly evident that a back reflected wave also visible which is propagation toward the center. Due to artificial defect on the surface of the PZT ceramics the propagated ultrasonic waves were scattered, back reflected, and attenuated on the defect area.

3. Conclusion

The evolution of the scattering and attenuation of acoustic waves in piezoelectric sintered ceramics is demonstrated using point contact excitation and detection method in combination with acousto-electric coupling method. The evolution of these waves that finally lead to the conversion to surface skimming longitudinal and mode converted waves are observed within the scanning area. Due to insertion of a surface defect on the PZT ceramics the attenuation and scattering of longitudinal waves are clearly visible. The excitation and detection method presented here is independent from coupling media which are necessary for most of the ultrasonic experiments. The described non-invasive and non-destructive method can be implemented in the structural health monitoring of the piezoelectric materials.

Acknowledgement

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