Field Deployable Spray-on Transducers for Lamb Wave Generation in High-Temperature Conditions

Y. P. Trivedi[1], C. J. Lissenden[1]B. R. Tittmann[1]

[1]*Department of Engineering Science and Mechanics, Pennsylvania State University, University Park, PA 16802*

Damage detection in the power industry is always vying for optimized and cheaper techniques. Most components in the energy sector utilize metallic structure, whether it is for power generation, storage, transportation or waste management. Some of these even operate at a high-temperature adding further challenges for its evaluation. Commercial transducers rated for elevated temperatures are limited and expensive. The use of spray-on film transducers for such purposes has been researched while keeping the fabrication simple enough for anyone to create them.

Bismuth Titanate (BIT) is an excellent piezoelectric which has a curie temperature of 670^0 C and a safe operating level till about 500^0 C, considerably higher than PZT. Unlike the preceding sol-gel method, this fabrication process involves a lithium-silicate based inorganic binder and parts water to mix with the Bismuth Titanate powder. This slurry is then sprayed on multiple times onto a metal substrate to form a film greater than 120 µm in thickness. Electrodes are then attached and the film is poled in an electric field to impart piezoelectricity. With the initial bulk-wave characterization of the film, it was noted that despite a lower piezoelectric coefficient than PZT, the film transducers performed at high-temperatures. Another major advantage is the straightforward fabrication procedure and the ability for these films to cure at a room temperature. Another method to produce these films consisted of all organic materials instead of using the high-temperature inorganic binder. The organic films were also excellent in heat resistance despite having a slightly complicated fabrication procedure compared to the inorganic films. Lithium Niobate (LiN) films are another example of the thin film fabrication procedure.

The Curie temperature of Bismuth Titanate and Lithium Niobate make them ideal candidates for high-temperature testing. These films were inserted in the tube furnace and peak-to-peak voltage measurements for the first and second reflection from an edge were recorded. The furnace was set to increase the temperature of the films at a rate of about 6 ^{0}C/min. The Bismuth Titanate films were tested to a temperature of 650^0C, whereas the Lithium Niobate films were tested to a temperature of 900^0 C. The first and second echoes were recorded in terms of the signal amplitude and plotted in relation with the temperature ramp seen here in Figures 1 and 2.

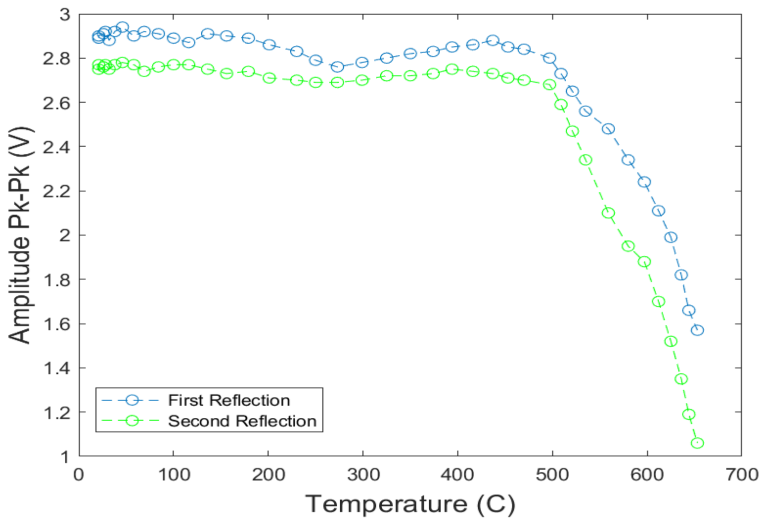

Fig. 1. Signal amplitude (peak-to-peak) for the first two reflections as a function of the temperature for BIT film.

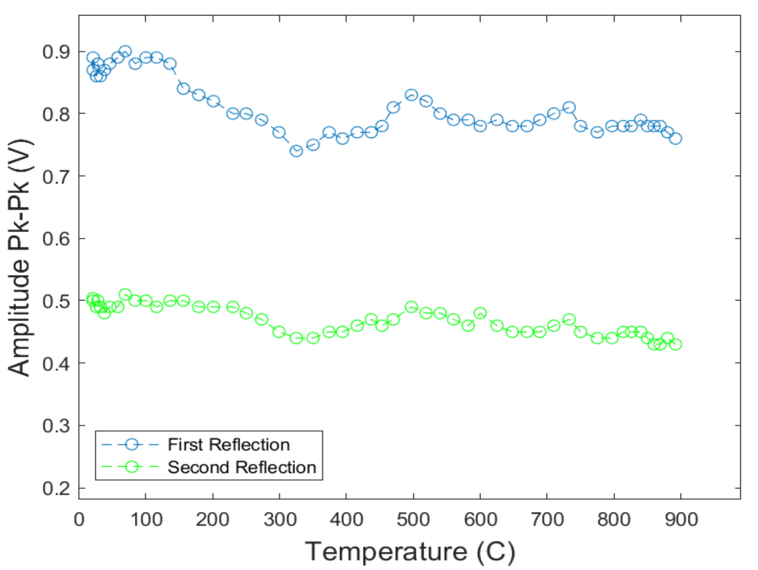

Fig. 2. Signal amplitude (peak-to-peak) for the first two reflection as a function of the temperature for LiN film.

From the various bulk-wave research conducted at the Penn State University[b][c], there was a successful assimilation of these film transducers into guided wave technology. To prove their ability to perform as a guided wave sensor, the primary Lamb wave modes (A0, S0, A1, S1) were generated using a comb transducer arrangement. Of which, the S1 mode was taken under consideration and compared with a PVDF sample previously created[a]. Aluminum plates of two different thicknesses and areas were chosen as the waveguides. Sets of the comb transducer were then applied onto the plate a certain distance apart in a through-transmission setup as shown in Figure 3.

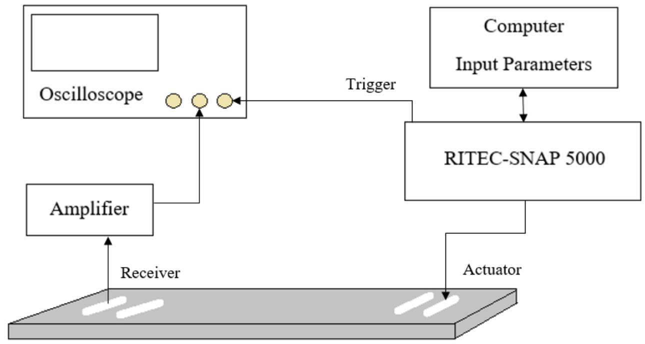

Figure 3. *Schematic of the experiment setup for generation of lamb waves in an aluminum plate*

The number of actuating and receiving elements were altered to give rise to various configurations for better quantifying the transducers. Calculations were performed previously for the comb elements to be spaced by the same length as the wavelength of the preferential excited mode. A tone-burst of 15 cycles was introduced in the actuator sets of the transducer and the A-scan was plotted. According to the excitation parameters and the comb spacing, the S1 mode should be the first to be received as shown in Figure 4. The readings were then recorded through various receiving elements and calculation were performed to compare the experimental group velocity for S1 mode with its theoretical value at that particular frequency.

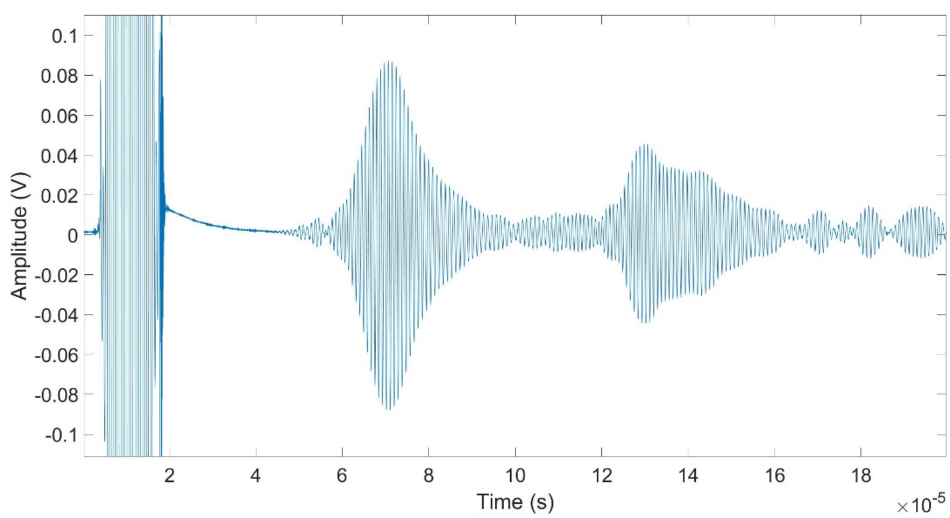

Figure 4. *A-scan for one of the tested plates showing the guided wave modes*

References

[a]. H. Cho, "Toward Robust SHM and NDE of Plate-like Structures using Nonlinear Guided Wave Features", Ph. D Thesis, 2017. The Pennsylvania State University, University Park, PA

[b]. K. R. Ledford, "Practical sprayed-on transducer composites for high temperature applications", Master's Thesis, 2015. The Pennsylvania State University, University Park, PA

[c]. J. L. Xu, "Practical Ultrasonic Transducers for High Temperature Applications using Bismuth Titanate and Ceramabind 830", Master's Thesis, 2017. The Pennsylvania State University, University Park, PA