EXPERIMENTAL CHARACTERIZATION OF MACRO FIBER COMPOSITE SENSORS FOR CYLINDRICAL GUIDED WAVE GENERATION

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Abstract: Ultrasonic structural health monitoring of in-operation engineering structures demands the development of new sensors that easily can adapt, have high sensitivity, are low energy demanding and have low cost. Macro Fiber Composite (MFC) sensors are made of piezo ceramic roads and can provide in-plane and out-of-plane displacement which makes them appropriate for guided ultrasonic generation and sensing. In this work, we present an study for the experimental characterization of MFC sensors for the generation of cylindrical waves, which have a potential application for damage detection in pipeline structures. The comparison is carried out in time and time-frequency domain analysis. Preliminary results show that MFC sensors at low frequencies are capable of generating cylindrical guided waves, also it was possible to identify the in-plane and out-of-plane displacements of propagated cylindrical modes.

1. INTRODUCTION

The need for a continuous monitoring of engineering structures has led to research and development of new sensor technologies that could be used for early damage detection [1]. It includes optimizing their: size, power requirements, weight, robustness and adaptability to complex geometries of current commercially available sensors [3].
Recently NASA Langley Research Centre developed a new type of flexible sensor based on composite material, Macro Fiber Composite (MFC) sensors. These sensors can be used as sensor and actuator at a lowered cost than typical piezoelectric transducers (PZT). They also require in some cases low power consumption and are easily adaptable to the shape of the testing structure. The MFC sensors have been studied for guided wave generation of Lamb waves or plate waves [4]. However, more work to characterize directionality, mode generation and sensing sensitivity is still needed.
The aim of this work is to experimentally characterize a MFC sensor for the generation of cylindrical guided waves. The objectives are 1) to identify vibration modes generated by MFC in a cylindrical structure; 2) to determine in-plane and out-of-plane displacement sensitivity; 3) to study the directionality of MFC response.

2. MFC SENSOR DESCRIPTION

A basic structure of an MFC sensor is shown in Figure 1. It is formed by rectangular piezoceramic fibers locked in an epoxy matrix and sandwiched between two arrays of integrated electrodes. An electric field is generated by the electrode pattern on polyimide film on the top and bottom of the MFC sandwiched sensor to generate in-plane and out-of-plane displacements depending on the polarization direction of the fibers and the electrodes polarization.

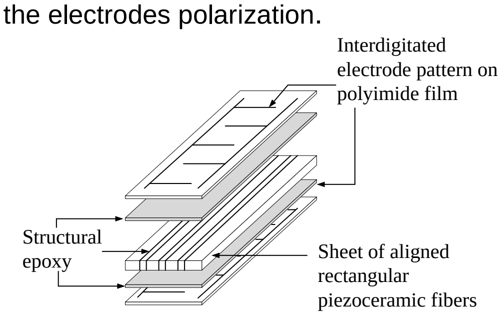

Fig. 1. *Scheme of a typical MFC sensor.*

Here, MFC sensors for generation of cylindrical guided waves are studied. There are three different cylindrical modes that can be generated: longitudinal, torsional and flexural [4](Figure 2a). As the ratio wavelength/ diameter of the cylinder gets smaller modes converge to Lamb wave modes. Both type of guided waves propagate along the structure and can be dispersive (phase velocity is frequency dependent).

3. EXPERIMENTS DESCRIPTION

Experiments were carried out on an A-36 steel pipe (48.2 mm outer diameter and 2.3 on wall thickness).
MFC sensor was attached to the cylinder's exterior surface with double sided tape. The distance between sensors was 5.3 m. Fig. ***3*** shows MFC and PZT-SH placed on the test cylinder. A five cycles tone burst with frequencies between 50 and 100 kHz, was excited with a function generator, and amplified with a power amplifier. The signals were gathered using a

broadband receiver as shown in Figure 3. In this range of frequencies the cylindrical modes are not overlapped and that helps to experimentally identify the vibration modes.

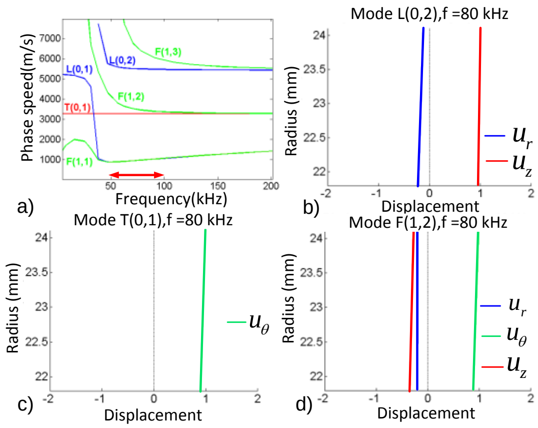

Fig. 2. *a) Cylindrical phase velocity dispersion curves. Red arrow indicates frequency range used in the experiments; Normalized displacements on the pipe wall thickness for b) L(0,2), c)T(0,1) and d)F(0,2) at 80 kHz.*

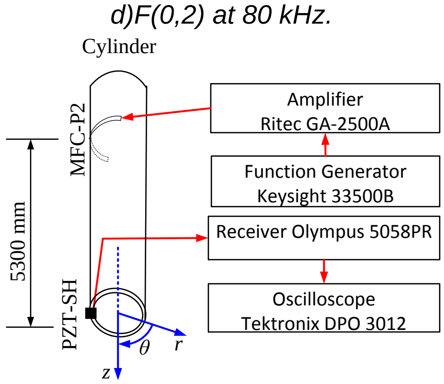

Fig. 3. *Experimental set up scheme.*

4. RESULTS AND DISCUSION

Figure 4 shows MFC directionality on an aluminum plate of in-plane displacements for Lamb waves S0 mode.

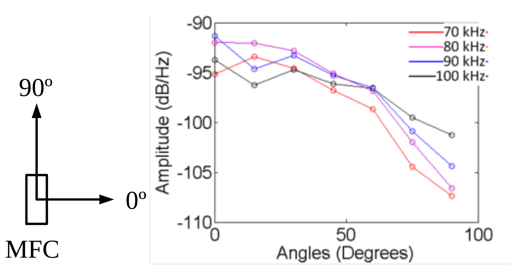

Fig. 4. *MFC directionality amplitudes correspond to S0 mode in aluminum plate. Scheme at left side of graphic indicates MFC position during tests.*

A larger sensitivity was found in the 0º direction. Figure 5 shows a time domain signal and its corresponding time-frequency description of T(0,1), L(0,2) and F(1,2) modes was identified. The in-plane or θ displacements (Figure 2c and d) of the modes were detected by the PZT-SH. On the other hand, L(0, 2) exhibits a low amplitude because it is mostly formed by out-of-plane displacements (Figure 2b).

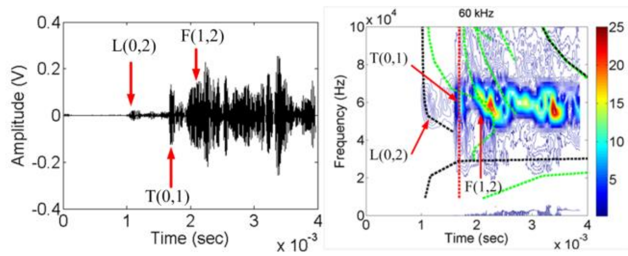

Fig. 5. *T(0,1), L(0,2) and F(1,2) generated by the MFC sensor. Dashed lines are theoretical group velocity curves.*

5. CONCLUSIONS

The directionality of a MFC sensor was determined experimentally. It was found that MFC sensors are capable of generating cylindrical waves that are identified with theoretical dispersive curves in the time-frequency domain. The future work focuses on the development of algorithms that can filter specific cylindrical modes to aid in the detection of hidden damage.

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