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Development of a 3D Acoustic Borehole Integrity Monitoring System

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***Abstract*— In this work, the development of a 3D acoustic borehole integrity monitoring system is described. After reviewing the state of the art in borehole integrity monitoring, it was determined that a critical technology gap existed. Although tools are in use that can generate high resolution images of the casing, as well as other systems that can generate low resolution images far out into the formation, no tools existed that could provide high resolution images up to the near-borehole formation region. A low-frequency collimated acoustic source was integrated into a borehole integrity monitoring system, resulting in resolution on the order of 5 mm at distances up to ~2 m into the reservoir formation. This system has the capability of providing not only integrity monitoring of the borehole, but also advanced warning of cracks that are migrating from the formation towards the borehole. This translates into cost savings for relevant industries, as the increased high resolution imaging range will allow for better maintenance planning, reducing offline time for the borehole.**

***Keywords*— Borehole Integrity, Collimation, Defect Detection**

I. Introduction

Borehole integrity is important for a wide range of industries, including oil and gas, geothermal, and CO2 sequestration. There are multiple technologies that can provide high resolution images, but limited to the casing. Alternatively, other technologies can image far into the formation, but with poor resolution. The latter lack the resolution to detect small cracks that could be precursors to future casing damage. This paper details the development of a 3D acoustic borehole integrity monitoring system based on a novel acoustic source that can generate a collimated, yet low frequency acoustic transmission [1-3] that provides both high resolution and increased penetration depth. This work focuses on the design of the system and preliminary results obtained on simulated boreholes in the lab.

II. Experimental

Both transducers that were used in this study were sourced from The acoustic source consists of a single Boston PiezoOptics PZT-5A, 1 MHz, 50 mm diameter piezoelectric transducer. The transducer is radially clamped by mounting it into a Plexiglas tube and affixing it to the tube walls using a Tungsten epoxy. A detailed drawing is shown in Fig. 1 below.

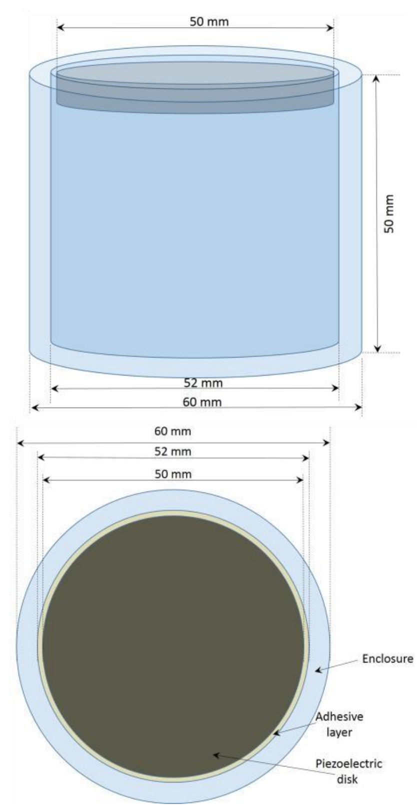

Fig 1. Drawing of the acoustic source.

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The receiver array consists of 15 Boston PiezoOptics PZT-5A, 12.7 mm diameter, 500 kHz transducers that have been potted into a Plexiglas array at regular 15 mm inter-receiver distances, see Fig. 2.

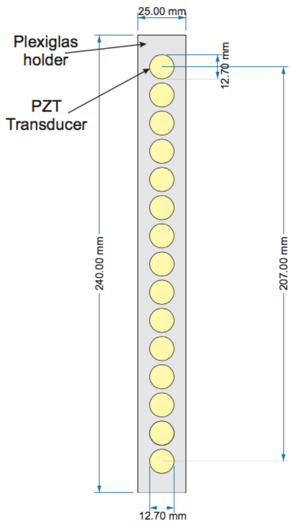

Fig 2. Drawing of the transducer array.

The transmitter is mounted below the receiver array in an assembly that allows for the transducer to be tilted at any desired angle relative to the receiver array. The transmitter and the receiver array are locked into a position such that the axis normal to their centers are always coplanar to each other. A detailed drawing, with dimensions, is shown in Fig. 3.

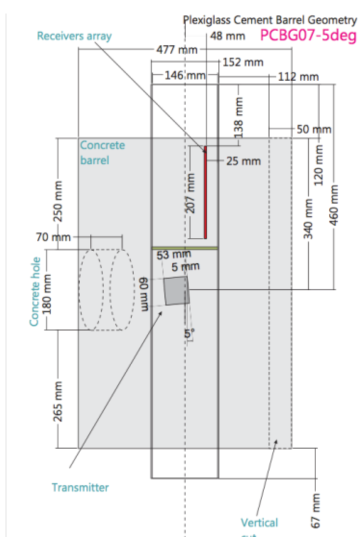

Fig 3. Drawing of the 3D Acoustic Borehole Integrity Monitoring System, as mounted in a concrete barrel with open borehole.

For laboratory testing, the complete system is mounted to a Velmex precision linear stage, for lowering down the borehole, as well as a Velmex precision rotating stage, for rotating it 360° inside the borehole at each depth. The transmitter is excited by a Tektronix Arbitrary Function Generator (AFG) 3102 using a fixed-frequency Tukey envelope at the resonant modes (radial modes) of the transmitter, identified by a Bode 100 Vector Network Analyzer (29 kHz, 42.4 kHz, 58 kHz, and 118.8 kHz). The pulse duration was 200 µs for the first two frequencies, and 50 µs for the second two, in order to ensure that at least 3 cycles were present in the pulse. The receivers were routed through a Keithley 7001 multiplexer and then into a Keithley 3940 Programmable Digital Filter which applied a bandpass of 25-350 kHz (Butterworth) and 40 dB gain. The signal was then digitized by a Tektronix Digital Phosphor Oscilloscope (DPO) 7054. Images of the clamped transmitter, as well as the completed system are shown below in Fig. 4.

Fig 4. The Clamped Transmitter (top), and the completed system (bottom).

The simulated borehole to test the system is a concrete barrel with Plexiglas casing (to simulate an open hole with no casing) with a simulated fracture (a large groove was machined on one side of the barrel). The simulated borehole is shown below in Fig. 5.

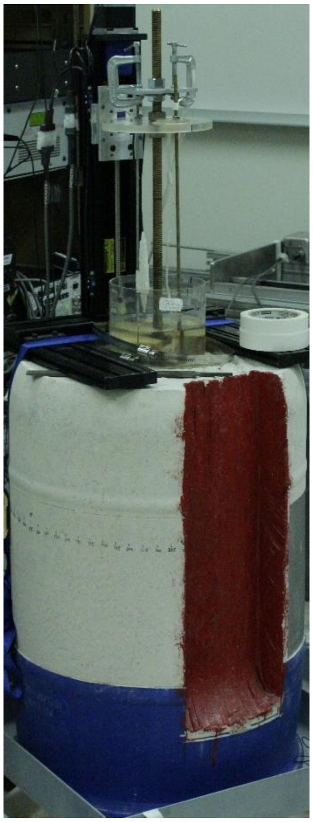

Fig 5. Simulated borehole with Plexiglas casing to mimic the open borehole configuration

Data was collected over an azimuthal span of 180° with a 5° step size, with the red groove being approximately centered along the span.

III. Results and Discussion

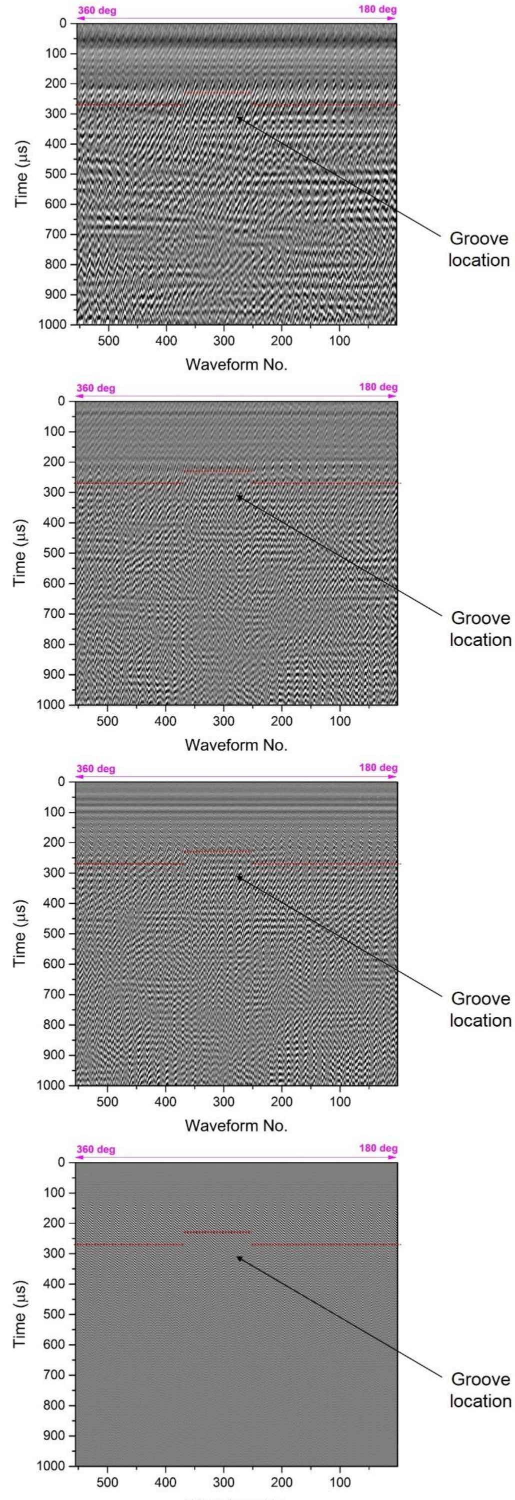

Fig 6. Reflection seismology plots for 29 kHz, 42.4 kHz, 58 kHz, and 118.8 kHz (top to bottom).

Using a common azimuth representation of the data (reflection seismology), the groove location becomes clear for all four resonant modes of the transmitter. In this case, the groove is located by using the first reflection off the edge of the concrete barrel. As expected, the higher frequency modes give a higher resolution, but for future field tests, it is expected that they will lack the penetrating power to see out into the formation. These results give strong verification that the system works, and future tests are planned to test the system on more realistic defects.

IV. Conclusion

In this work, a system for high resolution imaging of the near-borehole region was developed. Using a novel collimated yet low frequency acoustic source, a combination of high resolution and high penetrating power was achieved. By testing the system on a simulated open borehole, it was confirmed that the system works as expected. Future tests should be able to prove real-world applicability of the system.

References

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