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New transducer geometry for improved data interpretation of ultrasonic rock testing

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Introduction

Ultrasonic laboratory measurements of rock physical properties in anisotropic rocks are often challenged on the basis that the transducer size (e.g., 8.6 mm diameter housing with a 5 mm piezoceramic) is large compared to the rock sample (80 mm high and 38 mm diameter), impacting the interpretation of experimental wave speeds in terms of group or phase velocities. At the same time the usual assumption during data interpretation is that the first break of the ultrasonic signal corresponds to the (straight) ray connecting the center of the source and receiver transducers. To address this ambiguity, we: (i) design new transducers with a smaller effective diameter, and (ii) introduce the finite size of the transducers as part of the data interpretation (rather than assuming that they are point sources, or that the measured wave speeds are phase velocities).

New transducers design principles

Figure 1 illustrates the conceptual difference between a conventional and a newly-designed transducer. The key feature of the new design is that instead of full aluminum transducer body we use a low impedance washer to reduce the effective radiation footprint of the sensor. Another minor difference between the two designs is that we moved away from a curved surface matching the cylindrical geometry of the rock sample, and using a flat surface. Originally it was thought that curved surface would improve the acoustic energy transfer from the transducer into the rock as well as distribute the stress evenly over the rock surface. In practice though it is quite challenging to align the transducer surface with the rock sample and therefore it is not clear where exactly the contact between the rock and the transducer is located. We believe that this is the main reason why the data presented in [1] were scattered around the fitted curves even in the case of homogeneous synthetic samples.

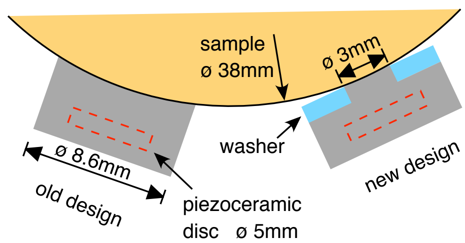

Figure 1: Sketch of the new transducer design (relative scale of rock and transducer is preserved)

To test the above hypothesis, we produced a set of transducers with polyether ether ketone (PEEK) washers. The acoustic impedance of PEEK is about 6 times lower than that of aluminium. We also confirmed that PEEK is able to sustain 80^{o} C and 70 MPa of confining pressure, which is the working limit of many tri-axial rigs used for routine rock testing.

Design validation

Figure 2 shows the results of transducers characterization using a laser interferometer (see [2] for details). One can see that the amplitude of the displacement is not significantly affected by the presence of the washer in the new design. On the other hand, most of the recorded displacement is located within the aluminium pin 3 mm in diameter. Moreover, the displacement profile is relatively flat along the pin with an abrupt change near the edges. Thus, from a modelling point of view the new transducer can be effectively approximated by a flat piston-like source 3 mm in diameter.

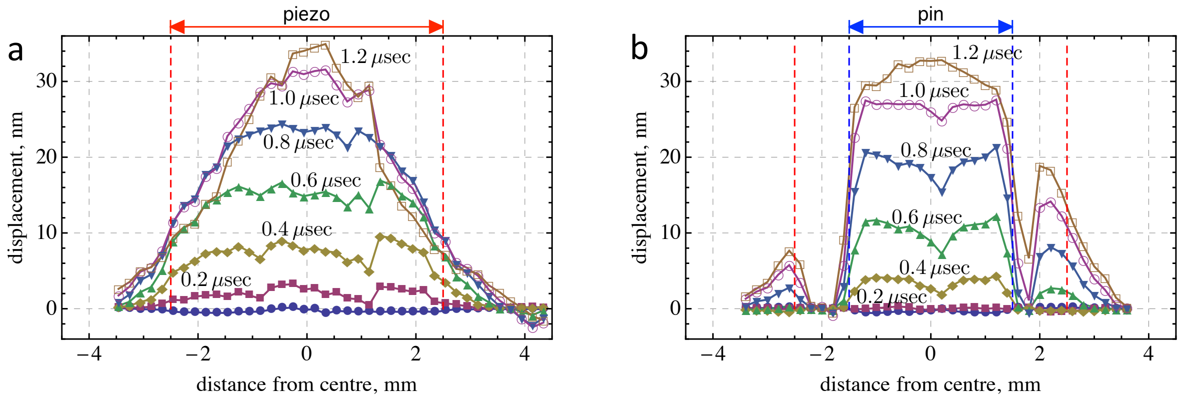

Figure 2: Transducers characterisation using laser interferometer [2] (a) old design (b) new design.

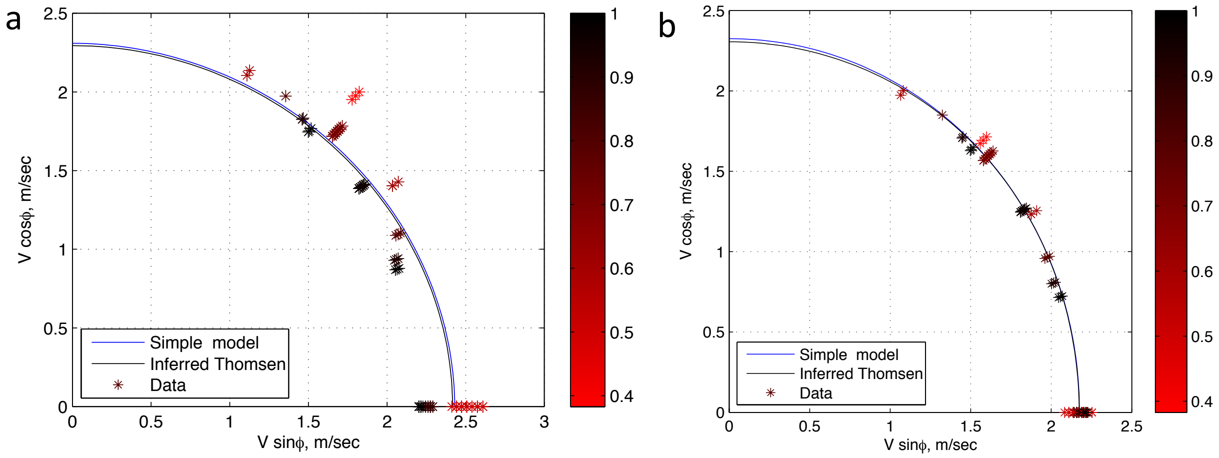

Figure 3: Acrylic glass sample characterisation with the newly-designed transducers [1] (a) assuming point source/receiver (b) assuming 3mm source/receiver.

Figure 3 illustrates the results of the inversion of data acquired on acrylic glass sample using full array of newly-designed transducers (see [1] for details). One can see that if we incorrectly assume point source/receiver, we obtain that the data is quite scattered around the fitted curve. On the other hand, assuming a finite size dramatically reduces data scatter. Note that correcting for the finite size of the conventional transducers did not reduce data scatter.

Conclusions

Here we demonstrated that the newly-designed transducers improve ultrasonic characterization of rock samples. The reason is twofold: (i) geometrically the source size is reduced, while the contact with the rock is improved, and (ii) the new transducer can be modelled as a flat piston-like source to account for its finite size.

References

*[1] Y. Kovalyshen, J. Sarout, and J. Dautriat, "Inversion of ultrasonic data for transversely isotropic media", Geophysics **82**, 2017.*

*[2] Y. Kovalyshen, J. Sarout, and M. Lebedev, "On the interpretation of ultrasonic laboratory measurements in anisotropic media", Geophysics **83**, 2018.*