

Investigation of Ultrasound Transducer Response

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- Ultrasonic Transducers
- Nonlinear Elasticity

- Motivation

2. Experiment 1: No Transducers

3. Experiment 2: Uncoupled Transducers

4. Experiment 3: Coupled Transducers

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Ultrasonic Transducers

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- Ultrasonic transducers convert between mechanical energy (sound) and electric current.
- Changes in ultrasound wave speeds can be used to determine elastic properties of media.

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Ultrasonic Transducers

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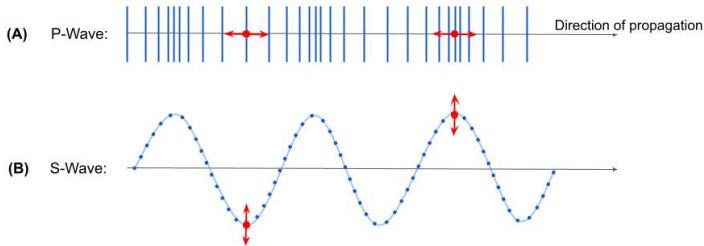
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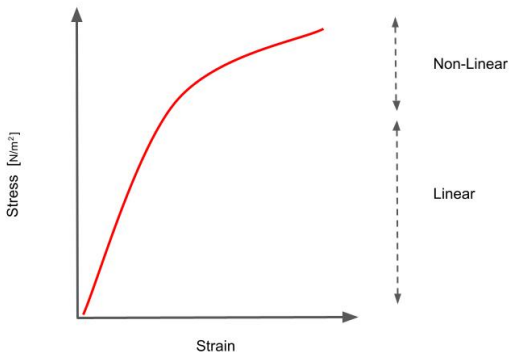
Motion of Particles in Rock



Background

Non-Linear Elasticity

- Elasticity describes the stress-strain relationship of materials.
- Elasticity is non-linear when this relationship does not adhere to Hooke's law.



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Non-Linear Elasticity

Non-linear elasticity is an indicator of material damage.

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Non-linear elasticity is an indicator of material damage.

Acoustic techniques are used across many disciplines (i.e. geophysics, medicine, and civil engineering) to characterize the structure of complex solids, such as:

- Rocks

Ex: Riviere, J., Roux, P. *J Acoust Soc Am* (2017) **142** 2723.

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Muller et al. *J Biomech* (2008) **41** 1062.

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Muller et al. *J Biomech* (2008) **41** 1062.

- Concrete

Ex: Riviere, J., Roux, P. *Constr Build Mater.* (2016) **114** 87.

Background

Transient Wave Dynamic Acousto-elastic Testing

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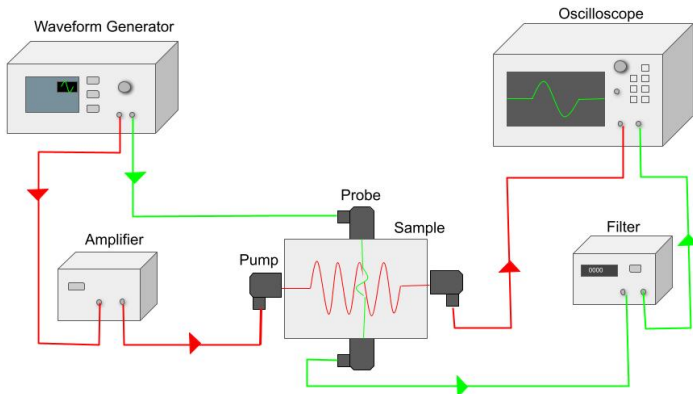
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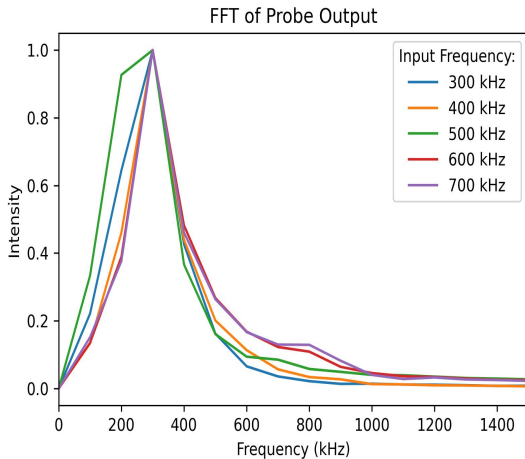


Pump-Probe setup for measuring non-linear elastic properties.

Motivation

The plot that started it all...

Existing research suggests that the waves induced in a material do not necessarily have the same properties as the input waveforms (Newman, 2021). Ex:



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(a) Verify the functionality of our equipment.

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(a) Verify the functionality of our equipment.

(b) Investigate transducer outputs for different coupled systems.

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(a) Verify the functionality of our equipment.

(b) Investigate transducer outputs for different coupled systems.

(c) Develop a protocol to inform researchers of necessary parameter adjustments when working with ultrasound transducers.

Wave Generator to Oscilloscope

Methods

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Wave Generator to Oscilloscope

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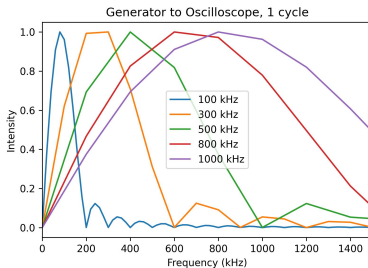


Figure: FFT of 1 cycle pulse.

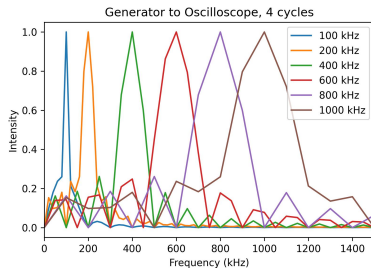


Figure: FFT of 4 cycle pulse.

Uncoupled Transducers

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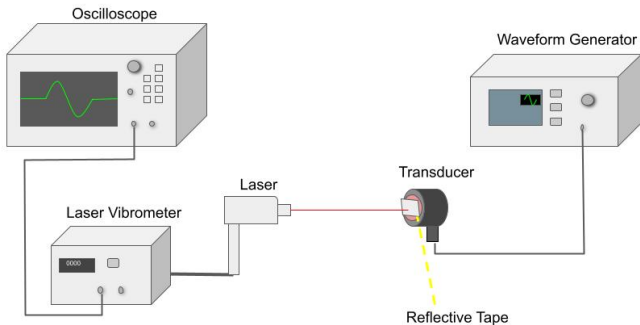
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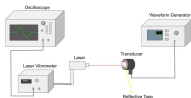
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Uncoupled Transducers: S-wave

Results



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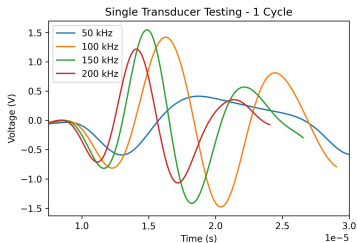


Figure: Raw Data

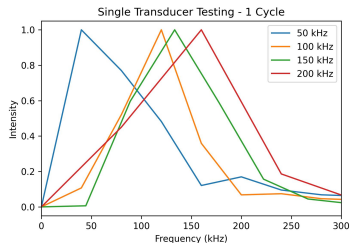
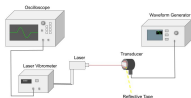


Figure: FFT

Uncoupled Transducers: S-wave

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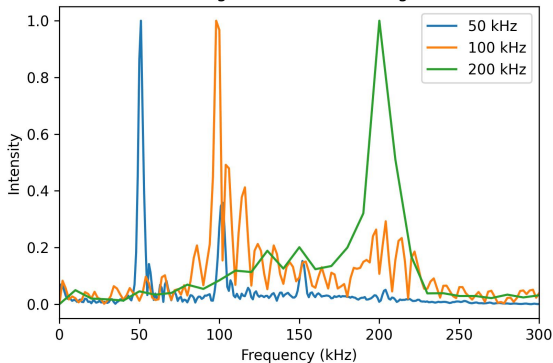
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Single Transducer Testing



Coupled Transducers

Methods

Analyze FFT spectrum after changing:

- Input frequency
- Type of transducer (S-wave or P-wave)
- Number of cycles
- Sample material

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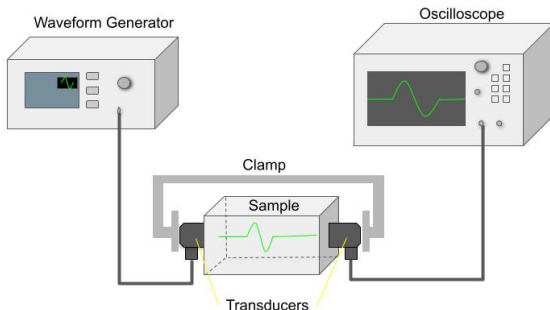
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Coupled Transducers: S-Wave

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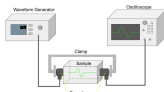
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4 cycles:

Homogeneous Cement: Amplified S-wave Probe, P-wave part, 4 cycles

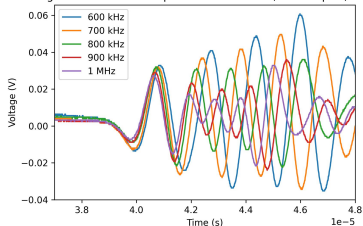


Figure: Raw Data

S-wave Probe Coupled with Homogeneous Cement

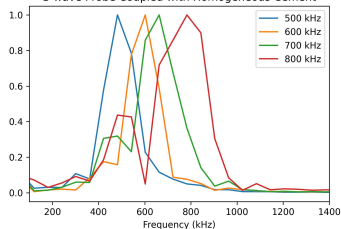
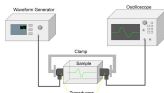


Figure: FFT

Coupled Transducers: S-Wave

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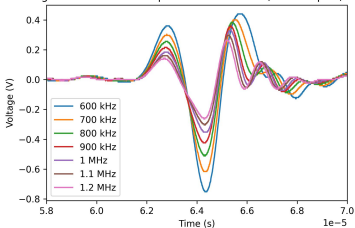
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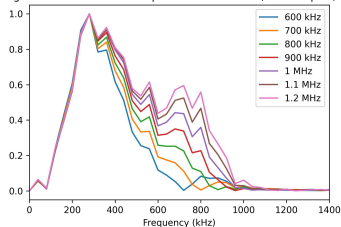
Future Work

1 cycle:

Homogeneous Cement: Amplified S-wave Probe, S-wave part, 1 cycle

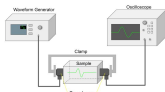


Homogeneous Cement: FFT Amplified S-wave Probe, S-wave part, 1 cyc



Coupled Transducers: S-Wave

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S-wave Probe:

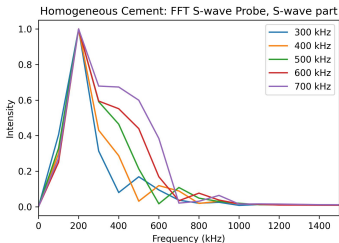


Figure: My 1 cycle S-wave probe.

Motivation Data:

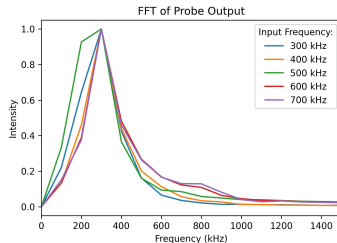
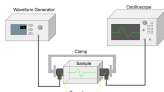


Figure: The plot that started it all.

Coupled Transducers: P-Wave

Results



1 cycle:

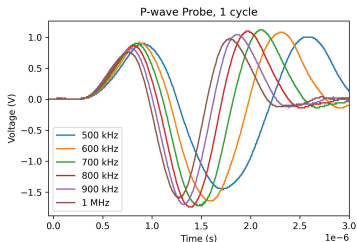


Figure: Raw Data

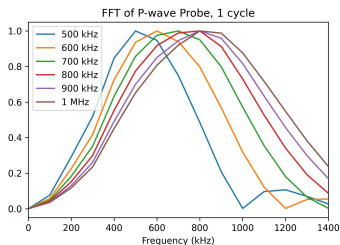


Figure: FFT

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- The equipment is functional.
- When coupled, S-wave transducers generate a unique coupling signature whose frequency is independent of the frequency set on the generator.
- S-wave transducers are not a viable option for measuring the relationship between probe frequency and nonlinear elasticity.

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- Using a P-wave probe to investigate the relationship between probe frequency and non-linear elasticity.
- Investigate if the S-wave coupling signature can be used to identify unknown samples.