SAMPLE GEOMETRY DEPENDENCIES IN MEASUREMENTS OF ULTRASONIC WAVE VELOCITY

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OVERVIEW AND LITERATURE

Measuring the velocity of an ultrasonic wave and deducing the material stiffness from it requires basic knowledge of wave propagation in solids. The theory applied to describe the relation between wave propagation and material stiffness is based on the concept of a plane elastic wave propagating in an infinite medium (this wave is called bulk wave). While the former assumption of a plane wave is justified for most experimental situations, this is not true for the latter assumption, which does not hold for specimens of all sizes and forms.

In an infinite (non-dispersive) medium, the measured (bulk) velocity is independent of the frequency of the wave, and depends exclusively on the mass density and stiffness of the investigated material. However, in finite samples, the ultrasonic wave velocity depends on geometrical parameters, including the frequency-governed wavelength.


ULTRASOUND

How are ultrasonic waves generated?

- Receiver: amplifies signal (bandwidth 0.1 - 35 MHz, voltage gain up to 59 dB).
- Mechanism: transducer converts electrical signal to mechanical signal.

How are waves and stiffness related?

Combination of the conservation law of linear momentum, of the generalized Hooke’s law, of the linearized strain tensor, and of the general plane wave solution for the displacements inside an infinite solid medium yields the elasticity tensor components as functions of the material mass density and the wave propagation velocity [2].

Elastic constants

ELASTIC CONSTANTS

How are the elastic constants determined?

ULTRASOUND TESTS

- 1 specimen cube a=100 mm (infinite medium)
- tests at all frequencies: 0.1 - 20 MHz, L-Transverse
- measured density, v (7 values), v (6 values)

QUASI-STATIC TENSILE TESTS

- 2 specimens: cross-section 10/10 mm
- load-controlled tensile tests (up to 75 MPa)
- measured lateral and longitudinal strains

DIMENSIONAL ANALYSIS

What is the aim of dimensional analysis?

The aim of dimensional analysis [1] is to extract relevant parameters of a given physical problem, i.e. the functional relation between one physical quantity (the dependent variable) and several other physical quantities (the independent variables), through the study of the dimensions of the all involved quantities, while making sure that the functional relationship does not depend on the units of measurements.

[4] Low frequencies: a < h/2
[5] a < h/10
[6] a < h/100

RESULTS

Longitudinal ultrasonic waves of 7 different frequencies (0.1 - 20 MHz) were sent through the aluminum specimens, leading to 77 data-points covering a range of 3 orders of magnitude of the two remaining independent variables of the dimensionless functional relation of the physical problem. In specimens with smaller cross-sectional dimension a ‘Young’s modulus mode’ [3] occurs at lower frequencies (bar wave propagation velocity).

What are the limits for bulk wave propagation?

- highly resistant in extreme environments (sea water, chemicals)
- highest strength (due to magnetism) of non-heat treatable alloys