International Journal of Computational andExperimentalScience and ENgineering (IJCESEN)

Vol. 10-No.2 (2024) pp. 200-202
http://www.ijcesen.com

ISSN:2149-9144

Research Article

The Determination of Some Sizes and Physical Characteristics of Metals by Ultrasound

Naim SYLA[1], Havushe AHMETI[2], Fisnik ALIAJ[3] and Bashkim DALIPI[4]*

[1]University of Prishtina, Department of Physics, Eqrem Cabej Str. 51, 10000 Prishtina, Republic of Kosovo
Email: naim.syla@uni-pr.edu - **ORCID:**0000-0003-0857-4685

[2]Gymnasium "XhevdetDoda", 10000 Prishtina, Kosovo
Email: havusheahmeti@live.com - **ORCID:**0009-0004-4384-0795

[3]University of Prishtina, Department of Physics, Eqrem Cabej Str. 51, 10000 Prishtina, Republic of Kosovo
Email: fisnik.aliaj@uni-pr.edu-**ORCID**:0000-0002-9967-8334

[4]Public University Kadri Zeka, Faculty of Education, rr."ZijaShemsiu" pn. 60000 Gjilan, Kosovo
* **Corresponding Author Email:**bashkim.dalipi@uni-gjilan.edu - **ORCID:**0000-0002-8133-0452

Article Info:

DOI:10.22399/ijcesen.315
Received :27 April 2024
Accepted :10 June 2024

Keywords

ultrasound
thickness
speed of ultrasound
modulus of elasticity
transducer

Abstract:

Recently, ultrasound has found extensive applications in various areas such as industry, medicine, and agriculture. This paper introduces a method of determining the thickness, speed of propagation of ultrasound in metal, and the modulus of elasticity for selected metals by ultrasound. The determination of these properties was done with the NDT USM25 ultrasonic flaw detector by Krautkramer. For this purpose, straight beam contact transducer and angle beam transducers (60°) were used. The presented method offers a practical and reliable way of measuring thickness and other properties of metal and metal alloys.

1. Introduction

Sound presents mechanical waves that propagate through all physical mediums (gaseous, liquid, and solid). One of the main physical characteristics of sound is frequency. Sound with a frequency greater than 20kHz represents ultrasound. Such waves, the human ear does not hear [1]. Ultrasound is produced and detected using an ultrasound transducer, which can send an ultrasound to detect the sound afterward and convert it to an electrical signal that is then diagnosed [2]. A transducer is a piezoelectric crystal, which is connected to an alternating current. The alternating current flowing through the transducer causes it to vibrate at high speed and produce ultrasound. This conversion of electrical energy to mechanical energy is known as the piezoelectric effect. Whereas, when ultrasound falls on the piezoelectric crystal (transducer), in this case, a conversion of mechanical energy into an electrical one will be produced.

If the ultrasound wave falls on the boundary separating two mediums that are distinguished by their density and speed of propagation, part of the energy is reflected, while the rest passes to the second medium. The part of the energy that penetrates the medium (material) is interesting to consider and can be used to investigate possible defects in the material. The part of the reflected wave is determined by the reflection coefficient, $R = \frac{Z_2 - Z_1}{Z_2 + Z_1}$, while the part of the penetrated wave depends on the penetration coefficient, where $Z = \rho \cdot c$ represents the acoustic impedance, ρ-density of the medium and c-speed of sound in the given medium [3,4].
Now, acoustic methods, not only in medicine but also in materials science are known for determining and investigating some of their physical properties and quantities [5-8]. In this study, our goal was to use the acoustic method to determine some of the physical sizes of steel and aluminum samples.

2. Experimental details

For the experimental investigation, we used the USM25-Krautmer ultrasound device, figure 1. The physical quantities we determined were: the thickness and the speed of sound propagation for steel and aluminum samples, and the modulus of elasticity for an aluminum sample.

***Figure 1.** USM25 ultrasound device.*

Calibration of the device for a normal transducer is done with block k1, whereas for the angle transducer (60^0) block k2 is used [9]. Calibration parameters were: display range $D_r = 100mm$, scale factor $k = \frac{D_r}{10} = 10\frac{mm}{scale\ grad.}$ andlongitudinal, respectively transversal ultrasound speed in blocks k1 and k2 (are produced from pure steels), $c_l = 5920\frac{m}{s}$ and $c_t = 3255\frac{m}{s}$.

3. Results and Discussions

To determine the thickness d of the steel plates, we used the expression $s_j = kT_j$, where s_j is the sound path (equivalent to the thickness of the material), k is scale factor, and T_j is scale position or the echo coordinate at the time axis [9], table 1.

***Table 1.**The thicknesses of some steel plates.*

$D_r(mm)$	100	100	100	100	100
$k = \frac{mm}{scale\ grad.}$	10	10	10	10	10
T_j(s)	1.8	2.2	4.5	2.6	3.7
$d = s_j = kT_j(mm)$	18	22	45	26	37

In the following, table 2, we present the results of measuring the thickness of the steel plates according to the multi echo method.

***Table 2.**The thickness of the steel plates measured according to multiple echoes.*

$D_r(mm)$	200	200	200	200
$k = \frac{mm}{scalegrad.}$	20	20	20	20
T_j(s)	6.3	5.1	3.8	2.5
n-order of echoes	5	4	3	2
$s_j = kT_j$	126	102	76	50
$d = \frac{s_j}{n}(mm)$	25.2	25.5	25.3	25.0

Whereas, thickness of aluminum plates can be determined by the expression,

$$d_{Al} = \frac{c_{Al}}{c_l}kT_j \qquad (1)$$

where $c_l = 5920\frac{m}{s}$ and $c_{Al} = 6300\frac{m}{s}$ is the speed of ultrasound propagation in steel, respectively in aluminum. Measurement results are shown in table 3:

***Table 3.**The thickness of aluminum plate*

$D_r(mm)$	100	100	100	100
$k = \frac{mm}{scalegrad.}$	10	10	10	10
T_j(s)	0.8	1.7	2.4	3.8
$d_{Al} = \frac{c_{Al}}{c_l}kT_j(mm)$	8.51	18.09	25.54	40.43

Then, we took the example to calculate the speed of ultrasound propagation in steel, respectively aluminum plates. In advance we have measured the thickness of the plates with a VarnierCalliper.

From the expression for the thickness of the material, equation 1, we can conclude that the speed of ultrasound propagation in aluminum c_{Al} respectively steel c_S,

$$c_{Al} = \frac{d_{Al}}{kT_j}c_l \qquad (2)$$

$$c_S = \frac{d_S}{kT_j}c_l \qquad (3)$$

The aluminum plates had these thicknesses 16mm and 7.5mm, while the steel plate had the thickness 27mm. We have presented the speed of propagation of ultrasound in the two materials in table 4 (last column).

Knowing the speed of ultrasound propagation in aluminum (equation 2), we can also determine the modulus of elasticity for aluminum. The modulus of elasticity can be calculated according to the expression [10],

$$E = 4\rho\frac{\frac{4}{3}c_l^2 - c_t^2}{\frac{c_l^2}{c_t^2} - 1} \qquad (4)$$

Table 4.*The propagation speed of ultrasound by aluminum and steel.*

$D_r(mm)$	100	100	100
$k = \frac{mm}{scalegrad.}$	10	10	10
T_j(s)	1.5	0.7	2.
$c_S(m/s)$	5920	5920	5920
$d_{Al;S}(mm)$	16	7.5	27
$c_{Al;S}(m/s)$	6314.6	6342	5920

It is known to be approximately valid, $c_t \cong \frac{1}{2} c_l$, from where for the module E, we are able to get: $E \cong \frac{2}{3} \rho c_l^2$

From table 4, for speedc_l we get 6314.6 m/s, while the density of aluminum is $\rho = 2700 \frac{kg}{m^3}$, from which, finally, for the module of elasticity of aluminum we get:

$$\mathrm{E} \cong \frac{2}{3} \rho c_l^2 = 7.16 \cdot 10^{10} \frac{\mathrm{N}}{\mathrm{m}^2} \qquad (5)$$

This value is comparable to the tabular one $\mathrm{E} = 6.9 \cdot 10^{10} \frac{\mathrm{N}}{\mathrm{m}^2}$[11]

4. Conclusions

- With ultrasound method we can determine some physical sizes of materials.
- It is an elegant method and easy to apply.
- With the comparison method, we can determine the thickness of the material and the speed of ultrasound propagation in a given material.
- Once we have determined the speed of transverse wave and taking the perforation$c_t = \frac{1}{2} c_l$, we can calculate the modulus of elasticity of the material.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:**The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

- **Acknowledgement:**The authors declare that they have nobody or no-company to acknowledge.

- **Author contributions:**The authors declare that they have equal right on this paper.

- **Funding information:** The authors declare that there is no funding to be acknowledged.

- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

[1] Peter B. Nagy (1999). Acoustics and Ultrasonics. *Experimental Methods in the Physical Sciences*. 35:161-221. DOI:org/10.1016/S0076-695X(08)60416-0

[2] Giorgio Rizzatto (1998). Ultrasound transducers, *European Journal of Radiology*. 27(2);S188-S195. DOI:org/10.1016/S0720-048X(98)00061-8

[3] Pascal Laugier and Guillaume Haïat (2010) Introduction to the Physics of Ultrasound. *Bone Quantitative Ultrasound*. 29-45. DOI:org/10.1007/978-94-007-0017-8_2

[4] Nimrod M. Tole (2005). Basic physics of ultrasonic imaging, ISBN 92 41592990. https://www.who.int/publications/i/item/9241592990

[5] Yildiz F. (2017) Properties of Sound Panels Made from Recycled Footwear Treads. *Acta Physica Polonica A*. 132;936-940. DOI:org/10.12693/APhysPolA.132.936

[6] Adalberto Perez and Douglas H. Kelley (2015) Ultrasound Velocity Measurement in a Liquid Metal Electrode. *Journal of Visualized Experiments.* 5(102):e52622. DOI: 10.3791/52622

[7] Lars Büttner, Richard Nauber, Markus Burger, Dirk Räbiger, Sven Franke, Sven Eckert and Jürgen Czarske. (2013). Dual-plane ultrasound flow measurements in liquid metals. *Meas. Sci. Technol.* 24;055302. DOI:org/10.1088/0957-0233/24/5/055302

[8]Bitong Wang and Douglas H. Kelley (2021) Microscale mechanisms of ultrasound velocity measurement in metal melts; *Flow Measurement and Instrumentation*. 81;102010. DOI:org/10.1016/j.flowmeasinst.2021.102010

[9] Berke M. Nondestructive Material Testing with Ultrasonics. *Krautkramer*. https://www.ndt.net/article/v05n09/berke/berke.pdf

[10] Shih-Jeh Wu;Pei-Chieh Chin; Hawking Liu (2019) Measurement of Elastic Properties of Brittle Materials by Ultrasonicand Indentation Methods. *Appl. Sci.*, 9(10);2-11 DOI:org/10.3390/app9102067

[11] https://www.sonelastic.com/en/fundamentals/tables-of-materials-properties/non-ferrous-metals.html