IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 1, August 2023

Ultrasonic Parameters and its Measurement Techniques

Deepti Khare and Dr. Sanjeev Kumar Shrivastava
Department of Physics
Bundelkhand University, Jhansi, India

Abstract: *The ultrasonic parameters viz velocity ,attenuation etc are studied using different techniques for low and high frequency ultrasonic waves In this paper the different ultrasonic parameters are discussed along with the different methods to calculate ultrasonic velocity and attenuation of given specimen*

Keywords: ultrasonic

I. INTRODUCTION

Ultrasonic refers to the mechanical vibrations whose frequency is above the normal hearing range .this developing branch of physics is an important tool for flaw detection, sonography ,industrial testing etc. ultrasonic is used for study of crystal defects ,magnetic ,thermal and electrical properties of matter. The propagation of ultrasonic waves in a medium can be as longitudinal wave, shear wave ,surface wave and lamb wave .The two most common are longitudinal and shear wave. The ultrasonic velocity and the attenuation are the propagation parameters that relates many thermo physical properties of the crystals under different physical conditions.

These propagation parameters can be measured using two methods –one is continuous wave method which requires wave length of the wave and using this ,ultrasonic velocity is measured. Other is pulse echo method which take into account ,the transit time that is calculated by the echo of the wave.

Velocity

Ultrasonic wave velocity is related to the elastic properties of the material. This helps to characterize the crystalline materials non destructively than destructive microscopic methods. In solids ,shear as well as longitudinal waves corresponds to the velocity. The time taken by an ultrasonic pulse wave to travel from transducer to other or get echoed is a simpler velocity measurement. If the time taken between the two consecutive echoes is T and wave velocity V then

$$V = d / T.$$

One other method is by comparing the phase transmitted wave with the recieved wave. Oscilloscope is used to measure attenuation and velocity . High degree resolution and accurate methods to calculate velocities are pulse echo overlap method. To get the accurate results prescribed size ,proper substance and transducers is also required along with proper techniques.

Attenuation

Attenuation is the losses due to scattering ,diffraction and absorption . polycrystalline materials shows the attenuation due to scattering. The inhomogeneity which includes porosity, coarse grains, inclusions etc is the basic cause of scattering. Absorbtion occurs when there is a conversions of sound energy into other form of energy. Basic absorption increases with the frequency of the particle. When the ultrasonic waves travels through the medium ,the rate of decay of it can be described as attenuation. Attenuation can be expressed as

$$I = I_O e^{-\alpha}{}_d$$

Here I_O initial sound intensity, I is the final sound intensity . distance travelled by decibels ,

$$\alpha_{d} = 20 [\log I_o/I] \text{ db}$$

and the gain of the device in terms of power ratio is

$$\text{gain} = 10 \log_{10} p_2/p_1 \text{ db}$$

it means that attenuation is a power loss of the system.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 1, August 2023

Attenuation = - 10 $\log_{10} p_1/p_2$ db
Or attenuation = -20 $\log_{10} V_1/V_2$ db

Specimen

The selection of material type is quite of interest in ultrasonic testing metals ,ceramic ,glass are few which transmit ultrasound easily. Rubber ,fibre glass etc are much more attenuating.

Talking about thickness , thin materials are measured at high frequency and vice versa. Measuring ultrasound at sharp curve , requires coupling efficiency between the transducers and the test materials. If the corners of the materials are not plane or parallel , then waves could after reflection meets the transducers with an angle. This gives rise to different phases of waves by different surface areas and results in

If ultrasonic waves travel from liquid into any metal, initially the speed of the sound increases in metal. Due to this recombination of sound waves occurs which gives rise to differences in travel time. If this time period is half of that of time period of sound then net energy inside the metal is zero. This destructive interference is caused due to the critical roughness shown by

$$R_c = \lambda_1 V_2 /2(V_2-V_1) = \lambda_2 V_1 / 2(V_2 - V_1)$$

Here λ_1 is the wave length of the sound in the liquid, λ_2 is the wave length of sound in the metal ,V_1 and V_2 are the velocities respectively .finally R_C is the critical roughness.

Couplant :

A couplant eases the ultrasonic energy to travel from transducers to the test surface or viceversa .the couplant removes all air between the test surface and transducers. Basically oil ,water or glycerine are the couplants used in the ultrasonics. It smoothes the irregularities on the test surface. Immersion technique method use both the transducer and the test materials to be immersed in water. By doing this ,a consistent coupling is created and testing can be done easily.

Transducers :

Transducers are to convert electrical signal to mechanical waves. Transducers behavior depends on the material , its mechanical construction , electrical loads etc. for the maximum output the impedance matching layer is kept between the active element and transducer. Small thickness of the active element helps for the higher frequency of transducer.

In any crystalline material, if the particles are not moving in wave direction, energies are getting transferred at angular directions. This beam spread is affected by the frequency and diameter of transducer, which can be calculated by

$$\sin \theta = 1.2V /D f$$

Here θ is the beam angle from central point to where signal is of half strength.

V = sound velocity, D= diameter of transducer, f = frequency of transducer. By the use of ultrasonic pulse echo interferometer high accuracy while measuring T can be obtained. It is advantageous over other NDT methods in many ways. It is sensitive to surface discontinuities, single side access is required. It gives fast results. It does not have adverse effect on the test materials.

For the measurement of various quantities there are two types of basic techniques-

1) Low frequency technique 2) High frequency technique.

Low frequency technique: It has many categories.

1) Low frequency guided waves: these are the waves having long range and uses slow frequency to go through long range penetration, but somehow go low on sensitivity and resolution. It further has three types-

a) Longitudinal waves: they vibrate parallel along the wave direction. it has two displacement components U_r ,U_z (independent of θ). If a longitudinal wave moves in a direction of a rod of small diameter, young's modulus Y and density d,then velocity of sound travelling through the rod is

$$V = (Y/d)^{1/2}$$

b) Torsional wave : torsional mode does not have dispersion ,it only has displacement component . so its velocity V for isotropic medium is

$$V = (\mu / d)^{1/2}$$

μ is shear modulus.

c) Flexural wave: These waves have all the three components of displacement . if shear waves propagate through the rod, velocity is

$$V_f = 2\pi R_g \frac{\sqrt{Y/d}}{\lambda}$$

R_g is radius of gyration, λ is wave length. One can get high frequency longitudak and torsional waves by maintaining the wavelength to diameter ratio of rod is kept small.

2) Low frequency wave in isotropic media:

In isotropic media there are two functions which describes about dilatational and shear deformations of the media. Here dilatational and shear waves velocities are

$$V_1 = (\lambda_1 + 2\mu_1)^{1/2}$$

$$V = (\mu_1 + d)^{1/2}$$

λ_1 and μ_1 are lames elastic constants.

3) Low frequency waves in crystalline media :

In crystals when there is no symmetry present , then total of 21 elastic constants come into existence. The acoustic velocity can be obtained by the following formulae

$$\begin{matrix} \lambda_{11} - V^2 d & \lambda_{12} & \lambda_{13} \\ \lambda_{21} & \lambda_{22} - V^2 d & \lambda_{23} \\ \lambda_{31} & \lambda_{32} & \lambda_{33} - V^2 d \end{matrix} = 0 \quad \ldots\ldots 4.12$$

here V is the velocity , λ_{pq} is the function of the elastic constant and d is density of the medium.

4) Resonance method :

These are of two types. Differing from basic pulse methods in this method frequency of waves are continuously varying. It is basically used for thickness measurement or internal damage test.

Torsional Vibrations

When the test material is a thin wire ,then resonance frequency for that in normal modes are determined .following is the relation for isotropic materials f

$$f_r = [(Y/d)^{1/2}] /2l$$

here Y is young's modulus

also $f_r = [(\mu/d)^{1/2} /2l]$

here μ is shear modulus

Longitudinal Vibration

A type of specimen like quartz crystal is fixed on it, then the resonance frequencies of the specimen and quartz are related as

$$f_r = f + M_c (f - f_c) / M_s$$

with f is resonance frequency of composite transducer.

f_c is resonant frequency of crystal transducer

M_s and M_c are the masses of specimen and transducers.

High frequency techniques :

High frequency ultrasonic waves can be used for medical diagnosis , material characterization ,holography and many more. For precise measurement ,pulse methods is considered and continuously improving. Crystal transducers are used to propagate high frequency waves through attaching specimen to the transducers and let it vibrate in longitudinal modes.

1) Pulse superposition method :

This method is accurate for measuring ultrasonic velocity. Phase velocity is marked absolutely accurate due to its capability to measure between corresponding cycles of echoes in an echo train

This method uses a single transducer as transmitter and receiver. It is pulsed by a gated radio frequency generator and its pulse width and time period can be varied.

After sending the pulse wave into the transducer specimen assembly the transducer again sends an acoustic pulse wave into the specimen which gives rise to a train of echoes after each individual pulse. Time period is adjusted I such a way that it becomes very easy to bring the echo of the previous transmitted pulse to superimpose on the next transmitted pulse. since ultrasonic pulses are superposed o other pulse in the specimen ,so it is termed as pulse superposition method.

Sing around method :

This method uses two transducers ,one for transmitting and one for receiving the ultrasonic signal. The transmitter is used to transfer an electric signal to the transmitting transducer. Receiving transducer then amplify the received waves and it refires the transit time. Frequency is the reciprocal of the round trip transit time. So the repetition rate is measured and hence the velocity of the sound wave.

Thus the method is suitable for the relative measurement rather than absolute measurement.

Pulse echo overlap method:

Pulse echo overlap method is a fastly growing technique to measure wave velocity in different materials. Basically this method involves the sending of an ultrasonic wave into the test material. Echoes are generated when the waves is interrupted by the inhomogeneity in a medium due to which it send back a part of the incident energy back to the receiver.

Interferrometric technique :

Measurement of ultrasonic velocity in liquids can be done very accurately using an ultrasonic inetrferrometer. The basic principal here depends on the accurate measurement of wavelength in the medium standing waves are created in the medium by keeping the two plates at distance equal to the multiple of sounds wave length. This creates an electrical reaction on the generator driving the quartz crystal and the current of the generator reaches maximum. Maximum amount of anode current is read and then its n is calculated. ‘n’ along with the knowledge of ‘d’ helps to determine the value of λ., the total distance moved by the micrometer.

$$D=n\,\lambda/2$$

Further, the knowledge of wavelength λ gives the velocity v as follows

$$V = \lambda\, f$$

Phase comparison technique : Phase comparison technique uses a buffer rod to which a transducer is attached to its one end and a testing material to the other end. Buffer rod must have propagation path longer than the path in the testing material. A radio signal is send to the transducer as the signal reaches the test material ,it undergoes multiple reflections. The frequency is recorded for the echo pattern. The graph plot between phase and frequency gives due phase delay;

$$t = dN/df.$$

II. CONCLUSION

Different industries have the ultrasonic used as the tool to ease their job.some of them are surface microscopy washing and cleaning, holographic imaging, metal testing , spot welding ,drilling etc. It is a strong investigational method to study the physical phenomenon of solids, its internal structure and defects too. There are different methods for calculating ultrasonic parameters of different frequencies. Low frequency techniques are used in guided waves ,crystalline media and isotropic media. On the other hand high frequency techniques are uses suitable transducers and buffer rods. These methods made the process of finding ultrasonic parameters much easier. However with the development of high frequency digital and computer technologies it has become feasible to characterize materials for advance technologies.

REFERENCES

[1]. Lukashkin A.N., Lukashkina V.A. and Russell T.J., J.Acoust. Soc . Am.,111(2002)2740
[2]. Kapys R., Mapeika L. and Tumdys O., Ultragarasas , 42(2000)29
[3]. Vardharajan R., Sundaram S.K. and Pia K.M.E Ind. J.P.A. Ultra., 24(2002)15
[4]. Kumon R.E and Hamilton M.F., J.Acoust. Soc. Am., 111(2002)2060
[5]. Butkus J. and Jakevieius L., Ultragaras,42(2002)37
[6]. Panuszka R., Damijan Z., Rosinski T. and Misztal, Struc Waves Bio Engg., 10(2001)107
[7]. Dain Y.and Lueptow R.M., J. Acoust Soc Am .,110(2001)2974
[8]. Rajagopal S. and Sharma S.J., Ind. J.P.A. Ultra., 24(2002)1
[9]. Putterman S.J. and Weninger K.R., Ann. Rev. Fluid Mech., 32(2000)445
[10]. Jeon J.S., Yang I.J. and Kwak H.Y., J.Phys. Soc. Jpn .,69(2000)112