Journal of Asian Scientific Research

Online ISSN 2223-1331

Vol 1 No 7

November, 2011

Asian Economic and Social Society
www.aessweb.com

Effect of variable ultrasonic frequencies on some physical properties of Iraqi palm fiber PVA composite

Author

Abdul-Kareem J. Rashid
Physics Department, Facility of Science, Babylon University, Babylon, Iraq
Email: dr.Abdulkaream@yahoo.com

Burak Y. Kadem
Physics Department, Facility of Science, Babylon University, Babylon, Iraq
Email: burakwh@yahoo.com

Keywords: PVA composite; mechanical properties; solution casting method; ultrasonic frequency

Abstract

The palm fiber –PVA composite polymer membrane were prepared by solution casting method with different ratios of concentration in order to study the ultrasonic frequency affect on mechanical properties of this composite. Ultrasonic pulse technique of variable frequency (25,30,35,40,45 and 50 kHz) were performed ,some properties such as ultrasonic velocity, acoustic impedance ,bulk modulus ,transmittance and viscosity are decreasing with increasing frequency while absorption coefficient, relaxation time, compressibility and relaxation amplitude are increasing with increasing frequency .results shows that ultrasonic wave made degradation to the randomly coiled polymer chains ,when ultrasonic frequency increase there are more degradation that increasing the number of un-tie chains as a results of absorbing composite ultrasonic waves ,for this reason we pointed that palm fiber-PVA composite as a good ultrasonic absorber.

Introduction

The study of composite materials mixtures consisting of at least two phases of different chemical compositions has been of great interest from both fundamental and practical standpoints, the macroscopic physical properties of such materials can be combined so as to produce materials with a desired average response (Z. M. Chen *et al.* 2011). Composite materials structural integrity can be compromised via many mechanisms including presence of discontinuities or loss of mechanical properties. Ultrasonic methods are directly sensitive to these changes and can be used to assess the integrity of the composite structure(B. Boro 2009)Ultrasonic velocity measurements are relatively simple to make in bulk solids and can be related to the various elastic modules, especially for isotropic solids. For these bulk solids the sound speed may be weakly related to the crush or abrasion strength of the material (P.J. Coghill *et al*.2011) as the sound transmission depends on both the properties of the particles and their configuration care must be taken to understand the preparation of the sample for measurement. This includes shaking steps to consolidate the powder and prepare as uniform as possible configuration of the powders at measurement (P.J. Coghill *et al*.2011 , P. Phillippe *et al.*2002)The absorption of ultrasound in polymer composite systems is governed by local modes of motion and cooperative because of the existence of strong intermolecular interaction within the polymer (Al-Bermany 2005).Ultrasonic technique is good method for studying the structural changes associated with the information of mixture assist in the study of molecular interaction between two species; some of mechanical properties of different polymers were carried by some workers using ultrasonic technique (B. Boro 2009 , Al-Bermany 2005 , Hassun 1990).The manner in which the propagation of the ultrasonic wave is affected by structure of the material results in parameters that can lead to the characterization of the material. Several studies have demonstrated good relationship between the velocity of sound and mechanical properties of wood (Gerhards 1982 ,Bucur *et al*.1994 Bucur 1995,Oliveira *et al*. 2002, Wang *et al.* 2003). Researchers conducted studies on the relationship between ultrasonic velocity and density of wood. These results showed different relationships between ultrasonic velocity and density as follows: velocity increases with increased density (Fabiana 2006); velocity is not affected by density (Mishiro 1996) and finally it decreases with increased density (Bucur *et al.* 1991) while(Faleh 2003) study the palm leaves as insulating material.

Experimental

Sample Preparation

PVA (Gerhard Buchman -Germany) with 99.3 % assay and Iraqi palm fiber as powder material were used in our study to make composite polymer membranes, Palm fiber is ground by electrical grinder type (FRITSCH- Germany) for 6 hours then the powder was separated by laboratory test sieve type (Endecott LTD. England) with size (0.038 mm) to separate the fine pieces from large one then the fine pieces were grounded again for 3 hours and separated by another test sieve type (wykeham farrance Slough, England) with size (150 μm) to obtain the palm fiber in powder, this composite prepared by a solution casting method. The appropriate weight ratios of PVA are constant (1gm) were dissolved in (20ml) distilled water under stirring and heat (90◦C) for (1 hour) the palm fiber powder was added slowly with stirring to the solution with the ratios (0.1, 0.2, 0.3 0.4 0.5) gm, the resulting solution was stirred continuously until the solution mixture became a homogeneous at room temperature for (30 min.).Then the concentration under study were (0.004, 0.008, 0.012, 0.016 and 0.02 gm/ml).The composite polymer film is obtained by leaving the mixture solution in a Petri dish at room temperature for 1 week.

Ultrasonic measurements

Ultrasonic measurements were made by pulse technique of sender-receiver type (SV-DH-7A/SVX-7 velocity of sound instrument) with different frequencies (25,30,35,40,45 and 50 kHz),the receiver quartz crystal mounted on a digital vernier scale of slow motion , the receiver crystal could be displaced parallel to the sender and the samples were put between sender and receiver. The sender and receiver pulses (waves) were displaced as two traces of cathode ray oscilloscope, and the digital delay time (t) of receiver pulses were recorded with respect to the thickness of the samples (x). The pulses height on oscilloscope (CH1) represents incident ultrasonic wave's amplitude (A_0) and the pulses height on oscilloscope (CH2) represents the receiver ultrasonic wave's amplitude (A).

Theoretical calculation

The absorption coefficient (α) was calculated from Beer–Lambert law equation (Zong *et al.* 2002):

$$A/A_0 = e^{(-\alpha x)} \ldots\ldots (1)$$

Where (A_0) is the initially amplitude of the ultrasonic waves, (A) is the wave amplitude after absorption, the transmittance (T) is the fraction of incident wave at a specified wavelength that passes through a sample was calculated from the following equation: (Dipak 2001):

$$T = I / I_o \ldots\ldots\ldots (2)$$

The relaxation amplitude of ultrasonic wave was calculated from the following equation where (f) is the frequency (Tomasz et al 2010):

$$D = \alpha / f^2 \ldots\ldots\ldots (4)$$

The method of measuring the speed of ultrasound was by measuring the thickness of the sample and the time it takes inside the sample (Boutouyrie *et al.* 2009):

$$v = x / t \ldots\ldots (5)$$

Where (x) is the samples thickness measured by digital vernier; (t) is the time that the waves need to cross the samples. The wavelength (λ) of the ultrasound waves inside the sample was calculated by the equation (David *et al* 2002):

$$\lambda = v / f \ldots\ldots\ldots (6)$$

The acoustic impedance of a medium (Z) is a material property was calculated by this equation where (ρ) is the density (Eric *et al.* 2009):

$$Z = \rho v \ldots\ldots\ldots (7)$$

The bulk modulus (B) of a substance measures and the substance's resistance to uniform compression, it is defined as the pressure increase needed to decrease the volume; its base unit is the Pascal (Pa.) was calculated by following equation (Siddhartha *et al*. 2011):

$$B = \rho v^2 \ldots\ldots\ldots (8)$$

Compressibility (β) is a measure of the relative volume change of a fluid or solid as a response to a pressure (or mean stress) change, it was calculated by this equation Hassina *et al.* 2009):

$$\beta = (\rho v^2)^{-1} \ldots\ldots\ldots (9)$$

On the basis that all solids flow to a small extent in response to small shear stress, some researchers have contended that substances known as amorphous solids, such as glass and many polymers may be considered to have viscosity. This has led some to the view that solids are simply "liquids" with a very high viscosity; the viscosity of the samples was measured by using the equation (Kumagai *et al.* 2009 , Al-Bermany 2009):

$$\eta_s = 3\,\alpha\,\rho\,v^3 / 8\,\pi^2 f^2 \ldots\ldots\ldots (10)$$

The relaxation time (τ) was calculated from the equation (A. K. Al-Bermany 2009):

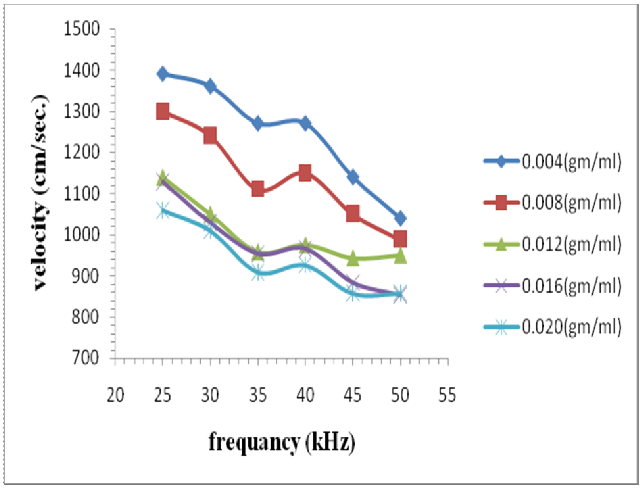
$$\tau = 4\,\eta_s / 3\rho v^2 \ldots\ldots\ldots (11)$$

Results and discussions

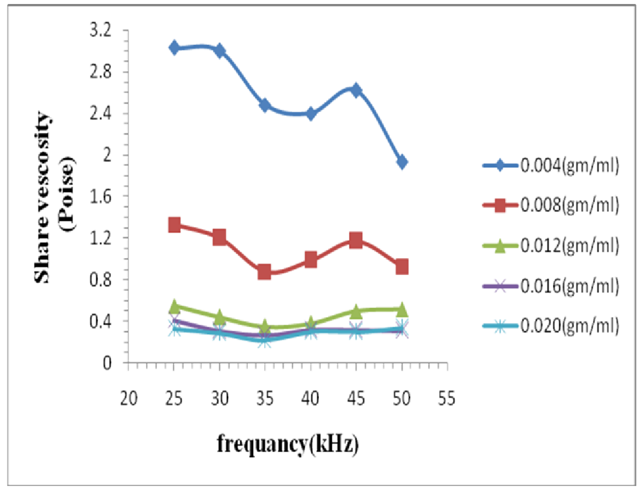
Ultrasonic velocity was determined versus different frequencies and concentrations of Iraqi palm fiber as shown in Fig. (1), the velocity are decreasing with frequency increasing this could be attributed to ultrasonic wave made degradation to the polymer chains, chain breaking of the polymer results in a slight decrease in the tensile properties which can be attributed to the decrease in the number of tie-chains (Tomasz et al 2010 , E.Foled *et al*. 1988, Formageau *et al.* 2003) Since frequency related to energy ,when the frequency increases incident energy also increases then degradation must increasing which reduced the number of tie-chains, so the velocity decreased. Fig. (1) also show that the composite at (0.004 gm/ml) concentration had higher value of velocity with respect to other concentrations, this attributed that as concentration increases there must be more degradation by ultrasonic increasing the broken chains that give composite more elasticity which reduced the velocity, so lower concentration have higher velocity (E.Foled *et al*. 1988) this behavior same to that obtained by (Al-Bermany 2009 A. K. Al-Bermany 2009) for other polymers. Share viscosity of this composite is decreasing with increase of frequency as shown in Fig. (2),this could be attributed that hydrogen bonding of water attached to oxygen sites ,this lead to salvation sheaths and increase the size of the molecules that reducing velocity ,increasing frequency reducing tensile properties by increasing degradation that lead to decrease viscosity.(Bucur *et al.* 1994 , Hasun 1989) The wavelength of ultrasonic is decreasing with increasing frequency as shown in Fig. (3) Since wavelength inversely related to the frequency. The compressibility of the samples were calculated using Laplace equation no.(9) the compressibility increasing with the increase of ultrasonic frequency as shown in Fig.(4) this attributed that ultrasonic wave transfer as compression and rarefaction, these made degradation to the polymer chains that randomly coiled and the broken chains compresses during ultrasonic propagation that reduces molecules conformations since more degradation happen at high frequency that increasing elasticity so it is easy for molecules to be compressed. (Hasun 1989,Al-Bermany 2004).The bulk modulus are decreasing with frequency increasing a shown in Fig.(5) , this could be attributed to the amount of contraction is governed by the compressibility, which is dependent on the intermolecular forces and because of the compressibility is inversely related to the bulk modulus by means of equations (8 and 9) so there are decreasing in bulk modulus with increasing frequency(Hassina et al. 2009). Fig.(5) shows that lower concentration has higher bulk modulus values since decreasing palm fiber concentration means there are more vacancies that make polymer chains that randomly coiled have higher bulk modulus(Wiggens *et al.* 1986) .Fig.(6) shows that transmittance are decreasing with frequency increasing ,this attributed when frequency increasing the energy increasing that made more degradation and ultrasonic energy transfer as compression and rarefaction so the un-tie chains damping these propagated waves then reducing transmittance, also Fig.(6) shows the lower palm concentration (0.004gm/ml) has high transmittance value since there are more vacancies according to low palm concentration and little degradation those increased ultrasonic wave transmittance. The absorption coefficient of the ultrasonic waves are increasing with increasing frequency as shown in Fig.(7) , this attributed when the frequency increasing the vibration increasing causes increasing and decreasing in pressure relative to atmospheric pressure. The compression and rarefaction decreasing by displacement of the molecules from their equilibrium positions so as a result to high frequency there are more degradation to polymer chains then increasing in absorption by composite, this agree with decreasing transmittance, this behavior same to that obtained by (Al-Bermany 2010 ,Al-Bermany 2009 ,Hasun 1989). Fig. (7) Also shows that high palm concentration has lower value of absorption coefficient since increasing palm concentration fills vacancies between polymer molecules and restricted the molecules movement, this lead to reduce elasticity and increasing tensile stress of the composite then reducing absorption coefficient (Joel et al. 2009). Relaxation amplitude is increasing with the increasing of frequency as shown in Fig.(8) this attributed that absorption coefficient are increasing with frequency increasing since compression and rarefaction decreasing by displacement of the molecules from their equilibrium positions so increasing frequency lead to increase molecules displacements then relaxation amplitude of the excited molecules must be increasing then increasing the relaxation time for displaced molecules to be stated in their positions as shown in Fig. (9).Fig. (8) Also shows that the lower concentration has high relaxation amplitude since there is little palm fiber in composite there are more vacancies between polymers chains that made these molecules to vibrated and displaced higher than that of high concentration, so it has high relaxation amplitude (E.Foled et al. 1988) , this results agree with increasing absorption coefficient. Fig. (9) Also shows that lower concentration has higher relaxation time since it has higher relaxation amplitude. The specific acoustic impedance is decreasing with increasing frequency as shows in Fig.(10) , this attributed that ultrasonic waves made degradation to the polymer chains that resist the waves to transfer and gave the membrane good acoustic impedance(A.K.Al-Bermany 2009 , Wiggens et al. 1986 ,Al-Bermany 2010) .Fig.(10) also shows that the lower concentration of palm fiber has higher values of acoustic impedance ,because there are more vacancies in the membrane that decreasing elasticity and impedance (A.K.Al-Bermany 2009), but at high concentration these vacancies filled with palm fiber that make membrane to be good medium to transfer ultrasound waves.

Conclusion

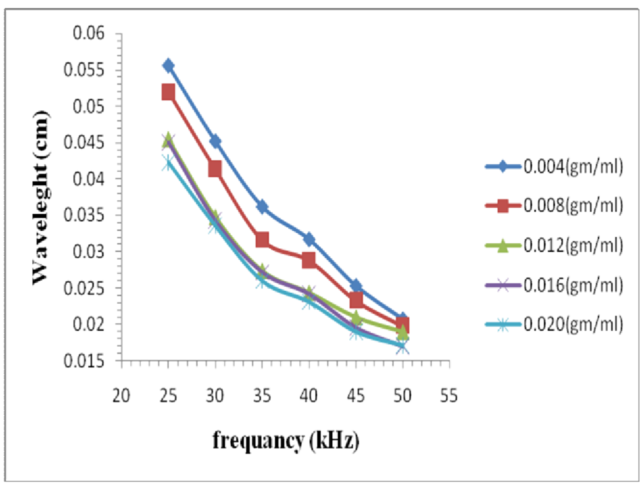
1. Results shows that palm fiber – PVA composite good absorber membrane for different range of ultrasonic frequency and can be applied in different surfaces that need this property.
2. Palm fiber –PVA composite damping ultrasound velocity for different range of frequencies.
3. Palm fiber – PVA composite is not good medium for transferring ultrasonic waves and not good transmittance.
4. This composite have strain as a result of ultrasonic stress because it compressed for increasing frequency.



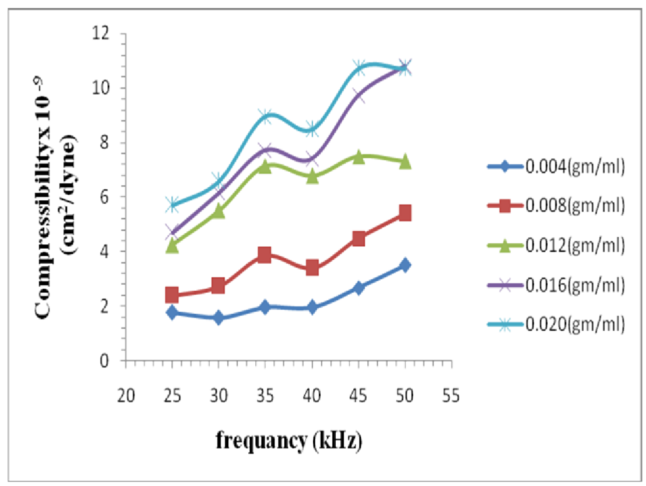
Fig(1) Ultrasonic velocity due to frequancy



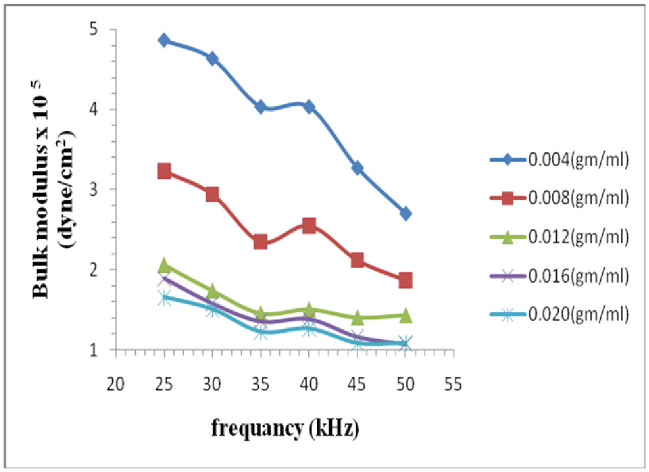
Fig(2) Share viscosity due frequancy



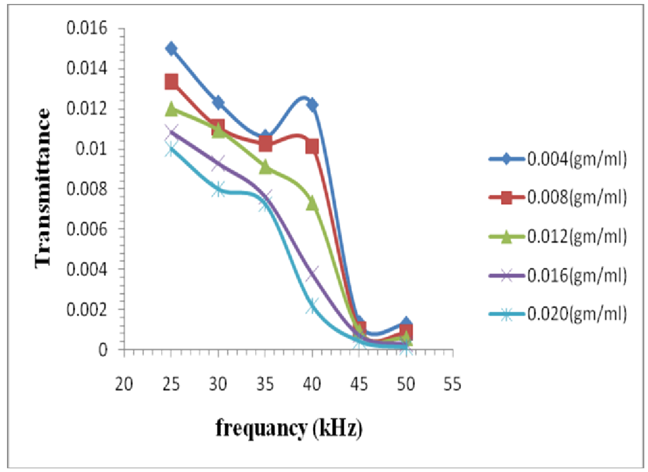
Fig(3) Wavelenght due frequancy



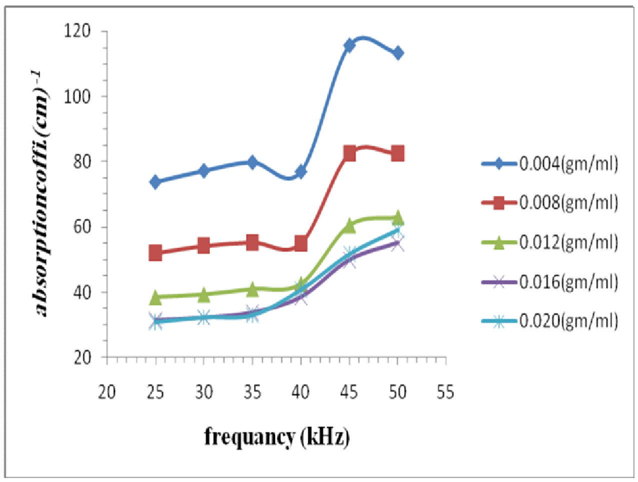
Fig(4) Compressibility due frequancy



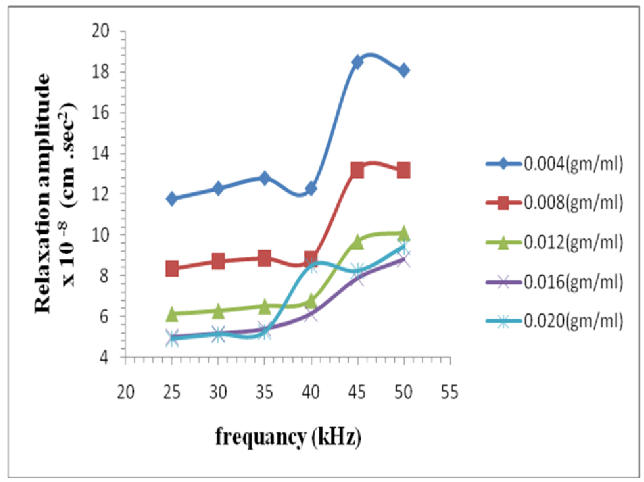
Fig(5)bulk modulus due frequancy



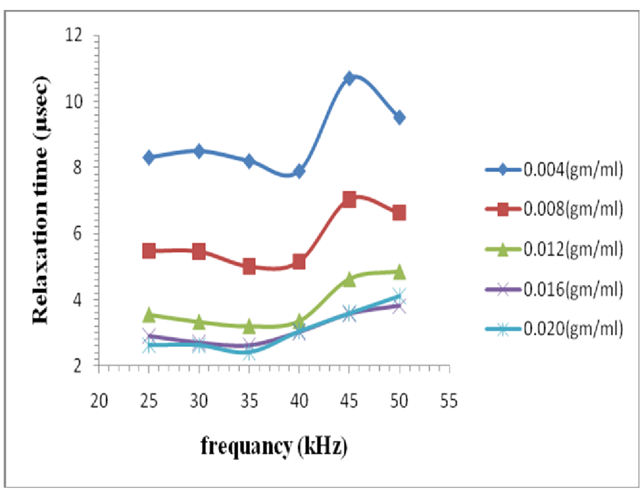
Fig(6)transmittance due frequancy



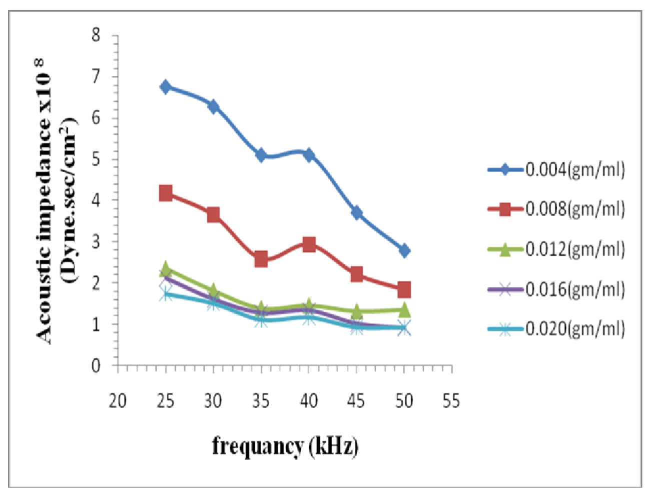
Fig(7)absorption coeffi. due frequancy



Fig(8)relaxation amplitude due frequancy



Fig(9)relaxation time due frequancy



Fig(10)acoustic impedance due frequancy

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