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A Study of Some Mechanical Properties of Iraqi Palm Fiber-PVA Composite by Ultrasonic

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Abstract

The PVA-Palm fiber composite polymer membranes were prepared by sol-gel casting method with different ratios of concentration, in order to study the mechanical properties of these composite ultrasonic measurements of variable frequencies (25,30,35,40,45 and 50 kHz) were performed , these properties are ultrasonic velocity ,density ,compressibility ,specific acoustic impedance ,relaxation time, relaxation amplitude , bulk modulus, shear viscosity ,absorption coefficient and transmittance. Results shows that all these properties were decreasing with concentration of palm fiber in composite ; so palm powder keep the degradations polymer chain isolated and their roots not interact again to forming entanglement interactions, this reason made these vales reduced except that scattering were dominant so we pointed that this composite more effective to reflect and scattered ultrasonic waves.

Keywords: PVA composite; ultrasonic method; mechanical properties; sol-gel method.

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 [1].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 [2] .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 [3] 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 [3,4].

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 [5].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 [2, 5, 6].The manner in which the propagation of the ultrasonic wave is affected by the 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 [7, 8, 9, 10, 11] .It should also be noted that the micro structural characteristics of hardwoods are more anisotropic and complex relative to softwoods and thus favor the dissipation of ultrasonic wave. 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 [12]; velocity is not affected by density [13] and finally it decreases with increased density [14], while [15] study the palm leaves as insulating material.

Experimental

Sample Preparation

PVA (Gerhard Buchman -Germany) with 99 % 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 Sieve to separate the fine pieces from large one then the fine pieces were grounded again for 3 hours and separated by another sieve to obtain the palm fiber as a 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 leave 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 petre 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 [16]:

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

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: [17]:

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

The relaxation amplitude of ultrasonic wave was calculated from the following equation where (f) is the frequency [18]:

$D = \alpha / f^2$……… (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 [19]:

$v = x / t$…… (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 [20]:

$\lambda = v / f$…… (6)

The acoustic impedance of a medium (Z) is a material property was calculated by this equation where (ρ) is the density [21]:

$Z = \rho v$…… (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 [22]:

$B = \rho v^2$…… (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 [23]:

$\beta = (\rho v^2)^{-1}$…… (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 [24, 25]:

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

The relaxation time (τ) was calculated from the equation [26]:

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

Results and Discussions

Ultrasonic velocity was determined for different concentration to PVA- Iraqi palm fiber composites at different ultrasonic frequencies are shown in Fig(1); The velocity are decreasing with the increase of concentrations this could be attributed to the interaction causing association between the three types of molecules ;polymer, solvent and palm molecules ,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[27,28]and when wave are propagated thought it the resultant periodical changes of wave pressure causes molecules to flow into vacancies in the lattice during compression phase and to return to their original positions in the lattice during rarefaction ,so when concentration increases the velocity decreases[28,29] , Fig.(1) also shows that ultrasonic velocity decreasing with the related of frequency this attributed that since frequency related to energy so high ultrasonic energy made more elasticity that reduced transferring ultrasound velocity[27].

The wavelength of ultrasonic are decreasing with the increase of concentration as shown in Fig.(2) , this attributed that when concentration increase the molecules will be close together and there are more interaction so there are more attenuation according to compression and rarefaction of wave propagation by these molecules. The specific acoustic impedance are decreasing with increase of concentration as shown in Fig.(3),this behavior like ultrasonic velocity parameter because equation (7) has only one more effective variable parameter which is velocity and density has very small variation with respect to velocity variation ,this behavior same to that given by [30] in his ultrasonic study of some mechanical properties of PVC; this caused when concentrations increasing there are rearrangements of the polymer network by breaking chains bonds ,it was probably that water clusters grew and came into contact with hydrophobic regions of the membranes resulting in a gradual change from small mobile palm clusters to larger clusters with stronger hydrogen bonds.[31] Fig.(3) also shows that at higher frequencies there are higher specific acoustic impedance since there are more degradation.

Compressibility of samples was calculated using Laplace equation no. (9), the results in Fig. (5) show that the compressibility are increasing with increasing palm concentration this behavior same to that given by [32,33] for other polymer; this could be attributed that ultrasonic waves propagation made polymer chains that randomly coiled to be each close together, this change confirmation and configuration of these molecules, so there are more compression happen of these molecules through ultrasound wave propagation [34], this compression fills the vacancies between polymer molecules and restricted the movement of these molecules this lead to reduce the elasticity of the composite with adding Palm fiber as shown in Fig.(4) The absorption coefficient of the ultrasonic wave is decreasing with increasing palm fiber concentration as shown in Fig.(6) this could attributed to attenuation of the ultrasonic wave in this composite is determined mainly by the distribution of the three types of molecules PVA, solvent (water) and the palm fiber rather ,the stronger increase of ultrasonic absorption in the low frequency region seems to indicate the presence of a relaxation process shows in Fig.(8) related to the monomer exchange between micelles formed by molecules and the suspending liquid [35] farther more attenuation of ultrasound wave depends on viscosity thermal conductivity ,scattering and intermolecular processes , the thermal conductivity was known to be negligible [32,36] ,therefore intermolecular processes were assumed to be responsible for reducing acoustic attenuation and some other scattering indicating an increase in the overall of complex formation between PV-OH macromolecules and water molecules that strongly combined with palm fiber when drying. Fig.(6) also shows at frequency (50kHz) there is high value of absorption coefficients with respect to other frequencies , since increasing frequency means increasing energy so the high frequency has ability to interaction with molecule chains hence compression and rarefaction be more effective so increasing absorption coefficient by increasing frequency [28] , the transmittance are decreasing with concentration shows Fig.(7)this caused that when adding palm fiber to PVA solutions these palm fiber powder fills the vacancies between polymer chains and restricted these chains in fixed volume , so when ultrasonic passes through composite it faces strong resistance to flow and transmit, since the absorption coefficients was decreasing and transmittance also decreasing with the increase of concentration ,so the scattering wave are ore dominate then both transmittance and absorption , so palm fiber has good property for reflecting ultrasound waves , Fig(7) also shows that the lower frequency waves do not interact with composite molecules since it has low energy.

The relaxation amplitude of the molecules are decreasing with increasing of concentration as shown in Fig.(8) since polymer molecules swelling water and increase its size and adding palm fiber make molecules to be restricted and free radicals obtained as a result of degradation [27] reduced absorption coefficients , so reduced relaxation amplitude, this result agree with decreasing absorption coefficient. The share viscosity shown in Fig.(10) was calculated from equation (10) and the results show that the viscosity decreasing with increasing palm concentration,this attributed that hydrogen bonding of water attached to oxygen sites then lead to salvation sheaths and increase the size of the molecules ,so the palm fiber between new macromolecules lead to reduces its viscosity [37,38].Relaxation time decreasing with concentration as shown in Fig. (9) ,we saw absorption coefficient decreasing with concentration so reducing the number of molecules as a results of degradation, this lead to reducing relaxation time for these molecules to be stated in their positions.

Conclusion

1. The wave velocity measurement can directly sense mechanical properties of composite material and experimental confirm the utility of the composite material properties scanning.
2. The ultrasound waves made degradation to the polymer chain then effects on the velocity.
3. The variation of the velocity depended on the thickness of the composite and the frequency.
4. The vacancies between the polymer molecules had been filled with palm fiber and restricted the movement of these molecules.

5. There is small strain of the composite as a result of ultrasonic stress because the compressibility decreases with increasing palm fiber concentration.
6. The velocity and viscosity results show this composite is not good medium to transfer ultrasound waves.
7. This composite is a good reflected medium for ultrasound waves and can be applied in different surfaces to be reflected and scattered these waves

Figure 1: Velocity due to ZnO concentration

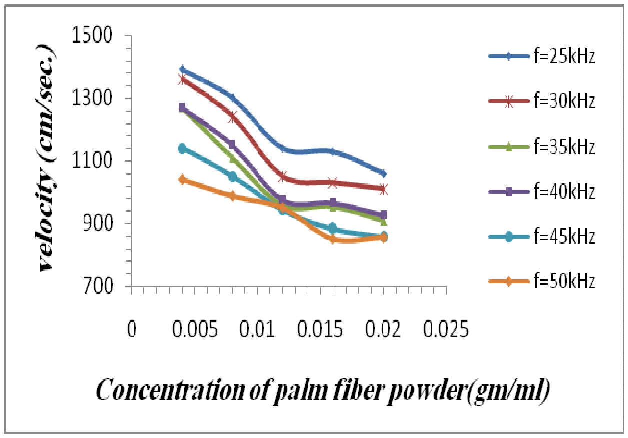


Figure 2: Wavelenght due to ZnO concentration

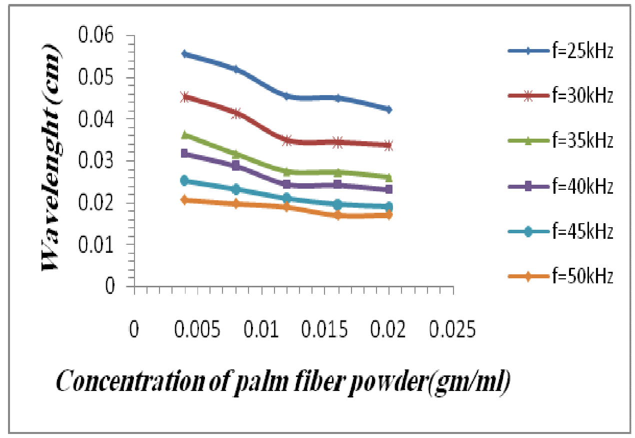


Figure 3: Acoustic impedance due to ZnO concentration

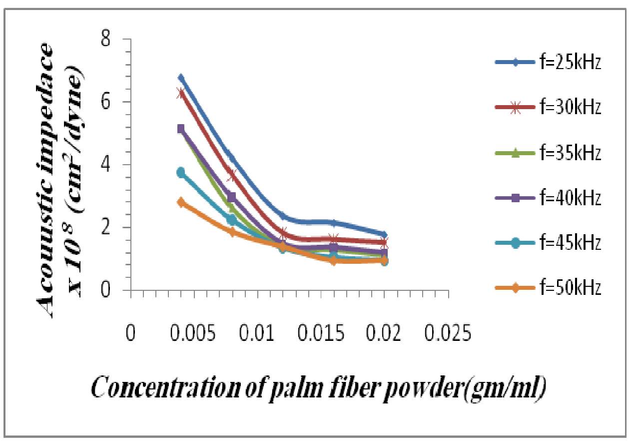


Figure 4: Bulk modulus due to ZnO concentration

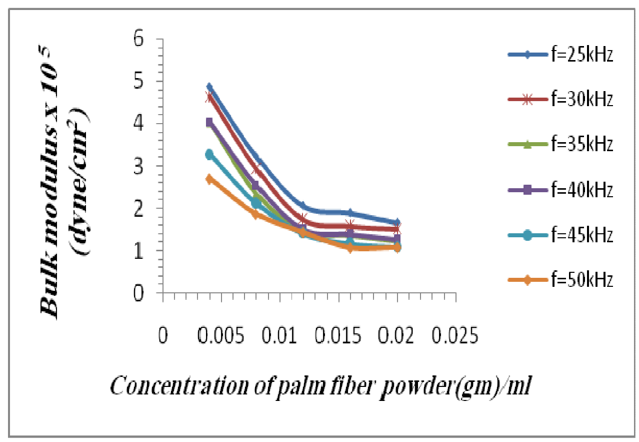


Figure 5: Compressibility due to ZnO concentration

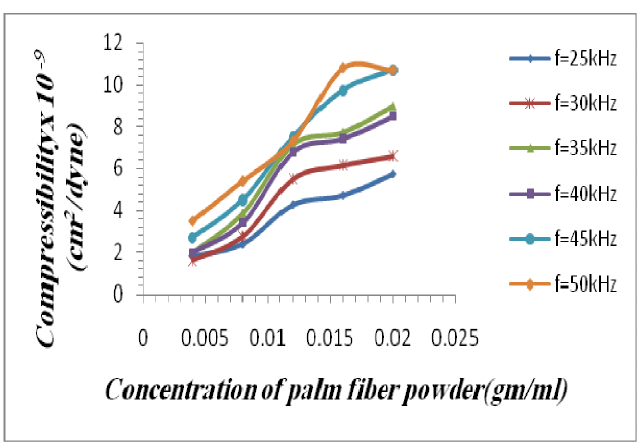


Figure 6: Absorpance coeffi. due to ZnO concentration

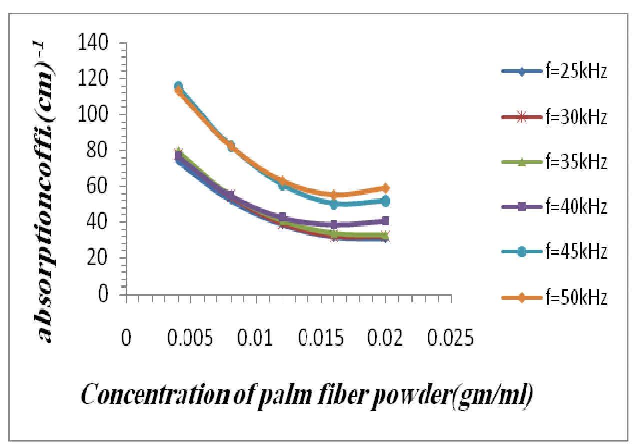


Figure 7: Transmittance due to ZnO concentration

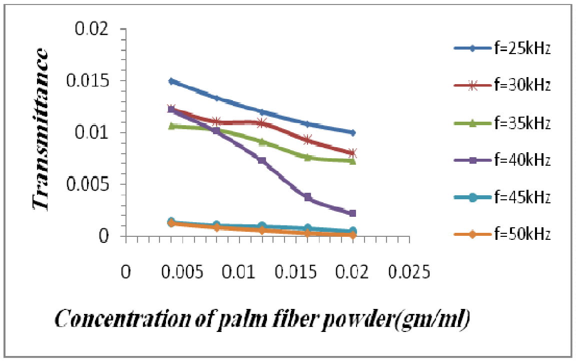


Figure 8: Relaxation ampletude due to ZnO concentration

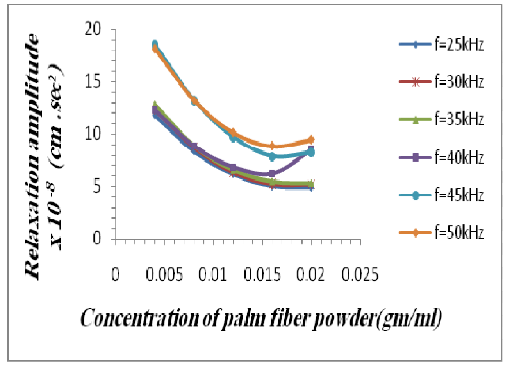


Figure 9: Relaxation time due to ZnO concentration

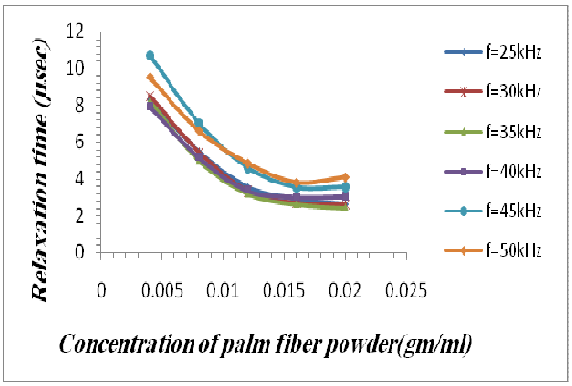
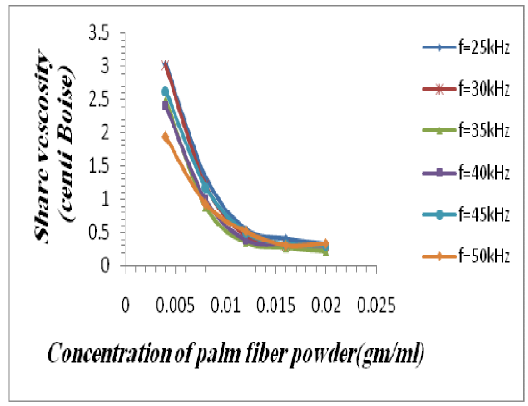


Figure 10: Share viscosity due to ZnO concentration



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