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Mechanical Properties of Xanthan Cellulose Gum-TiO_2 Composite

الخصائص الميكانيكية لمتركب صمغ الزانثان السلسلوزي-TiO_2

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Abstract:
Some of physical properties of xanthan cellulose gum (Xn) dissolves in distilled water had been studied at different concentrations (0.1, 0.2,…, 0.8)% g/mL before and after adding (0.25and 0.5) g of (TiO_2) for all concentrations. The mechanical properties such as ultrasonic velocity has been measured by ultrasonic waves system at frequency(25 kHz) and other mechanical properties have been calculated such as absorption coefficient of ultrasonic waves, relaxation time, relaxation amplitude, specific acoustic impedance, compressibility and bulk modules. The results show that all these properties are increase with the increasing of the polymer concentration except compressibility, also, the results show that when adding (TiO_2) these properties are increasing except compressibility is decreasing. But adding (TiO_2) to (Xn) enhances these properties.
Keywords: Xn Solution, TiO_2, Mechanical Properties, Ultrasound Technique.

الخلاصة :
بعض الخصائص الفيزيائية لبوليمر صمغ الزانثان السيليلوزي (Xn) المذاب في الماء المقطر قد درست بتراكيز مختلفة(0.1, 0.2,…,0.8) ٪ غم/مل قبل وبعد إضافة (0.25 و0.5) غم من (TiO_2) لجميع التراكيز، الخواص الميكانيكية مثل سرعة الموجات فوق الصوتية قد تم قياسها بوساطة جهاز الموجات فوق الصوتية عند التردد (25)كيلو هرتز، وقد حسبت الخواص الميكانيكية الأخرى مثل معامل امتصاص الموجات فوق الصوتية، زمن الاسترخاء، وسعة الاسترخاء ، الممانعة الصوتية النوعية ، الانضغاطية و معامل المرونة الحجمي. أظهرت النتائج أن جميع هذه الخصائص تتزايد مع زيادة تركيز البوليمر ماعدا الانضغاطية فأنها تتناقص مع زيادة التركيز . وتبين النتائج أنه عند إضافة (TiO_2) فأن هذه الخصائص تتزايد إلا الانضغاطية فأنها تتناقص .النتائج أيضا أظهرت أن إضافة (TiO_2) للبوليمر يعزز هذه الخصائص.
الكلمات المفتاحية : محلول الزانثان، ثنائي اوكسيد التيتانيوم، الخواص الميكانيكية، تقنية الموجات فوق الصوتية.

1. Introduction

Xanthan cellulose gum is a polysaccharide widely used in food, cosmetics, and enhanced oil recovery (EOR) by polymer flooding. In polymer flooding addition of polymers increases the viscosity of the injection water used for oil extraction from the oil producing wells. It is desirable to take advantage of biopolymers in(EOR), due to their biodegradability and easily accessible raw materials of low costs [1].

Water soluble polymers are vastly used in oil and gas wells. Xanthan gum is most commonly used polymers in enhanced oil recovery [2]. Xanthan is a polyelectrolyte and soluble in both hot and cold water. Xanthan provides high viscosity of solutions, even at low concentrations. The viscosity depends highly on the shear rate, due to the shear thinning, or pseudo plastic, properties of xanthan at low shear rates xanthan is highly viscous, while at high shear rates the viscosity decreases [3].

Xanthan cellulose gum has a wide range of applications due to its low cost Because of its polymeric structure and high molecular Weight, it can be used as filler in bio- composite films [4]. Xanthan cellulose gum was commonly used for increasing production of oil from its original traps in oil drilling [5] . Solvent effects might therefore be expected to influence the ultrasonic relation behavior the absorption of ultrasonic in liquid polymer systems is governed by local modes of motion and cooperative whole molecule movement because of the strong intermolecular interaction within the polymer it should be possible to observe cooperative motion in the ultrasonic range.

However these properties are dependent on humidity, in other words, with higher humidity more water is absorbed, the water which acts as a plasticizer, will then reduce its tensile strength, but increase its elongation and tear strength. Acoustic relaxation measurements on other polymers have been reported by several workers[6 ,7], 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 [8].

The purpose of this research was to investigate the mechanical properties of xanthan cellulose gum Xn with titanium dioxide TiO_2 as aqueous solutions by ultrasound wave at fixed frequency (25 kHz) and study the effect of adding TiO_2 on the mechanical properties of Xn to enhance these properties.

2. Theoretical Part

The absorption coefficient (α) was calculated from Lambert - Beer law [9]:

$$A/A_{\circ} = \mathbf{e}^{(-\alpha x)} \quad (1)$$

Where (A) is the initially amplitude of the ultrasonic waves,($A_{\circ}$) is the wave amplitude after absorption and (x) is the distance between the sender and receiver.

The ultrasonic wave velocity (V) was calculated using the following equation [10]:

$$V = x / t \quad (2)$$

Where (t) is daily time. Attenuation is generally proportional to the square of sound frequency so the relaxation amplitude (D) were calculated from the following equation [11]:

$$D= \frac{\alpha}{f2} \quad (3)$$

where (f) is the ultrasonic frequency.

The acoustic impedance of a medium (Z) has been calculated by equation [12]:

$$Z= \rho V \quad (4)$$

Where ρ is the density.

Bulk modulus (K) is the substance's resistance to uniform compression, it is defined as the pressure increase needed to decrease the volume, it was calculated by the equation [13]:

$$K= \rho V^2 \quad (5)$$

Compressibility (B) 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 the following equation [14]:

$$B= (\rho V^2)^{-1} \quad (6)$$

The relaxation time (τ) was calculated from the equation [15]:

$$\tau = 4\eta_s/3\rho V^2 \quad (7)$$

Where η_s is the shear viscosity.

3. Experimental part

The materials used in this paper are xanthan cellulose gum with different additives of (TiO_2).

3.1 Preparation of polymer solutions

The Xn solution was prepared by dissolving a known weight of Xn powder in (500 mL) distilled water under stirring at (70 °C) for (60 min). The Xn concentrations were (0.1, 0.2, …., and 0.8)% g/mL, then TiO_2 added with weights (0.25 and 0.5)% g to each Xn concentrations. The resulting solution was stirred continuously for (60 min) until the solution mixture became a homogeneous.

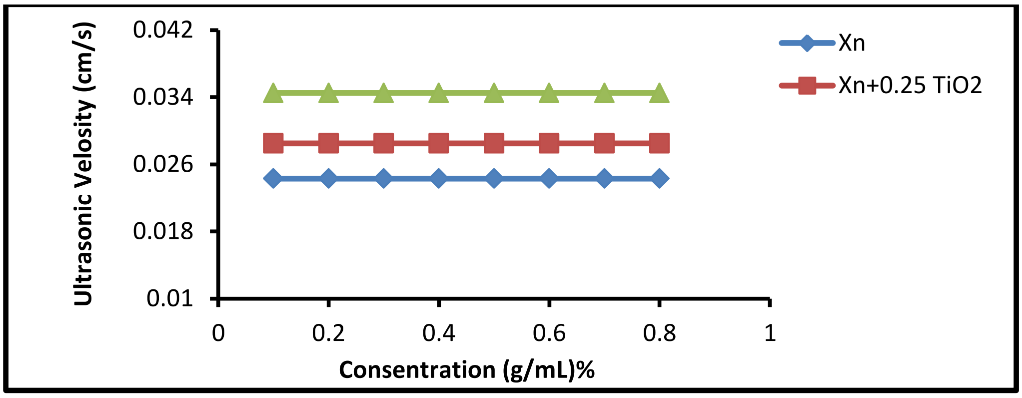
3.2 Ultrasonic measurements

Ultrasonic measurements were made by pulse technique of sender-receiver type (SV-DH-7A/SVX-7velocity of sound instrument) with constant frequency (25 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 (CH_1) represents incident ultrasonic wave's amplitude ($A_\circ$) and the pulses height on oscilloscope (CH_2) represents the receiver ultrasonic wave's amplitude (A).

4. Results and Discussion

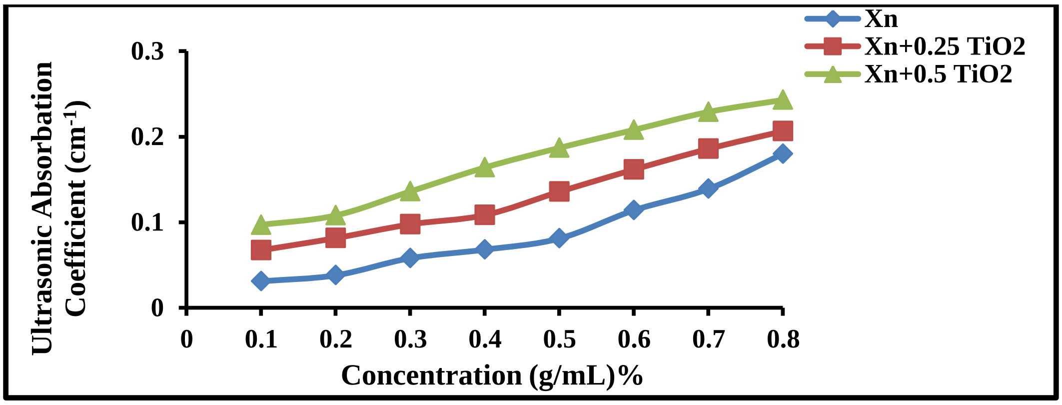
This paper includes the results and discussions of the mechanical properties of Xn polymer before and after adding (TiO_2) and discussed the behavior of these properties with concentration in solution and in the case of addition different weights of (TiO_2).

Ultrasonic velocity is increase with increasing TiO_2, as shown in Figure (1) this because structural or volume relaxation it occurs in associated liquids such as polymers, a liquid when at rest has a lattice structure similar to that possessed by solid when waves are propagated through it, the resultant periodic 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 is also increase [16]. Ultrasonic velocity is increase with adding TiO_2, this attributed that ultrasonic waves interact with polymers causing association between the two types of molecules that lead to increase the velocity [17].



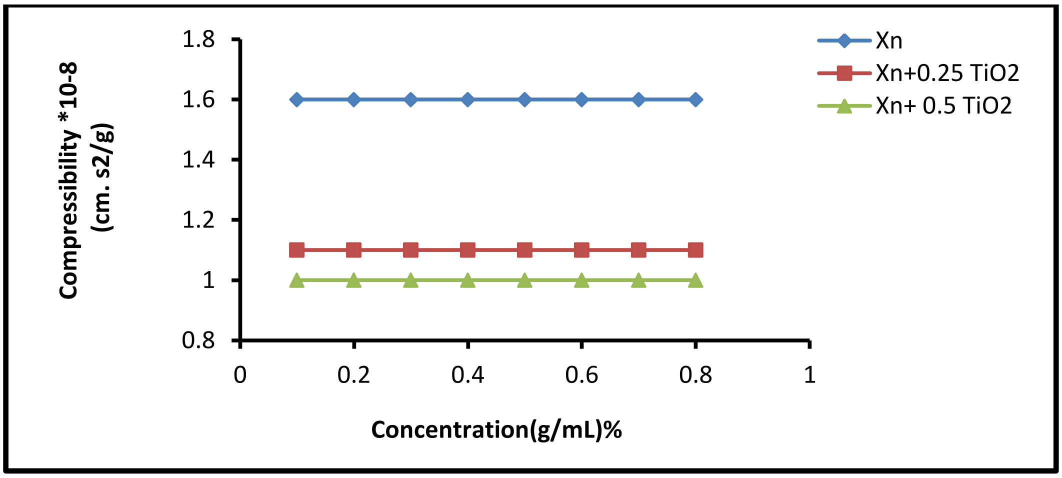
(Fig.1): Velocity due to concentration

The absorption coefficient as shown in Figure (2), that is increasing with concentration this attributed to the fact when polymer concentration increase there will be more molecules in solution. This lead to more attenuation against wave propagation. The attenuation can be attributed to the friction and heat exchange between the particles and the surrounding medium, as well as to the decay of the acoustic wave in the forward direction due to scattering by the particles [18]. Adding TiO_2 enhances absorption coefficient by increasing its values. This attributed as we explained that adding TiO_2 increased the viscosity of the solution, this means that there were more flexibility for these polymer chains in solution as a result of adding TiO_2 molecules, because ultrasonic waves propagate as compression and rarefaction in a medium so there are variation in density medium and there were more attenuation to energy of ultrasound waves when adding TiO_2 [19].



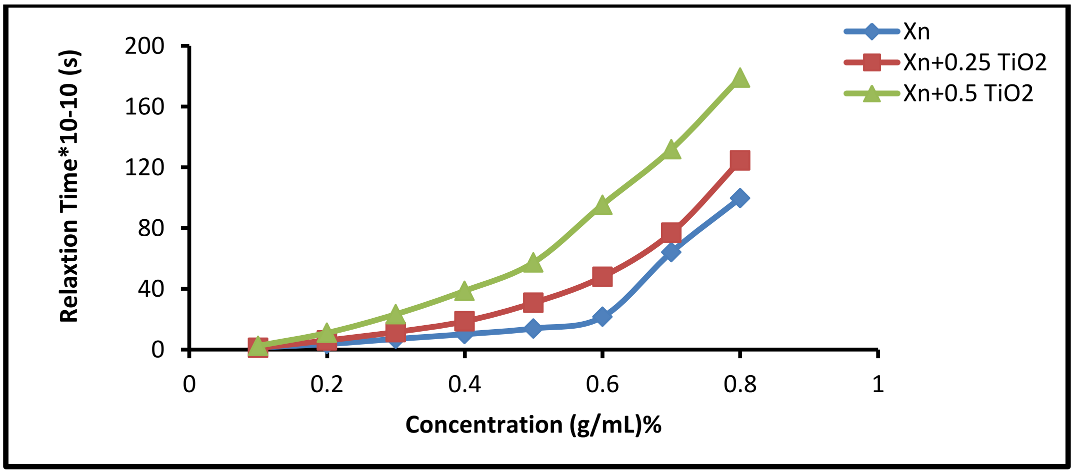
(Fig.2): Absorption coefficient due to concentration

The compressibility decreases with the increasing of concentration as shown in Figure (3). This attributed to the fact that in Laplace equation (6) there are inverse proportionality between compressibility and ultrasonic velocity [20, 16].

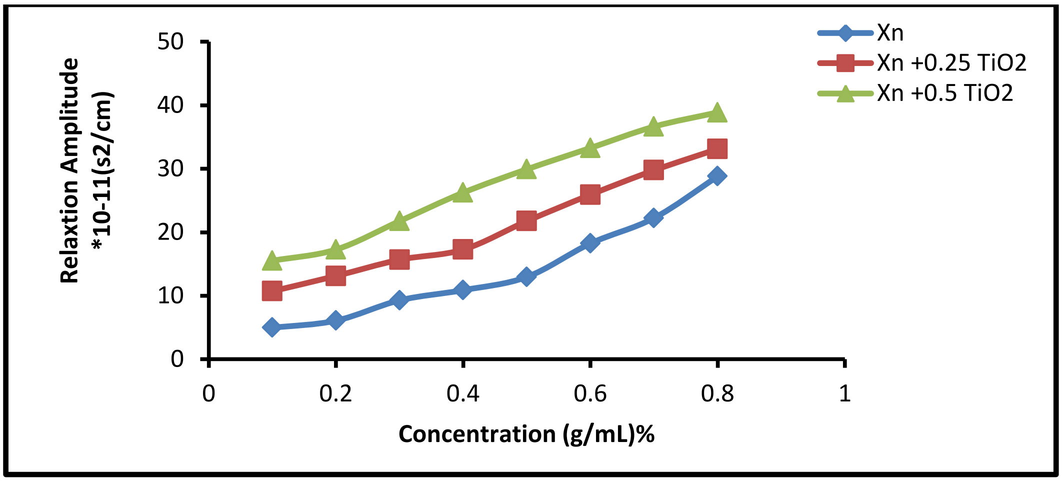


(Fig.3): Compressibility due to concentration

Ultrasonic relaxation time was calculated by using equation (7) as shown in Figure (4) and The relaxation amplitude as shown in Figure (5) was calculated from equation (3). These values are increasing with concentration, this behavior is the same to that given by [21] for other mater the fact that ultrasonic energy depends on viscosity ,thermal conductivity, scattering and intermolecular processes. Thermal conductivity, scattering are known to be negligible, so viscosity is responsible for the increase of relaxation amplitude for this reason absorption coefficient commonly known as visco- absorption [22].



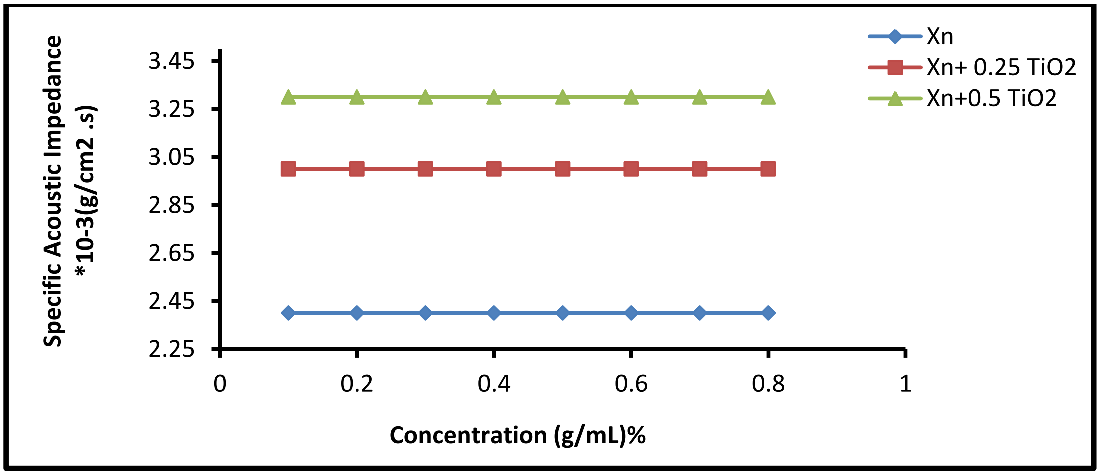
(Fig.4): Relaxation time due to concentration



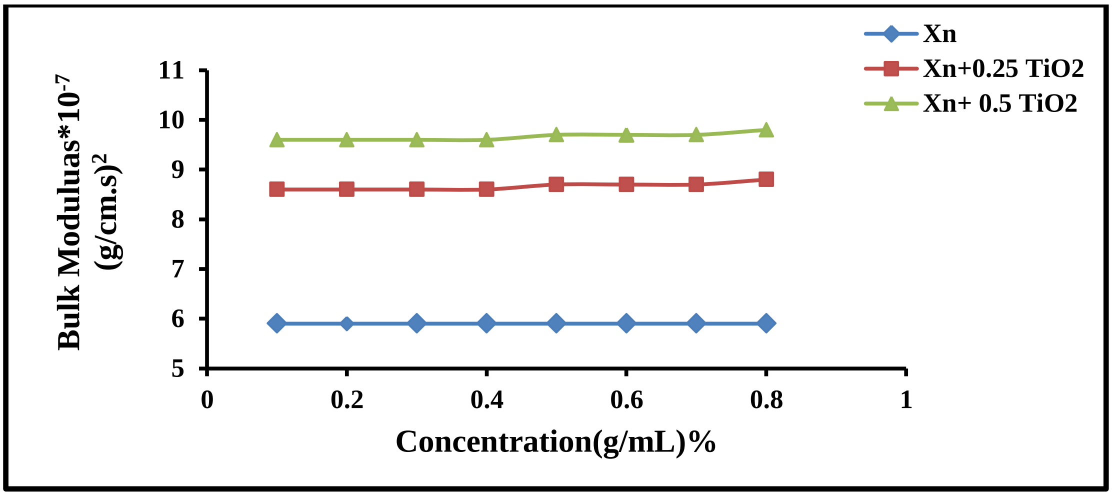
(Fig.5): Relaxation amplitude due to concentration

Specific acoustic impedance as shown in Figure(6)is increasing with concentrations this behavior same to that given by[23]and attributed to the equation(4)has only one variable parameter which is velocity and density has very small variations with respect to that velocity and when adding TiO_2 increased acoustic impedance because TiO_2 particle fills the valances by swallowing water molecules and be closer to Xn macromolecules that increasing specific acoustic impedance [24].

The bulk modulus is increasing with concentration as shown in Figure (7), this behavior same to that give by [24], because the bulk modulus is the inverse of the compressibility.



(Fig. 6): Acoustic impedance due to concentration



(Fig.7): Bulk modulus due to concentration

Conclusion

1. Adding TiO_2 increases the ultrasonic velocity so the blend can be used as good medium for transferring ultrasonic waves in such medical instruments.
2. This blend has good mechanical properties so it may use as resistant materials against environment.
3. Ultrasonic absorption coefficient increases with increasing concentration so it can be used as coated materials for moving bodies in order to detect by ultrasonic technique.
4. Adding TiO_2 reduced compressibility, this lead to increase interaction between polymer molecules this cause enhancement for mechanical properties against environments.

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