Study Of Some Mechanical Properties Of High Viscosity Carboxy Methyl Cellulose Using Ultrasonic Wave System

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Abstract

Some physical properties of high viscosity Carboxy Methyl Cellulose dissolved in distilled water had been studied. The study includes mechanical properties by using ultrasonic wave system of frequency (40 KHz). These properties are ultrasonic velocity, ultrasonic absorption coefficient, compressibility, relaxation time, relaxation amplitude, specific acoustic impedance and bulk modulus and shear viscosity.

Results show that all these properties were increasing with the increase of the ultrasonic velocity except compressibility was decreasing with the ultrasonic velocity. Results show that ultrasonic make degradation to the polymer chains, and the free radicals rebounded to make entanglement interactions which is responsible for increasing the properties. The aim of this research is to find different properties of this polymer and determine its different industrial applications according to these properties.

الخلاصة

تمت دراسة بعض الخصائص الفيزيائية لمادة كاربوكسي مثيل سليليوز عالي اللزوجة المذاب في الماء المقطر بإستخدام منظومة الموجات فوق السمعية وبتردد (٤٠ كيلو هرتز). الخصائص تشمل سرعة الموجات فوق السمعية، معامل الامتصاص فوق السمعي، الانضغاطية، زمن الاسترخاء، سعة الاسترخاء، الممانعة الصوتية النوعية، معامل المرونة، واللزوجة القصية. اظهرت النتائج زيادة طردية في جميع الخصائص مع زيادة سرعة الموجات فوق السمعية ما عدا خاصية الانضغاطية حيث كانت تنقص مع زيادة سرعة الموجات فوق السمعية. تبين النتائج فوق السمعية تدهور السلاسل البوليميرية وان التغيرات الجوهرية الحاصلة تعيد تكوين الاواصر بحيث تجعل التفاعلات التشابكية مسؤولة عن الزيادة في هذه الخصائص. الهدف من البحث ايجاد الفرق في خصائص البوليمر وكيفية حسابها في التطبيقات الصناعية المختلفة المطابقة لهذه الخصائص.

Introduction

Carboxy methyl cellulose (CMC) or cellulose gum is a cellulose derivative with carboxy methyl groups **(- CH$_2$-COOH)** bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone. It is often used as its sodium salt, sodium carboxy methyl cellulose.

It is synthesized by the alkali-catalyzed reaction of cellulose with chloroacetic acid. The polar (organic acid) carboxyl groups render the cellulose soluble and chemically reactive. (Alimentarius, 2009).

The functional properties of CMC depend on the degree of substitution of the cellulose structure (i.e., how many of the hydroxyl groups have taken part in the substitution reaction), as well as the chain length of the cellulose backbone structure and the degree of clustering of the carboxy methyl substituents. (James, Mark, 2007)

CMC is used in food science as a viscosity modifier or thickener, and to stabilize emulsions in various products including ice cream. As a food additive, It is also a constituent of many non-food products, such as K-Y Jelly, toothpaste, laxatives, diet pills, water- based paints, detergents, textile sizing and various paper products. It is used primarily because it has high viscosity, is non-toxic, and is non-allergenic. (Alimentarius, 2009). In laundry detergents it is used as a soil suspension polymer

designed to deposit onto cotton and other cellulosic fabrics creating a negatively charged barrier to soils in the wash solution. CMC is used as a lubricant in non¬volatile eye drops (artificial tears). Sometimes it is methyl cellulose (MC) which is used, but its non-polar methyl groups (-CH3) do not add any solubility or chemical reactivity to the base cellulose. (Harold, Emil, 1991).

Following the initial reaction the resultant mixture produces approximately 60% CMC plus 40% salts (sodium chloride and sodium glycolate). This product is the so-called Technical CMC which is used in detergents. A further purification process is used to remove these salts to produce pure CMC which is used for food, pharmaceutical and dentifrice (toothpaste) applications. An intermediate "semi-purified" grade is also produced, typically used in paper applications. (Yoneda, 2005).

CMC is also used in the oil drilling industry as an ingredient of drilling mud, where it acts as a viscosity modifier and water retention agent. Poly-anionic cellulose or PAC is derived from CMC and is also used in oilfield practice. (Al-Bermany, 2005).

Insoluble micro granular carboxy methyl cellulose is used as a cation-exchange resin in ion- exchange chromatography for purification of proteins. Presumably the level of derivatization is much lower so that the solubility properties of micro granular cellulose are retained while adding sufficient negative charged carboxylate groups to bind positively charged proteins. (Al-Bermany, 2005).

The mechanical properties were studies using ultrasonic pulse technique. Acoustic relaxation measurements on other polymers have been repotted by several workers (Al-Bermany, 2010). The acoustic relaxation has been ascribed to the conformation changes of the polymers back bone and the breath of the relaxation has been explained in term of a number of specific conformational transformation (Hassun, Rahman, 1990) (Khalida, 2004).

Practical part.
I: Preparation of solutions.

The CMC solution were prepared by soluble the CMC in distilled water with many different concentrations (0.2% - 1%) gm/ml, the solubility is made by addition of unknown weight of the polymer to affixed volume of water and then heating this mixture under reflux whilst agitating with magnetic stirrer for about 20 min. Until a clear solutions were obtained (Yoneda, 2005).

II: Measurements
1. **Rheological calculations.**

The density of the solution was determined and their viscosities measured using an Ostwald viscometer, with accuracy of + 1.05%, the method of measurement has been described, elsewhere(Hassun, 1990). The Shear viscosity had been calculated by the following equation:

$$\frac{\eta_s}{\eta_o} = \frac{t_s \, \rho_s}{t_o \, \rho_o} \quad ----- 1$$

Where ρ_s and η_s are the solution density and viscosity respectively, ρ_o and η_o are density and viscosity of distilled water respectively obtained by (Curti, 2006).

2- Measurements and Mechanical Calculations

The Ultrasonic velocity (V) was measured using the pulse ultrasonic technique of sender- receiver type SV-DH-7A, SVX-7 with (0-50 kHz) variable frequency in our study, the frequency fixed at (40 KHz), the metal vibrator was coated with oil and kept in contact with the wall of the glass tank containing the test sample the receiver quartz crystal was mounted on a digital venire of slow motion. The receiver crystal could be displaced parallel to the sender through 10 cm. The sender and receiver pulses were displaced on two traces of cathode ray oscillograph

Theoretical values such as absorption coefficient (a) of ultrasonic waves, relaxation time (τ), relaxation amplitude (D), compressibility (β), specific acoustic impedance (Z) and bulk modules (K) for the polymer solutions have been calculated using the following equation(Blitz, 1967. Hassun, 1990).

The absorption coefficient had been calculated by the following equation

$$a = \frac{8 * \pi^2 f^2 \eta}{3\rho v^3} - - - - - 2$$

where f the frequency of ultrasonic waves, η is the viscosity of solution, ρ the density, v the velocity of ultrasonic waves .

The relaxation time τ had been calculated by the following equation

$$\tau = \frac{4\eta}{3\rho v^3} - - - - - 3$$

The relaxation amplitude had been calculated by the following equation

$$D = \frac{a}{f^2} - - - - - - 4$$

The specific acoustic impedance had been calculated by the following equation

$$Z = \rho V - - - - - 5$$

The compressibility β had been calculated by the following equation

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

The bulk modules K had been calculated by the following equation

$$K = \beta^{-1} = \rho V^2 - - - - - 7$$

Results and discussions

The ultrasonic velocity is increasing with the increase of concentration of as shown in fig (1). This behavior same to that obtained by (Al- Bermany, 2005) for other polymers and attributed to the fact that ultrasonic velocity transfers as compression and rarefaction in a medium as a result there will be more degradation to the polymer chains that randomly coiled. The free radicals and roots entanglements each to other so the velocity increasing when concentration increasing. Agree with (Hassun, 1990. Al-Bermany, 2010).

The density of concentration is increasing with the increase of ultrasonic velocity as shown in fig (2). This behavior same to that given by (Ehsan, 2004) for other polymers and attributed that compression and rarefaction can be described by density changes and by displacement of atoms and molecules from their equilibrium positions (A. Yoneda, 2005) so increasing velocity leads to increase polymer density.

Specific acoustic impedance is increasing with the increase of ultrasonic velocity. This behavior same to that given by (Hassun, 1990) for other polymers and attributed to the equation (5) has only one variable parameter which is velocity, and

density has very small variations with respect to that of velocity and since ultrasonic increasing then specific acoustic impedance increasing also.

The compressibility is decreasing with the increasing of ultrasonic velocity as shown in fig (4). This behavior same to that obtained by (Hassun, 1990. Ehsan, 2004) for other polymers and attributed to the fact that in Laplace equation (6) the velocity inversely related to compressibility and since velocity increasing so compressibility decreasing and also attributed that when velocity increasing, there are more degradation to the polymer chains reduces compressibility (Tomaz *etal*, 2010).

Shear viscosity is increasing with the increase of velocity as shown in fig (5) and attributed that when velocity increasing there ions mechanism that hydrogen bonding of water attached to oxygen sites, this lead to solvation sheats and increase the size of molecules, viscosity, and network formations (Hassun, 1990. Al- Bermany, 2010).

Absorption Coefficient of CMC is increasing with the increase of ultrasonic velocity as shown in fig (6). This attributed that ultrasonic waves make changes in structural relaxation which is responsible for the excess of absorption, and as velocity increases, it will make degradation to polymer chains so these molecules will randomly coiled that increase the attenuation (Boeing, 2007).

The bulk modulus is increasing with the increase of ultrasonic velocity as shown in fig (7). This behavior same to that given by (Ehsan, 2004. Al-Bermany,2010) and attributed. Equation (7) shows strongly depends on velocity so bulk modulus have same behavior of velocity.

Relaxation amplitude was calculated by equation (4) and shown in fig (8) their values are increasing with velocity this attributed to the fact that ultrasonic energy depends on viscosity, thermal conductivity, scattering and intermolecular processes, thermal conductivity and scattering effects are known to be negligible (Blitz, 1967. Hassun 1990) so viscosity is responsible for the increase of relaxation amplitude for this reason absorption coefficient commonly known as visco- absorption.

Relaxation time increasing with ultrasonic velocity as shown in fig (9), and attributed when ultrasonic increasing the molecules will displaced the molecules and leaving their equilibrium positions so when velocity increasing the displacement increasing also the relaxation time for these molecules to be stated increasing (Blitz, 1967. Tomaz, 2010).

Conclusions

1.   This study shows that ultrasonic make entanglement interactions between polymer and solvent molecules and network formations.
2.   There are complexes molecules were formed in the solution by the effects of peroxide and roots.
3.   Ultrasonic procedure enhances mechanical properties of CMC because these properties are increasing when ultrasonic velocity increasing.
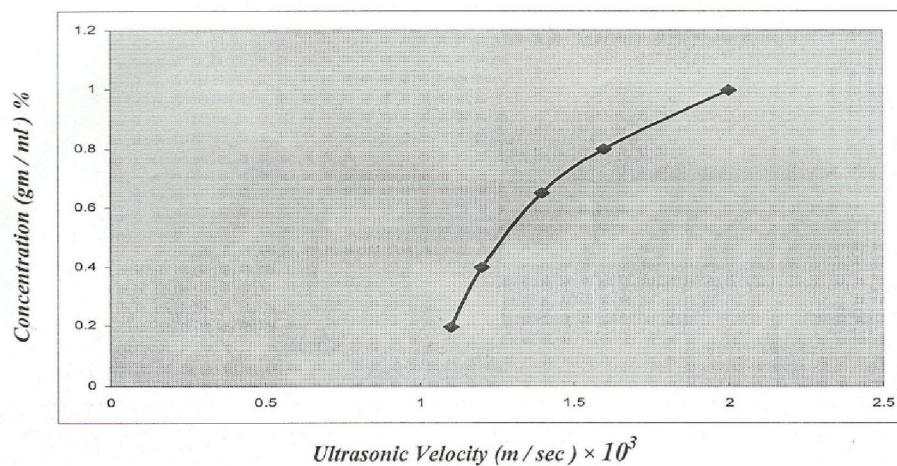
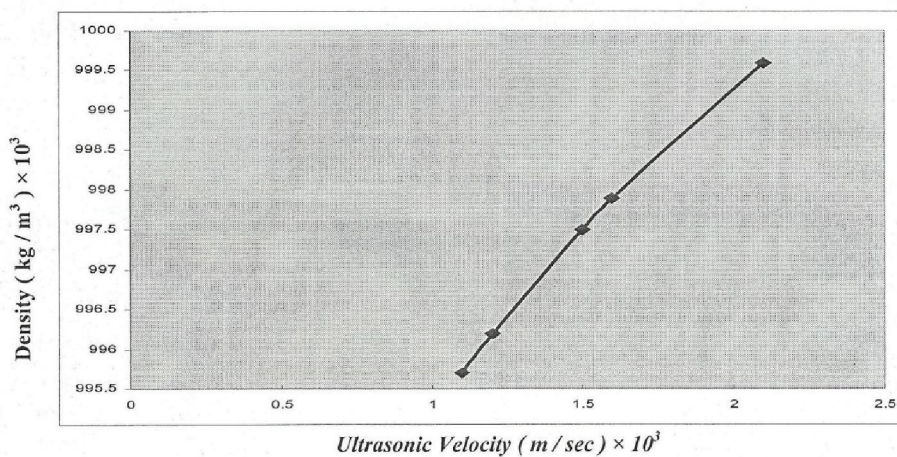Fig (1) : The Variation of Concentration Vs Ultrasonic Velocity of CMC.

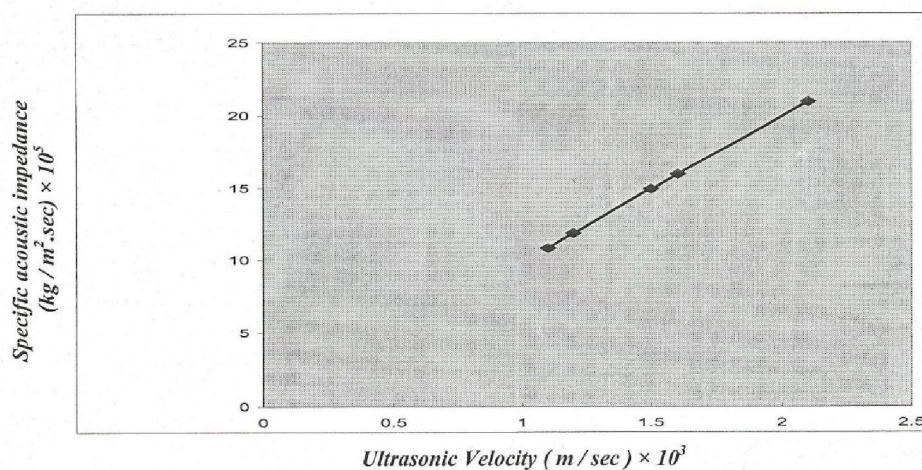Fig (2) The Variation of Density Vs Ultrasonic Velocity of CMC.

Fig (3) The Variation of Specific impedance Vs Ultrasonic Velocity of CMC.
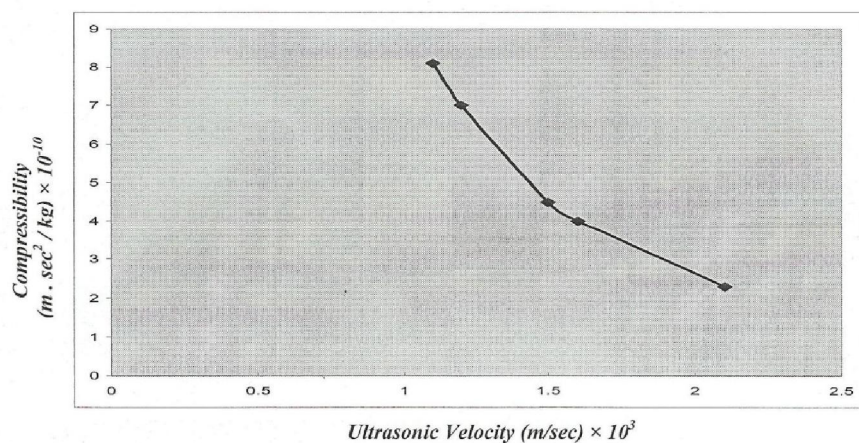
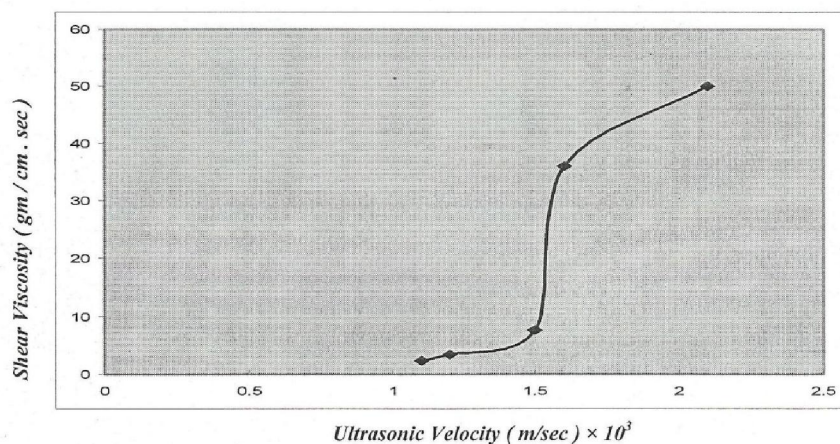Fig (4) The Variation of Compressibility Vs Ultrasonic Velocity of CMC .

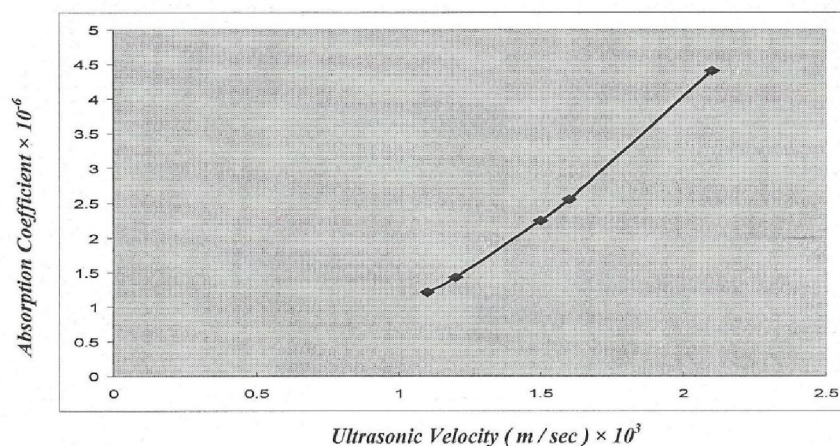Fig (5) The Variation of Shear Viscosity Vs Ultrasonic Velocity of CMC .

Fig (6) The Variation of Absorption Coefficient Vs Ultrasonic Velocity of CMC .
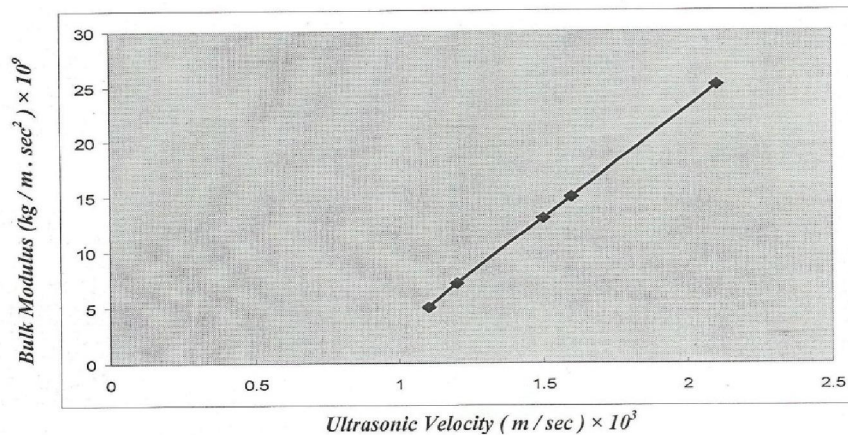
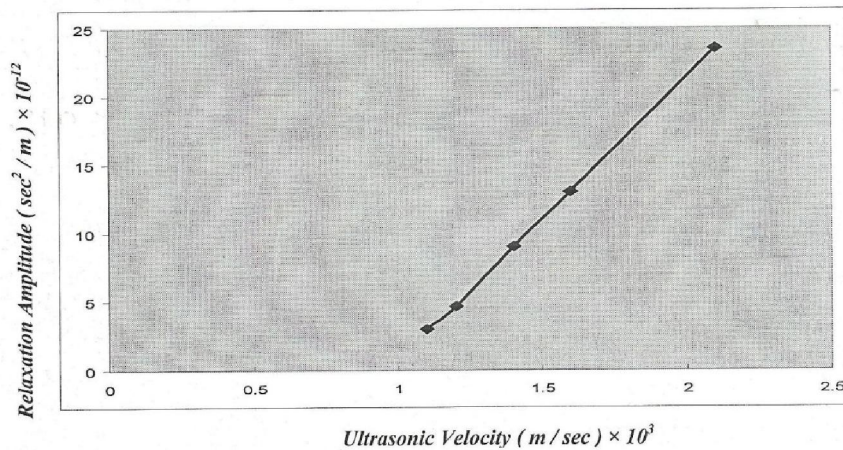Fig (7) The Variation of Bulk Modulus Vs Ultrasonic Velocity of CMC.

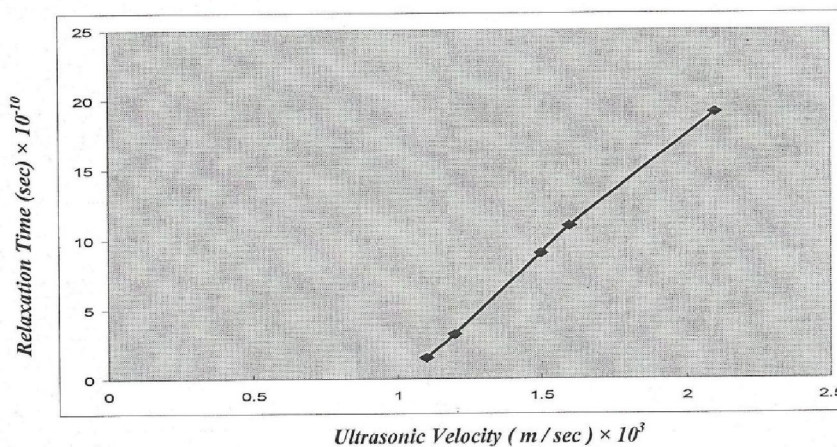Fig (8) The Variation of Relaxation Amplitude Vs Ultrasonic Velocity of CMC.

Fig (9) The Variation of Relaxation Time Vs Ultrasonic Velocity of CMC.

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