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Enhancement the mechanical properties of a product porcelain by a ceramic additives using ultrasonic technique

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Abstract

This investigation is concerned on the influence of addition ZnO , ZrO_2 ,TiO_2 on the mechanical properties of a porcelain body. Porcelain body is prepared from Iraqi clays (Kaolin Duekhla & Ardhma sand glass), and Feldspar Potash with different weight percent (40% Kaolin, 30% sand glass Ardhma, and 30% Feldspar Potash) , and granular sizes less than (100µm Kaolin, and 50µm for each of sand glass and feldspar). A prepared disk sample of 27mm in diameter was formed by compaction 75 Mpa for 5 min. The circumstances of heat treatment is 1300°C for 2hr and an elevation speed of 2 °C/min. Effect of the proportion added on mechanical properties of PVC were performed by ultrasonic technique using frequency of 30 KHz. Experimentally, it was found that the adding 2% ZnO + 1% TiO_2 made composite good medium for transferring ultrasound waves, so they can be used as a coated material for objects that we don't want them to be detected by sonar. Adding 1% ZrO_2 +2% TiO_2 enhances the absorption coefficient of porcelain and the composite becomes good absorber for ultrasound. Adding 2%ZrO_2 +2%TiO_2 made composite not good medium for transferring ultrasound waves , and adding 1%ZnO enhances the compressibility because it has the heights value and ZnO molecules fills the vacancies of porcelain chains.

Keywords: porcelain bodies, kaolin clay, ultrasonic waves

1. Introduction:

Ceramic product is made by heat treatment of a substance (or mixture of substances) nonmetallic and inorganic metal [1].

Porcelain producer ceramic hardness, white, semi-transparent and intensive impermeable to liquids. Porcelain is a mixture of materials composed mainly of kaolin, feldspar and quartz raw materials and white plastic firearms clays. The porcelain has many good features, such as, resistance to mechanical stresses and loads, and chemical influence which exposed him, in addition to good electrical resistance. Available two type of porcelain, the first one is hard porcelain and the second soft porcelain. The hard type is used to make insulators and chemical industry equipment, while the soft type is used in the manufacture of household and pottery materials [2]. Conducted some studies about the effect of ceramic additives on the properties of porcelain body reported by Al-Shamri, Ameera Kanaan [3]. She studied the influence of additives ZnO , ZrO_2 ,TiO_2 on the physical properties of a porcelain body, electrical dielectric falls within the standard values of the ceramic insulator.

The our work, searching for the effect of single and binary additions of oxides ZnO, TiO_2 , ZrO_2 on the mechanical properties(speed of ultrasound waves, absorption coefficient of ultrasound waves,density, relaxation amplitude of ultrasonic wave, acoustic impedance, bulk modulus, Compressibility, relaxation time and shear viscosity) of a porcelain body prepared from local clays (Duekhla Kaoline and sand glass ardma) addition to the feldspar potash, after a heat treatment of raw materials in line with the requirements of the ceramic insulator of high voltage.

2. Experimental and theoretical calculations:

2.1 preparations and analyzing porcelain body

The porcelain body composed from local clays (Duekhla Kaoline and sand glass ardma) addition to the feldspar potash as adjuvant on the melting with different weight percent and granular sizes and circumstances of heat treatment 1300^{o}C for 2hr and an elevation speed of 2 ^{o}C/min. The chemical composition of local clay is shown in Table 1. The Iraqi Duekhla Kaoline and sand glass Ardma powder were washed by distilled water each separately and leave the mixture stagnate for a period of one day, then repeated the process for six days, taking into account replacement of water each day in order to dispose of the all types of impurities, subsequently the mixture dried at 100^{o}C for 24 hr, then pass through the sieves (50 -100 µm). Mixing ratios of 40% Duekhla Kaoline (D<100µm), 30% Feldspar Potash (D<50µm), and 30% sand glass Ardma (D<50µm) with 100cc of distilled water by mixing a half hour each. Product was treated with adding PVA dissolved in 50cc of distilled water at 80^{o}C . Continue mixing to get a complete homogeneity, then added a number of oxides (1% ZnO), (1% ZrO_2) , (1% TiO_2), (2% ZnO), (2% ZrO_2) , (2% TiO_2), (2% ZnO + 1% TiO_2) , (2% ZrO_2 + 2% TiO_2) , (2% TiO_2 + 1% ZrO_2) , (2% ZnO + 2% ZrO_2) to a product (P). After that carried out two stage of drying process at 50 and 100 ^{o}C for 24hr by using the dryer type F. G. BODE&CO- Laboratory - Equipment - Hamburg-90 for each of them and then milling product. Disks were formed in a dry pressing using a press of 75 Mpa for time of 5 minutes, to ensure that the flow particles with each other. Mechanical properties were measured using ultrasonic technique at frequency of 30 KHz.

2.2Theoretical calculations

The absorption coefficient (α) was calculated from Beer–Lambert law equation [4]:

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

Where (A_0) is the initially amplitude of the ultrasonic waves, (A) is the wave amplitude after absorption. The relaxation amplitude of ultrasonic wave was calculated from the following equation where (f) is the frequency [5]:

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

The method of measuring the speed of ultrasound was by measuring the thickness of the sample and the time it takes inside the sample [6] :

$$v = x / t \quad \ldots\ldots\ldots (3)$$

Where (x) is the samples thickness measured by digital vernier; (t) is the time that the waves need to cross the samples. The acoustic impedance of a medium (Z) is a material property was calculated by this equation where (ρ) is the density [7] :

$$Z = \rho v \;\ldots\ldots\ldots\ldots\ldots\; (4)$$

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 [8] :

$$B = \rho v^2 \ldots\ldots\ldots\ldots\ldots (5)$$

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 [9] :

$$\beta = (\rho v^2)^{-1} \;\ldots\ldots\ldots\ldots\; (6)$$

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 [10,11] :

$$\eta_s = 3\ \alpha\ \rho\ v^3 / 8\ \pi^2\ f^2 \ldots (7)$$

The relaxation time (τ) was calculated from the equation [12] :

$$\tau = 4\ \eta_s / 3\rho\ v^2 \ldots\ldots\ldots\ldots (8)$$

3. Results and discussion:

Ultrasonic velocity for sample P_7 is increasing when adding ZnO and TiO_2 to porcelain as shown in Fig. 1. This attributed that adding ZnO and TiO_2 made hydrogen bonding attached to oxygen sites led to salvation the sheaths and increase the size of composite molecules, and fills the spaces between porcelain molecules in the lattice that responsible for increasing the velocity, and hence composite be good medium for transferring ultrasound waves.

The absorption coefficient is increasing at sample P_1 as shown in Fig. 2, since the sound velocity in this sample has lowest value with respect to other composites, this means that absorption coefficient must increasing, and attributed that the sample P_1 has low ZnO concentrations, this means there is no enough hydrogen bonding that reduces the stability and binding between lattice molecules. Since sound waves transfer as compression and rarefaction in the medium, so these molecules attenuated sound waves. The composite P_9 also has high absorption coefficient to ultrasound waves since its composed ZnO molecules that create some free rots in polymer chains that randomly coiled which made composite more flexible as a result of a week bonding between different molecules that vibrating through ultrasound waves and absorbing its energy .

Figure 4 shows that relaxation amplitude is increasing for sample P_9, since it has the higher absorption coefficient as shown previously so that the absorbed molecules take time to relax to their equilibrium positions. The specific acoustic impedance increasing at samples P_7 and P_8 which composed (ZnO and TiO_2) as shown in Fig. 5, since the concentrations of TiO_2 increasing in sample P_8 hence TiO_2 is responsible for increasing impedance and attributed that TiO_2 enhances the stability of the composite that impeding sound waves by binding the different types of the molecules and give entanglement interaction to the lattice. The compressibility of all samples are decreasing when adding different concentrations as shown in Fig. 7, since adding ZnO, TiO_2, ZrO_2 fills the spaces of a porcelain body (this behavior is expressed by variation of density as a function of additive ceramic as shown in Fig. 3) and made each molecule be close together then restrict the new lattice therefore good stability may obtained of this composite. Figure 9 shows the increasing of shier viscosity at samples P_7 and P_8, since these samples have high concentrations of ZnO and TiO_2 respectively, because viscosity related to concentration as described by Einstein.

4. Conclusions:

From the experimental results, it was conclude the following:

1- Adding 2%ZnO + 1% TiO_2 made composite good medium for transferring ultrasound waves. So they can be used as a coated material for objects that we don't want them to be detected by sonar

2- adding 1% ZrO_2 +2% TiO_2 enhances the absorption coefficient of porcelain and the composite becomes good absorber for ultrasound

3- Adding 2%ZrO_2 +2%TiO_2 made composite not good medium for transferring ultrasound waves

4- Adding 1%ZnO enhances the compressibility because it has the heights value and ZnO molecules fills the spaces of porcelain bodies.

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Table 1. The chemical composition of the raw materials involved in the formation of the porcelain body.

Oxide	kaolin wt%	Quartz wt%	Feldspar wt%
SiO_2	52.35	97.39	69.91
Al_2O_3	34.o2	0.38	15.7
Fe_2O_3	1.31	0.08	0.19
TiO_2	0.12	-	-
CaO	1.2	0.25	0.98
MgO	1.11	0.02	0.13
SO_3	0.45	-	-
Na_2O	-	0.18	3.25
K_2O	-	0.03	8.35
L.O.I	12.54	0.25	0.51

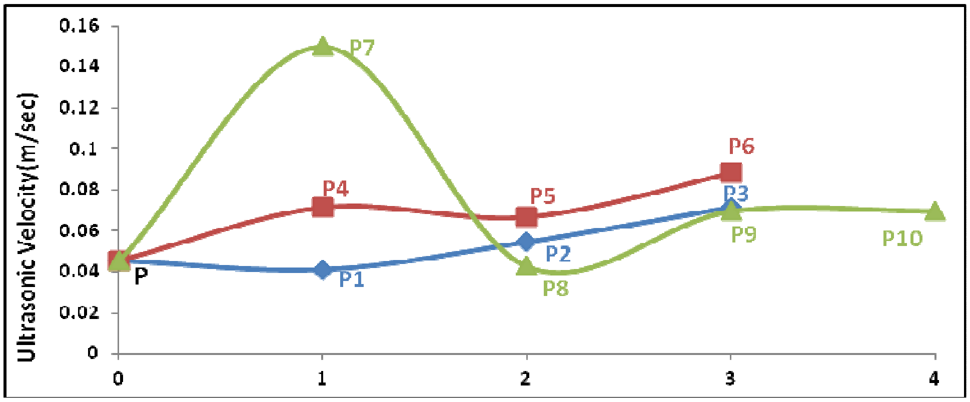

Figure 1. Plot of ultrasonic velocity as a function of additive ceramic (p1, p2, p3, p4, p5, p6, p7, p8, p9, p10).

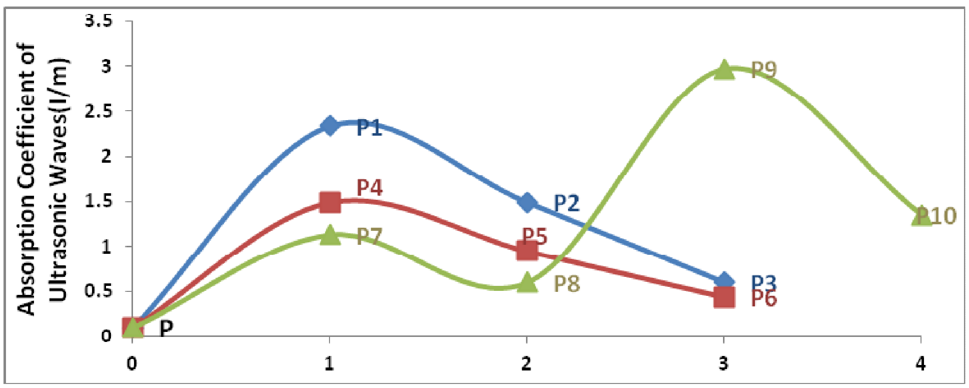

Figure 2. Plot of absorption coefficient as a function of additive ceramic (p1, p2, p3, p4, p5, p6, p7, p8, p9, p10).

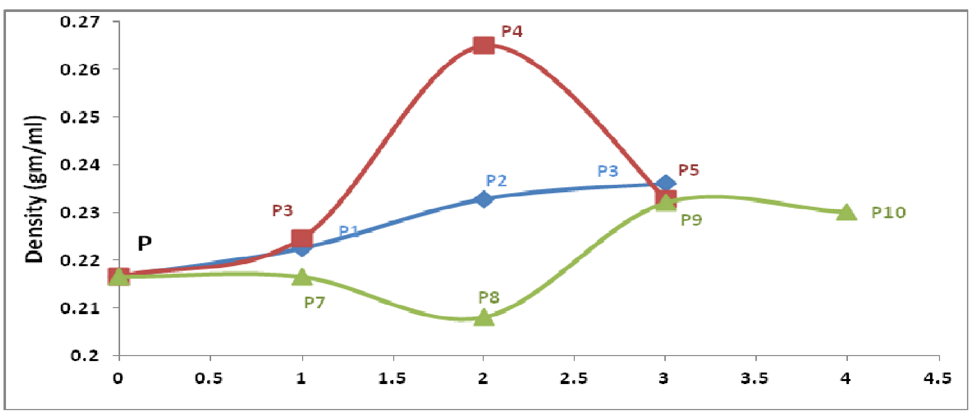

Figure 3. Plot of density as a function of additive ceramic

(p1, p2, p3, p4, p5, p6, p7, p8, p9, p10).

No. of additive ceramic	1	2	3	4
Type of additive ceramic	P1:(P+1%ZnO) P4:(P+2%ZnO) P7:(P+2%ZnO + 1% TiO_2)	P2:(P+1% ZrO_2) P5:(P+2 %ZrO_2) P8:(P+2%ZrO_2 +2%TiO_2)	P3:(P+1 %TiO_2) P6:(P+2 %TiO_2) P9:(P+2%TiO_2 +1%ZrO_2)	P10:(P+2%ZnO +2%ZrO_2)

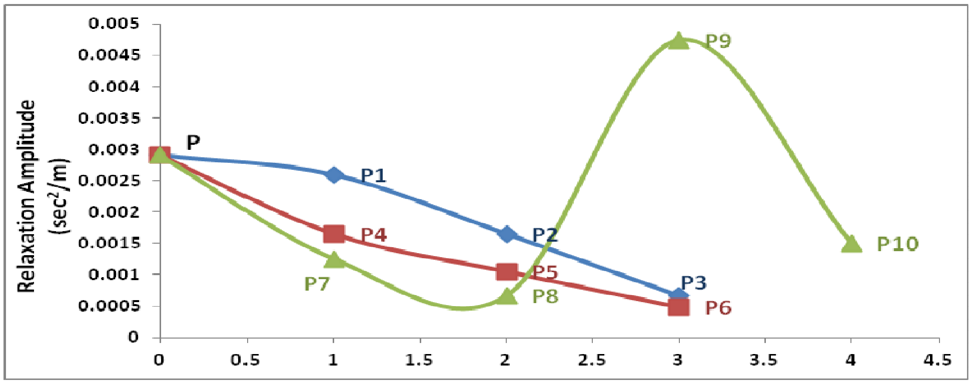

Figure 4. Plot of relaxation amplitude as a function of additive ceramic (p1, p2, p3, p4, p5, p6, p7, p8, p9, p10).

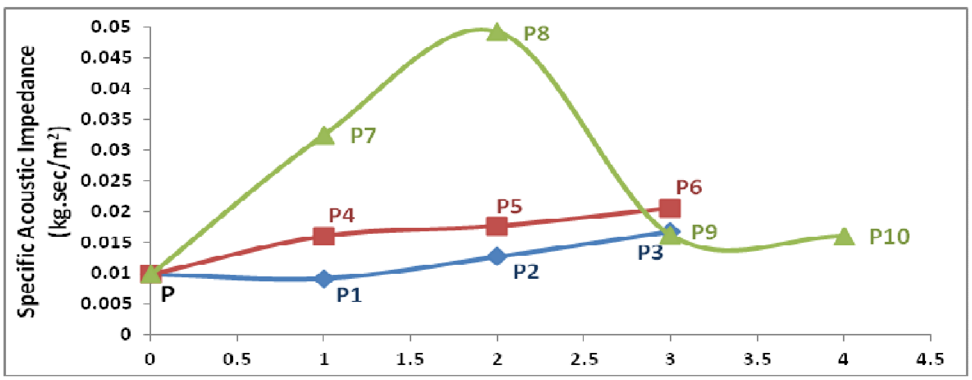

Figure 5. Plot of specific acoustic impedance as a function of additive ceramic (p1, p2, p3, p4, p5, p6, p7, p8, p9, p10).

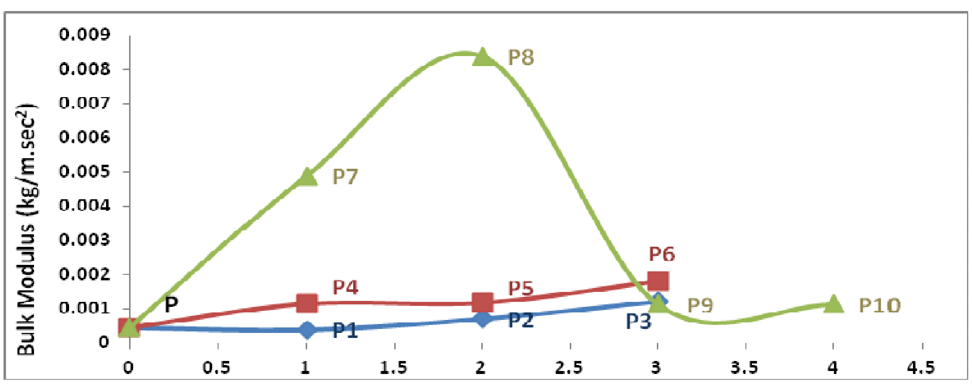

Figure 6. Plot of bulk modulus as a function of additive ceramic (p1, p2, p3, p4, p5, p6, p7, p8, p9, p10).

No. of additive ceramic	1	2	3	4
Type of additive ceramic	P1:(P+1%ZnO) P4:(P+2%ZnO) P7:(P+2%ZnO + 1% TiO2)	P2:(P+1% ZrO2) P5:(P+2 %ZrO2) P8:(P+2%ZrO2 +2%TiO2)	P3:(P+1 %TiO2) P6:(P+2 %TiO2) P9:(P+2%TiO2 +1%ZrO2)	P10:(P+2%ZnO +2%ZrO2)

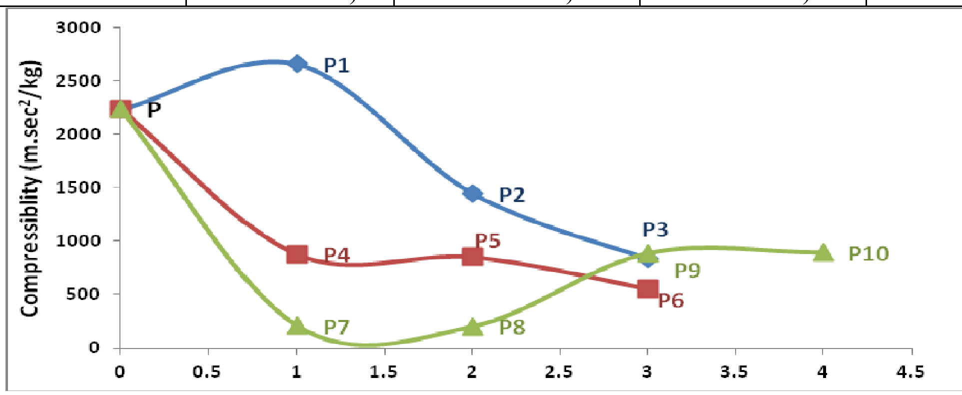

Figure 7. Plot of compressibility as a function of additive ceramic (p1, p2, p3, p4, p5, p6, p7, p8, p9, p10).

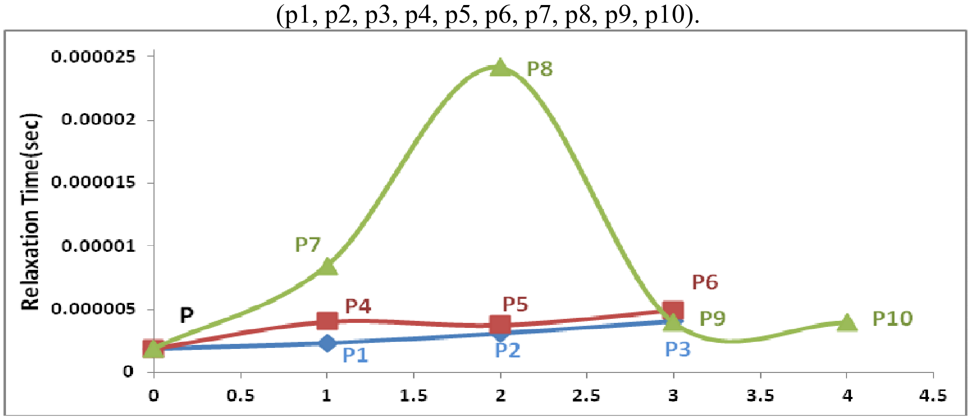

Figure 8. Plot of relaxation time as a function of additive ceramic (p1, p2, p3, p4, p5, p6, p7, p8, p9, p10).

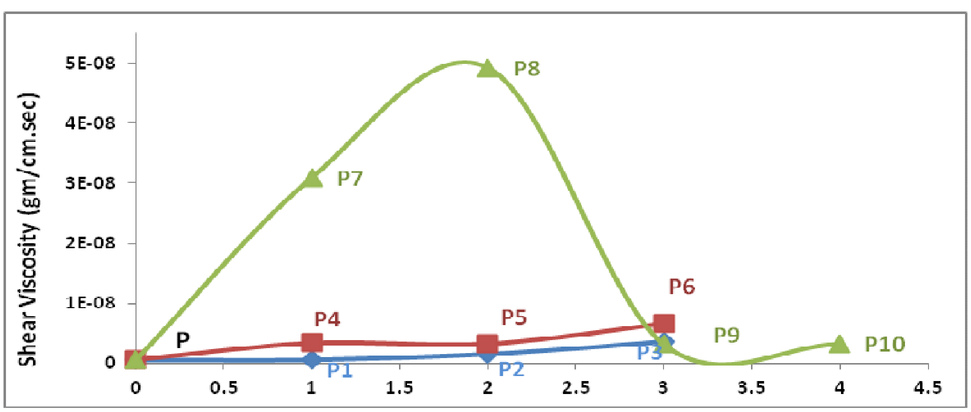

Figure 9. Plot of shear viscosity as a function of additive ceramic (p1, p2, p3, p4, p5, p6, p7, p8, p9, p10).

No. of additive ceramic	1	2	3	4
Type of additive ceramic	P1:(P+1%ZnO) P4:(P+2%ZnO) P7:(P+2%ZnO + 1% TiO2)	P2:(P+1% ZrO2) P5:(P+2 %ZrO2) P8:(P+2%ZrO2 +2%TiO2)	P3:(P+1 %TiO2) P6:(P+2 %TiO2) P9:(P+2%TiO2 +1%ZrO2)	P10:(P+2%ZnO +2%ZrO2)