Comparison of different Poly vinyl chloride (PVC) /Calcium Carbonate ($CaCO_3$) blends and their properties

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Received: 10 September 2021/ Revised: 18 September 2021/ Accepted: 24 September 2021/ Published: 30-09-2021

Abstract**—** *The effects of micro and nanoscale calcium carbonate ($CaCO_3$) particles on the mechanical properties of polyvinyl chloride (PVC) were investigated. Type of (PVC S5070) were used as the matrix in this study, hydrocarb 95T $CaCO_3$ as a micro size particles, and SOCAL 312 $CaCO_3$ as a nano size particles with different phr (0 wt%, 10 wt% and 20 wt%). The nano-$CaCO_3$ particles were observed by FT-IR spectras. Nano- $CaCO_3$ increased the tensile strength and affected the tensile strength of PVC more than micro-$CaCO_3$ particles. The raise in hardness shore (A) is more considerable in nano-$CaCO_3$ filled PVC compared to that of micro-$CaCO_3$. TSDC test investigated that nano-$CaCO_3$ in PVC samples have greater electrical resistance, and the maximum volume resistivity in micro-$CaCO_3$ in PVC samples which mixed by ultrasonic. Thermal characterization of PVC samples were tested by DMA. Storage modulus and loss factor (tan δ) examined and showed that the storage modulus of PVC decreased as a function of temperature. The storage modulus can be increased concurrently by the presence of $CaCO_3$. The glass transition of nano-$CaCO_3$ sample mixed by ultrasonic has higher glass transition than other samples which mixed by normal mixing.*

Keywords— Calcium carbonate, Polymer composites, PVC, Micro-$CaCO_3$, Nano-$CaCo_3$.

I. INTRODUCTION

Poly (vinyl chloride) as well known as PVC is one of the most using polymers around the world because of being in low cost [1-4], durability [5-7], flexibility [8-10]. However, they need to enhance their mechanical properties [11-13] such as toughness, morphological, thermal, and processing properties to work properly in widely and different range fields [14-17]. The mechanical properties of blends change as per various fillers [18]. Much improvement of the poorer properties of PVC has been carried out by the combination of additives such as plasticizers [19-20], antioxidant [21], and flame-retardant fillers [22-24] higher thermal stability [25] copolymerization, fillers and heat stabilizers with other monomers. Calcium carbonate ($CaCO_3$) nanoparticles are one of the viable nanofillers that enhance the thermo-mechanical properties of the polymer matrix composites [26-28].

PVC is the most common used to produce pipes, windows, entryways, and others in the development business [29-34]. The utilization of nanoparticles of calcium carbonate, not just improves the relentlessness, but also enhances electrical properties, heat opposition, radiation obstruction and different properties [35-39], yet in addition lessens the expense of the mixes [40-43], also in medical uses PVC have roles [44-48]. The mechanical properties of $CaCO_3$ microstructural additive on PVC are totally dependent on the interaction between the fillers [49-51], the polymeric matrix and the filling ratio, and the surface attributes [52-56].

The effects of the loads on the microstructure and on the properties of the PVC compounds are depending on the magnitude size and shape of the particle, combined size, surface treatment of the polymer and $CaCO_3$ filler. Therefore, by adding some low-cost additives to the PVC to develop it and create new formulation, it will be more affective and widely uses in more ways and application [57-59]. So as to acquire higher been utilized to treat nano $CaCO_3$ particles to improve the interfacial bond between the PVC lattice and the nano $CaCO_3$ molecule. The most regularly utilized adjusting operators to treat nano $CaCO_3$ molecule are stearate and titanate coupling specialists, and the last is noted to have a higher hardening and strengthening impact [60].

It is notable that calcium carbonate ($CaCO_3$) is a characteristic happening and bountiful mineral involving around 4% of earth crust [61-63]. Lately, many tests and exams have been committed to the calcium carbonate particles [64-67]. By adding some amount of calcium carbonate, tensile strength and impact strength will be improved [68-70]. $CaCO_3$ can be created by different ways, including precipitation, dry grinding, and wet grinding, and essential evaluations of $CaCO_3$ can be separated by size of particles, surface area and morphology [71-74].

In this research different amounts and percentages of the calcium carbonate ($CaCO_3$) and DIDP plasticizer added to the PVC blends to make samples, and studying the mechanical behavior for the samples. The samples made in Borsod-Chem at Miskolc-Hungary. The samples going through some tests and measurement. First of all, hardness mechanical test (shore A), then tensile strength test to know mechanical properties of new PVC including (elongation at break, tensile stress, tensile strain, and young modulus), electrical property by TSDC electrical test, FT-IR spectroscopy, then thermal characterization test by (DMA). After all measuring, the results will be comparing with the previously works of literatures. The aim of project is to investigate the new PVC composites with a better mechanical property for further application.

II. MATERIALS AND METHODS

2.1 Applied Materials

2.1.1 Type of: PVC S5070:

$(C_2H_3Cl)n$ with a melting range between 140°C to 200°C. The glass transition temperature is between 75°C to 85 °C and flow temperature is 140°C.

2.1.2 Plasticizer: DIDP

Diisodecyl phthalate (DIDP: increase flexibility of plastic and workability.

2.1.3 Heat Stabilizer ADVASTAB TM181

Advastab TM181 is performances as a heat stabilizer.

2.1.4 WAX E

Wax E is a classified class of natural mixtures: softening.

2.1.5 Hydrocarb 95T $CaCO_3$

Micro sized calcium carbonate which is extremely fine, size between 0.7 -100 µm.

2.1.6 SOCAL 312 $CaCO_3$

Ultrafine calcium carbonate is near to nano size. The particle size is below 0.01 µm. 3.2 Preparation of Samples.

The detail of all PVC samples shown in Table.1

TABLE 1
PVC SAMPLES WITH DIFFERENT AMOUNTS OF FILLERS AND MIXING. $CaCO_3$ (1) IS MICRO SIZED PARTICLE OF CALCIUM CARBONATE, $CaCO_3$ (2) IS NANO PARTICLE SIZED OF CALCIUM CARBONATE

Material /Sgn	ST0	ST1-10	ST1-10U	ST2-10	ST2-10U	ST1-20	ST1-20U	ST2-20	ST2-20U
PVC S5070	100	100	100	100	100	100	100	100	100
DIDP	50	50	50	50	50	50	50	50	50
Advastab-TM181	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Wax E	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
$CaCO_3$ (1)		10	10UH			20	20UH		
$CaCO_3$ (2)				10	10UH			20	20UH

2.2 Characterizations and Experimental Part

2.2.1 Fourier Transformation Infrared Spectrometry (FTIR)

Fourier-Transformation-Infrared spectroscopy (FTIR) is a scientific system used to checking the surface of PVC, and the comprehend the design of individual particles and the structure of molecular combinations. The machine was used for testing the samples for the FT-IR test was BRUKER TENSOR27 in the Institute of Ceramic and Polymer Engineering. The software that was used in computer for reading and analyzing the measurement data from the machine is called OPUS. First of all, the plate cleaned by ethyl-alcohol (Ethanol, C_2H_5OH) to make waves more accurately, also the sample should be cleaned before the testing. Then putting the sample on the plate and fix it under 65 scans measurements and wait until the data and result will be import to the computer, and repeating the same procedure for all the samples.

2.2.2 Tensile Properties Test

Tensile strength test was carried out on testing machine INSTRON 5566 speed of 100 mm/min. and room temperature 20°C as shown in figure 6. All of samples were cut and divided to 3 parallel measurements with size (length: 60 mm, thickness:2 mm, and width:10 mm) for each sample as shown in figure 7. In tensile test four measurements will be study which is the stress, strain, elongation at break and young modulus.

2.2.3 Hardness Test- Shore (A)

The shore A hardness of the PVC samples was measured using a machine named by Zwick Roell (type: H04.3150) as shown in figure 8. The indenter was pressed with sufficient band force for 5 seconds into the plastic specimen vertically with room temperature 20°C, and repeated the same procedure for each sample 10 times, each time in different point on the surface of sample as shown in figure 9. The results recorded and the average of hardness and standard deviation will be calculating. The shore (A) hardness scale measures the hardness of flexible mold rubbers that scope in hardness from very soft and flexible, toward medium and rather flexible, and toward hard with almost no flexibility at all.

2.2.4 TSDC Electrical Properties Test

PVC samples will examine under electrical direct current. In terms of their electrical properties, specific volume resistivity (ρ) will be measure with standard (IEC 93) for each PVC sample. Direct current (DC) is electrical current which flows consistently in one direction. The current that flows in a flashlight or another appliance running on batteries is direct current. Selecting DC voltage on the multimeter will be (voltage Um=500V) and electrode area ($A=44.15cm^2$). Thermal stimulated depolarization current (TSDC) is use to define the varying rules of charge distribution within insulation structure when it reaches the thermal equilibrium state and the specific parameters [112].

2.2.5 Thermal Characterization Test: Dynamic Mechanical Analysis (DMA)

Dynamic mechanical analysis (DMA) is a method for characterizing thermal behavior of PVC samples as a function of temperature, time, frequency, stress, atmosphere or an arrangement of these limits [74]. DMA measures stiffness and damping, these are reported as storage modulus and loss factor (tan δ) [26,40,43], and also describe the relaxation behavior of the PVC [4,6,22,44,53,69,72]. The DMA tests were measured by (Metravib 1Db DMA 25) machine. Tension and compression over a temperature range (-60 °C to 120°C) with heating rate of 2°C per minute at frequency 10Hz. The dimensions of PVC samples for DMA test are (length: 15 mm, width 12 mm, and thickness 1.2 mm).

III. RESULTS AND DISCUSSIONS

3.1 FT-IR Test Results and Discussion

FTIR procedures usually look at the PVC resin carbon- chlorine bond and plasticizer groups. The results of FT-IR spectras for all the samples was shown in Fig.1.

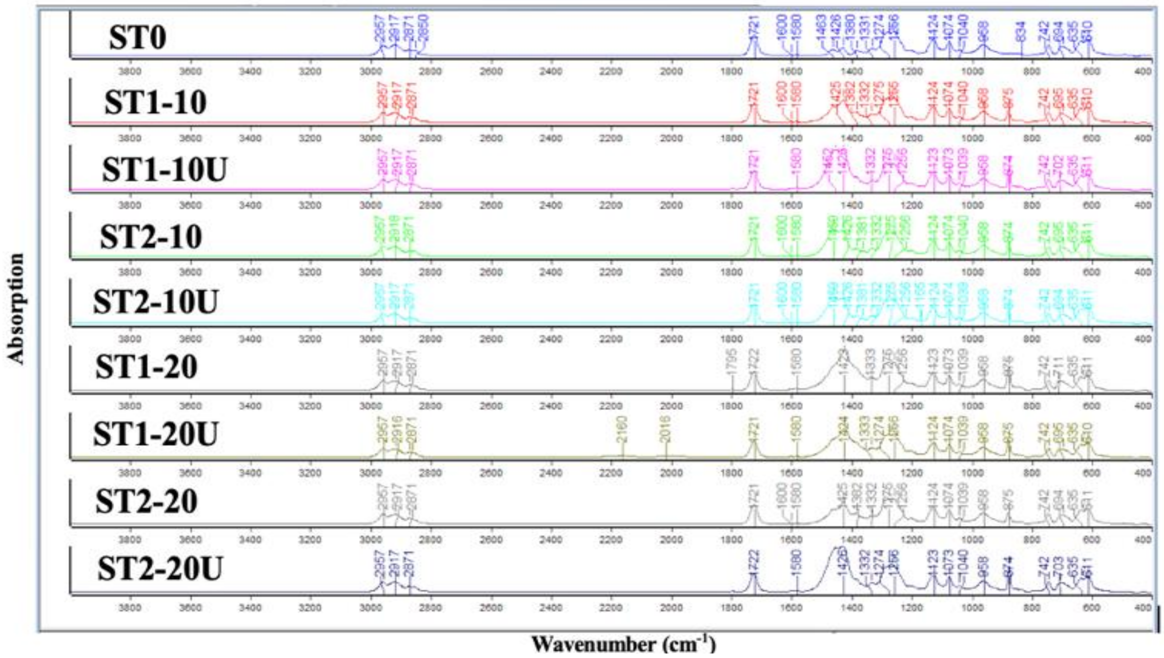

FIGURE 1: FT-IR spectras result for PVC samples.

FT-IR spectra of the plasticizers and the PVC samples were acquired. The main absorption bands in the infrared are shown in Table 2. Each sample can be obverse the peaks of 2957 cm^{-1} which is related to CH_3 stretching and at the peaks of 2916-1918 cm^{-1} can be observe the CH_2 stretching which is a behavior of PVC polymer [80,84,101,102,104]. CH_2 angular deformation mode at 1331-1333 cm^{-1} [101,102], and C-Cl stretching mode at 834-610 cm^{-1} [84, 96, 101-104]. The difference between the pure PVC which is sample (ST0) and sample (ST2-20U) can be seen from the FT-IR spectra that the sample (ST2-20U) is more sensitive comparing to the pure PVC (ST0), and the ST2-20U sample is extra homogenous and the plasticizer on the surface is not obvious, but its inside sample everywhere and well mixed, that is make it the best one among all of the samples.

TABLE 2
MAIN INFRARED ABSORPTION BONDS OF THE PLASTICIZERS AND PVC

Wavenumber (cm^{-1})	Assignment	References
2957	Asymmetric Stretching CH_3	84,101,102,104
2916-2918	Stretching CH_2	101,102,104
2871	Symmetric stretching CH_3	102
2850	CH_2 Symmetric stretching	102,104
1795	C=O stretching	103,80
1721-1722	C=O stretching	102,80
1580-1600	C=C aromatic stretching	102
1423-1463	Deformation (Wagg), CH_2-Cl	101,104
1380-1382	CH_3 Symmetric angular	102
1331-1333	CH_2 Angular deformation	101,102
1255-1275	Cl-CH Out of plane angular deformation	102,104
1123-1124	C-H aromatic	102
1039-1074	Rocking, CH_2	101,104
958	C-H or C-C aromatic	102
874-875	Stretching, C-Cl	84,103
834	Chain stretching	102,104
694-610	Stretching, C-Cl	96,101,102,104

3.2 Tensile Properties Test Results and Discussion

3.2.1 Tensile Stress and Strain Results

It can be ascertained from the figure 2 that the tensile strength is maximum at (13.71 MPa) in sample named (ST2-10U) which is contain 10 wt% of nano- $CaCO_3$ particle, by ultrasonic mixing, the results of tensile stress is shown in Fig.2.

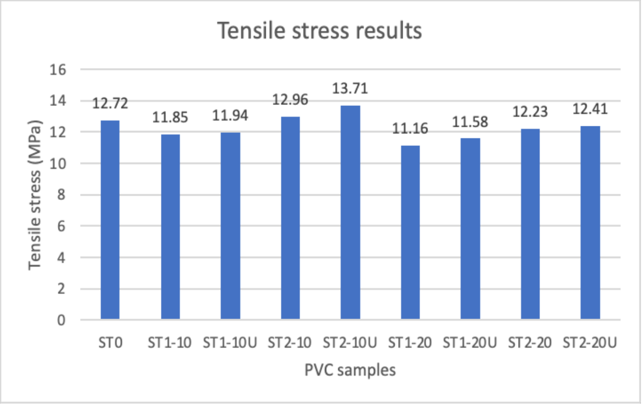

FIGURE 2. Tensile stress results

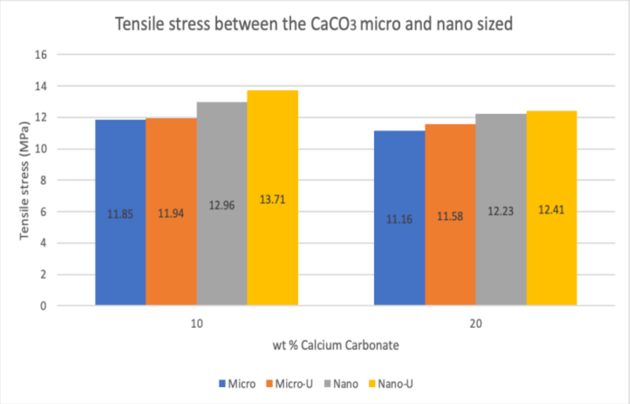

FIGURE 3. Comparing tensile strength between the $CaCO_3$ micro and nano sized particles

The reason behind increasing the tensile strength in the nano particle of $CaCO_3$ as shown in Fig.3 is that nano particles have excellent mechanical properties and unique properties that are not found in micro particle and nanocomposite products contain reinforcing or fillers in nanoscale. Most of the mechanical properties can be enhanced using nano scale particles this might be ascribed to the incredible similarity between nano $CaCO_3$ and PVC matrix.

The result of tensile strain is shown in Fig.4, the highest tensile strain is (428.33) which can be seen in two samples (ST2-10U and ST2-20U).

The results showed that the tensile strain of nano particle of $CaCO_3$ is higher than micro sized particle of $CaCO_{3.}$

Nano particle of calcium carbonate affected and increasing in tensile strain of the PVC more than the micro particles. The results of growth could be recognized to the huge boundary area between nano-sized particles and matrix.

3.2.2 Elongation at Break Results and Discussion

The maximum elongation is (6.97) which can be seen in sample (ST2-10U) which contain 10 wt % nano particles of $CaCO_{3.}$ Elongation at break initially increases and then decreases quickly when the quantity of $CaCO_3$ amount is greater than 10 wt % as shown in Fig.5. Comparing the PVC samples contain micro size of $CaCO_3$ particles to pure PVC, the pure PVC has higher elongation which increases in homogeneity and reduces the elongation

The nano particle affects more in raising the elongation at break of the PVC sample PVC samples filled nano particle of $CaCO_3$ have higher elongation than micro.

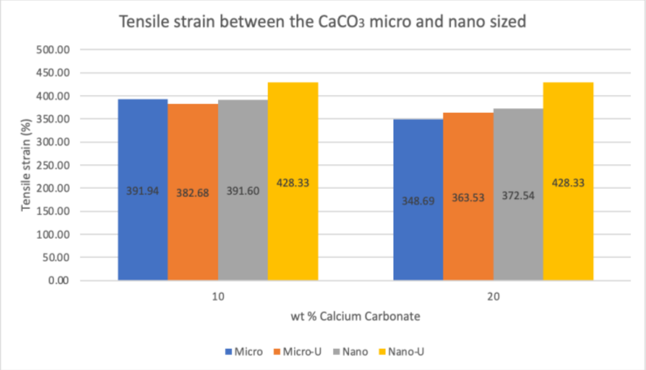

FIGURE 4. Tensile strain results

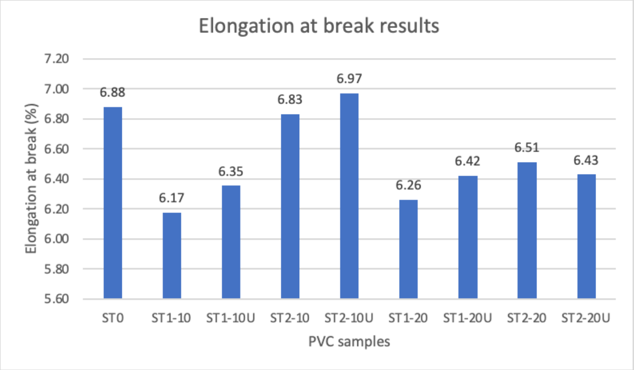

FIGURE 5. Elongation at break results

3.2.3 Young Modulus Results and Discussion

The results showed that young modulus increase by increasing the amount of $CaCO_3$ as shown in Fig.6 and it reached the highest value in 10 wt % of $CaCO_3$, but above 10 wt % young modulus gradually decreasing. Comparing the micro to nano $CaCO_3$ particle in PVC samples, the results showed that using nano sized particles of $CaCO_3$ in PVC sample have more positive affect than micro sized $CaCO_3$ particles.

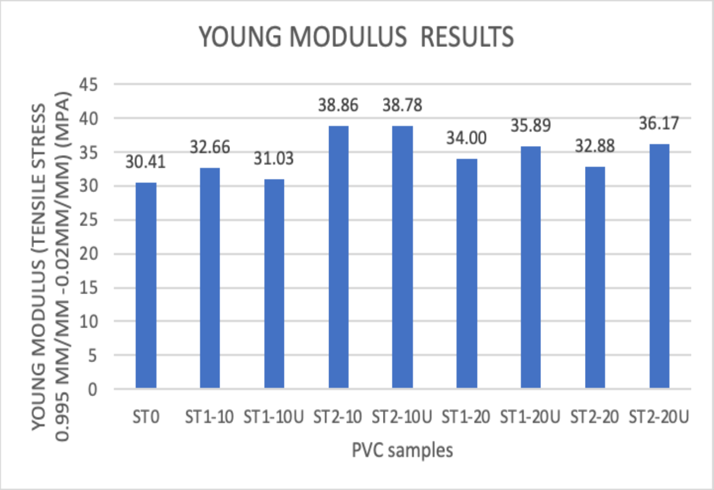

FIGURE 6: Young modulus Results

3.3 Hardness (Shore A) Results and Discussion

The highest value is (93.52 °Sh) for sample (ST2-10U) which contain 10 wt % nano particles of $CaCO_3$. The results showed in Fig.7. PVC samples have great resistance to indentation and they are hard materials. The raise in hardness is more considerable in nano $CaCO_3$ filled PVC compared to that of micro $CaCO_3$. The way of mixing also affected the raise of hardness, obviously the PVC samples with ultrasonic mixing results are much higher than the normal mixing of PVC sample.

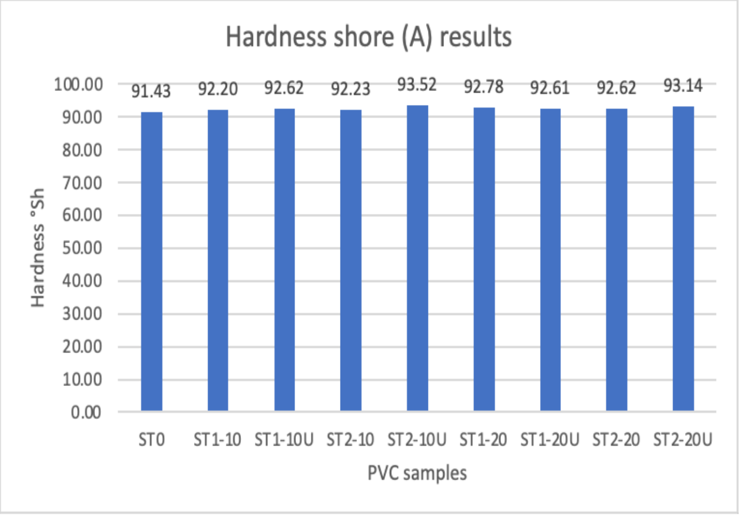

FIGURE 7: Hardness (shore A) results

3.4 TSDC Electrical Test Results and Discussion

The smallest electrical resistance: (ST1-10U) which is (0.9 MΩ), highest electrical resistance: (ST2-20U) which is (6.1 MΩ). The maximum volume resistivity : (ST1-10U) with value (3.34×10^{12} Ωcm) which is a PVC refilled with micro particles of $CaCO_3$ ultrasonic mixed as showed in Fig. 8 and Fig. 9. The specific volume resistivity in PVC micro sized $CaCO_3$ normal mixing is reducing by increasing the amount of $CaCO_3$ to 10 wt %, and slowly increase in 20 wt%. The specific volume resistivity in PVC micro sized $CaCO_3$ ultrasonic mixing is rapidly growth by increasing the amount of $CaCO_3$ to 10 wt %, and slowly decrease in 20 wt%. The PVC with nano $CaCO_3$ particles showed improvement in insulation resistance when compared to unmodified PVC.

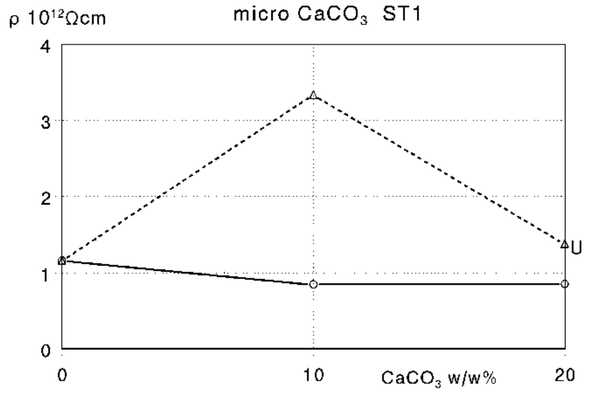

FIGURE 8. Result of electrical resistance and specific volume resistivity of micro sized $CaCO_3$ filled in PVC

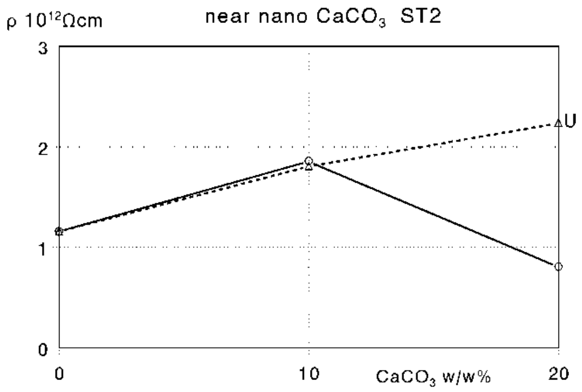

FIGURE 9. Result of electrical resistance and specific volume resistivity of nano sized $CaCO_3$ filled in PVC

IV. RESULTS AND DISCUSSION

4.1 Thermal Characterization Test (DMA)

The storage modulus of PVC decreased as a function of temperature that indicated that samples became in the rubber mood by increasing temperature. The storage modulus can be increased concurrently by the presence of $CaCO_3$ as showed in Fig. 10 and Fig.11.

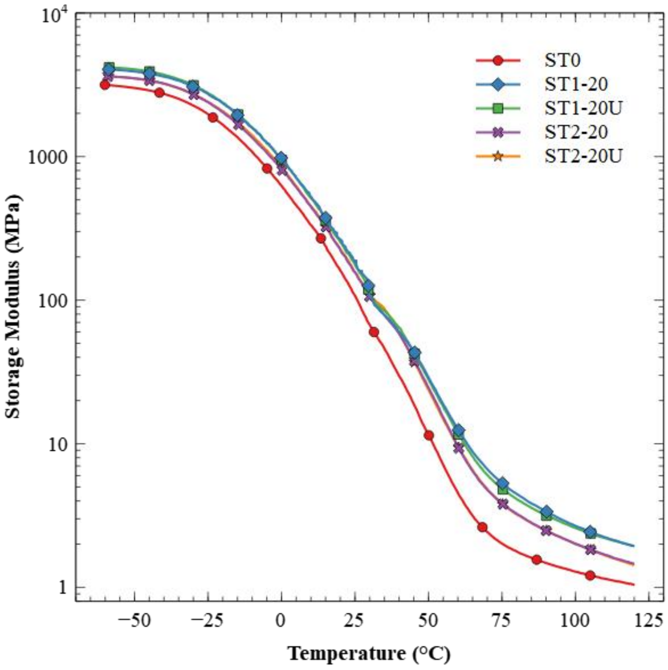

FIGURE 10. Dynamic storage modulus results for PVC samples

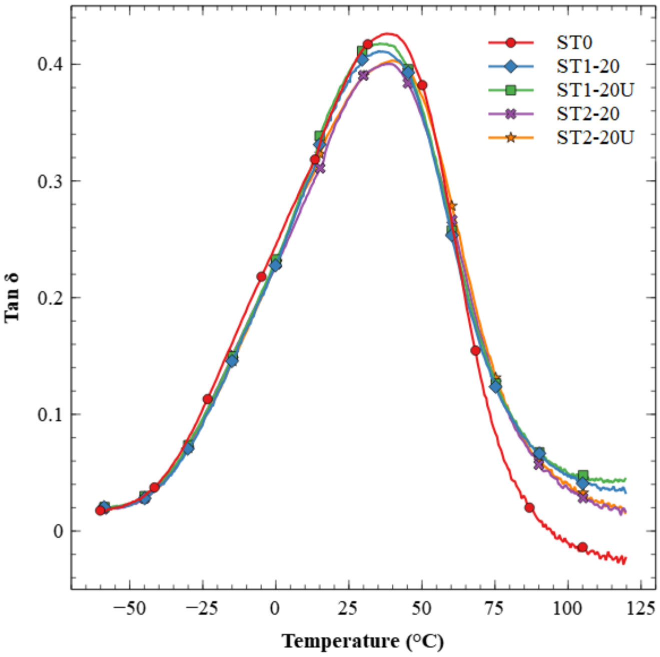

FIGURE 11. Loss factor (tan δ) results for PVC samples

The storage modulus of PVC decreased as a function of temperature that indicated that samples became in the rubber mood by increasing temperature [69]. The pure PVC (ST0) has storage modulus (3164.18 MPa) at temperature (-60 °C) which is lowest storage modulus comparing to other PVC samples at temperature (-60 °C). The highest storage modulus is in samples (ST1-20U) which it has (4180.93 MPa) at temperature (-60 °C) and (1.95 MPa) at temperature (120 °C). The storage modulus can be increased concurrently by the presence of $CaCO_3$ [78,91]. Loss factor (tan δ) of PVC samples is shown in Table 2. The glass transition of pure PVC is 37.9 °C and it is higher than comparing to the PVC micro- $CaCO_3$, but lower than nano-$CaCO_3$ samples.

TABLE 3
GLASS TRANSITION TEMPERATURE OF PVC SAMPLES

PVC samples	Glass transition temperature (T_g) (°C)
ST0	37.9
ST1-20	35.2
ST1-20U	35.5
ST2-20	38.7
ST2-20U	39.7

Comparing the glass transition temperature between micro-$CaCO_3$ and nano-$CaCO_3$ samples, it is obviously increased in nano-$CaCO_3$ [91,95,98,100], and the way of mixing affected the glass transition because the samples which mixed by ultrasonic has higher glass transition than those samples which mixed by normal mixing. It can be found that the stability properties of nano-$CaCO_3$ are better than that of the pure PVC resin. [97]. The DMA results are shown that loss factor (tan δ) of PVC/nano-$CaCO_3$ composites were higher than those of PVC, and all these indicate that the interfacial interaction between PVC and nano-$CaCO_3$ particles can be improved by modification of nano-$CaCO_3$ particles surfaces [98].

V. SUMMARY

PVC samples prepared for this research with micro and nano size of calcium carbonate particle with different phr (0 wt%, 10 wt% and 20 wt%), and different type of mixing. DIDP used as plasticizer added to PVC samples by 50 phr, which applied in the creation of plastic and covering to improve flexibility of plastic, and (Advastab TM181) added to PVC samples by 1.2 phr, which used for gives generally excellent long-haul tones and colors, and impact strength maintenance, and (wax E) added to PVC samples by 0.4 phr for softening to give low consistency of PVC. Roll-milling mixes were obtained utilizing a blender at 165°C for 5 minutes in a rotational speed. The obtained samples were shaped as 2-mm-thick sheets, and different ratio of each plasticizer and two type of mixing which is ultrasonic mixing and normal mixing. The ultrasonic electronic generator switches AC line power to a 20 kHz signal that powers a piezoelectric convertor/transducer.

The PVC samples were examined by FT-IR spectra considering appearance of the PVC resin carbon- chlorine bond and plasticizer groups of the plasticizers to study about the surface of the samples. The main absorption bands in the infrared were acquired. All samples observed the peaks of 2957 cm^{-1} which is related to CH_3 stretching and at the peaks of 2916-1918 cm^{-1} can be observe the CH_2 stretching which is a behavior of PVC polymer, and CH_2 Angular deformation mode at 1331-1333 cm^{-1}.Also C-Cl stretching mode at 834-610 cm^{-1} . The sample (ST2-20U) which contained 20 wt % nano particles of $CaCO_3$ with ultrasonic mixing acquired that it is extra homogenous and the plasticizer on the surface is not obvious, but its inside sample everywhere and well mixed, that is make it the best one among all of the samples.

The PVC samples were examined by tensile stress which measured the strength of a material, in this manner, it alludes to a power that endeavors to pull separated or stretch a material. The tensile strength measured highest in the sample (ST2-10U) which is 10 wt % of nano particle of $CaCO_3$ with ultrasonic mixing, and greater than any other compositions with value of (13.71 MPa). By increasing the amount of $CaCO_3$ above 10 % to 20 %, tensile stress decreased. The highest tensile strain is (428.33) which can be seen in two samples (ST2-10U and ST2-20U) which both of them contain nano particles of $CaCO_3$ ultra sonic mixed with 10 wt % and 20 wt %. The results showed that by increasing the amount of nano-$CaCO_3$ from 10 % to 20 %, does not affect the strain of the PVC and stay constant. Nano particle of calcium carbonate affected and increasing in tensile strain of the PVC more than the micro particles. The results of growth could be recognized to the huge boundary area between nano-sized particles and matrix.

The results showed that the tensile strain of nano particle of $CaCO_3$ is higher than micro sized particle of $CaCO_3$.

The maximum elongation was (6.97) which can be seen in sample (ST2-10U) which contain 10 wt % nano particles of $CaCO_3$, elongation at break initially increases until when the amount of $CaCO_3$ reach 10 wt %, and then decreases rapidly when the amount of $CaCO_3$ is greater than 10 wt %. Comparing the PVC samples contain micro size of $CaCO_3$ particles to pure PVC, the pure PVC has higher Elongation. The result showed that PVC samples filled nano particle of $CaCO_3$ have higher elongation than micro size of $CaCO_3$.

Young modulus examined and the results showed that young modulus increase by increasing the amount of $CaCO_3$ and it reached the highest value in 10 wt % of $CaCO_3$, but above 10 wt % Young modulus gradually decreasing. The results showed that using nano sized particles of $CaCO_3$ in PVC sample have more positive affect than micro sized $CaCO_3$ particles.

Hardness test examined and according to the results, the highest value in sample (ST2-10U) which is (93.52 °Sh) which contain 10 wt % nano particles of $CaCO_3$, and the lowest value is (91.43°Sh) for sample (ST0) which is pure PVC without $CaCO_3$ particles. The results showed that PVC samples have great resistance to indentation and they are hard materials. The raise in hardness is more considerable in nano $CaCO_3$ filled PVC compared to that of micro $CaCO_3$. The results showed that $CaCO_3$ affected the hardness of PVC and raise it respectively. The way of mixing also affected the raise of hardness, obviously the PVC samples with ultrasonic mixing results are much higher than the normal mixing of PVC sample.

The lowest value of standard deviation can be seen in sample (ST0) which is 0.11, and the highest value of standard deviation can be seen in sample (ST1-10) which is 0.45 as shown in figure 26. After that the standard deviation reduced in sample (ST1-10U) to 0.27. Then the value growth in sample (ST2-10) which is 0.31. The standard deviation decreases in sample (ST2-10U) to 0.23, then increase respectively in sample (ST1-20) to 0.24 and rise again sample (ST1-20U) to 0.29. After that it decreased in sample (ST2-20) to 0.19. Finally, in the last sample (ST2-20U) it increased to 0.28.

PVC samples examined with TSDC, electrical properties of them detected. In terms of their electrical properties, specific volume resistivity (ρ) with standard (IEC 93).The sample (ST1-10U) has the smallest electrical resistance which is (0.9 MΩ) and sample (ST2-20U) has the largest electrical resistance which is (6.1 MΩ). The PVC with nano $CaCO_3$ particles showed improvement in insulation resistance when compared to unmodified PVC. The maximum volume resistivity can be seen in sample (ST1-10U) with value (3.34×10^{12} Ωcm) which is a PVC refilled with micro particles of $CaCO_3$ Ultrasonic mixed. The specific volume resistivity in PVC micro sized $CaCO_3$ normal mixing is reducing by increasing the amount of $CaCO_3$ to 10 wt %, and slowly increase in 20 wt%. The specific volume resistivity in PVC micro sized $CaCO_3$ ultrasonic mixing is rapidly growth by increasing the amount of $CaCO_3$ to 10 wt %, and slowly decrease in 20 wt%. In contrast, the specific volume resistivity in PVC nano sized $CaCO_3$ normal mixing is growth by increasing the amount of $CaCO_3$ to 10 wt %, and rapidly decrease in 20 wt%. The specific volume resistivity in PVC nano sized $CaCO_3$ ultrasonic mixing is rapidly growth by increasing the amount of $CaCO_3$ to 10 wt %, and continue rising in 20 wt%.

Thermal characterization of PVC samples examined by DMA. Storage modulus and loss factor (tan δ) of PVC decreased as a function of temperature, that indicated that samples became in the rubber mood by increasing temperature. The storage modulus can be increased concurrently by the presence of $CaCO_3$. The glass transition of pure PVC is higher than PVC micro- $CaCO_3$, but lower than PVC nano-$CaCO_3$ samples. The way of mixing affected the glass transition because the samples which mixed by ultrasonic has higher glass transition than those samples which mixed by normal mixing. It can be found that the stability properties of nano-$CaCO_3$ are better than that of the pure PVC resin. Future work will be checking the thermal properties such as heat stability and flame retardancy, and colorization of the PVC samples.

In the PVC compounding industry the fillers are usually added in the high speed mixer. The general problem is the agglomeration of the filler particles. The lower is the particle size the higher is the danger of agglomeration. Therefore the advantages of the low particle size cannot be utilized. Nowadays the ultrasonic mixing is easily accessible even in industrial size therefore I tried to compare the mixing methods.

The mixing ratio is a question of application; it is decided at creating basic formulation. I have found that the ultrasonic mixing produces considerably better dispersion, by these way better properties. The limit of ultrasonic mixing is the filler/fluid ratio. The electrical industry, namely cable insulating materials, is the industrial sector where ultrasonic mixing is advantageous.

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