PVC COMPOUNDING: PREPARATION, PHYSICAL AND MECHANICAL PROPERTIES

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Abstract - Compounding of PVC representsan important class of engineering materials that havebeen intensively developed in recent decades. Theincorporation of different additives such as fillers, plasticizers, and stabilizers, into thermoplastics has beenwidely practiced in industry to extend them and toimprove their properties. Among these improvedproperties are mechanical characteristics, dimensionstability, permeability, processability, thermal stabilityand flame-retardant enhancements, as well as costreduction with respect to the bulk polymers. In the present study, compounding of Polyvinylchloride (PVC) with some additives is studied for the enhancement of physical and mechanical properties. Composites of poly(vinyl chloride) (PVC) is blended with different fillers, stabilizers , plasticizers and lubricant such as: calcium carbonate as a filler and stearic acid as a lubricant, tribasic lead sulfate as a stabilizer and Di-octyl phthalate (DOP) as a plasticizer, and the effect of compounding on the physical and mechanical properties of polyvinylchloride (PVC) is studied.The experimental work is conducted in a batch mixer at a temperature of 120º C for half an hour with continuous stirring for both rigid and soft PVC. In case of rigid PVC, the filler content ranged from 10- 20% by weight of sample, tribasic lead sulfate (2.2 wt%) and lubricant (stearic acid 0.5 wt%) and no plasticizer is added in the sample . In case of soft PVC, no filler is added, plasticizer ranged 60- 90%,by weight of sample, tribasic lead sulfate stabilizer (3 wt%) and lubricant (stearic acid 0.5 wt%). In case of rigid PVC, experimental results show that tensile stress increased with increasing filler content and reached maximum value of (531 kg/cm2) at12 % weight of CaCO3 filler. Yield stress increased with increasing filler content and reached maximum value of (521 kg/cm2) at 12 % weight of CaCO3 filler. On the other hand, the Izod Impact decreases with increasing filler content. % Elongation at break increased with increasing filler content and reached maximumvalue of (200 %) at 12 % weight of CaCO3 filler.Relative density of rigid PVC is directly proportional with % weight of filler. In case of soft PVC, experimental results show that tensile stress is directly proportional with plasticizer content and the optimum % plasticizer is 70 %. Relative density of soft PVC is directly proportional with % weight of plasticizer and the optimum % plasticizer is 70 %.% Elongation at break increased with increasing plasticizer content and reached maximum value of (380 %) at 70 % weight of plasticizer and then decreased. Hardness (shore A) is directly proportional with plasticizer content.

Key words - PVC, compounding, fillers, plasticizers,stabilizers,lubricant, physical properties, mechanical properties.

I. INTRODUCTION

Polyvinyl chloride, more commonly known as PVC, is a building block of various products, suchas electronic items, constructional materials, stationeries, chemical equipment, wires, cables etc. It is one of the major thermoplastics used today and produced in a huge amount worldwide [1, 2]. Presently there are 50 different basic types of plastics, included in 60,000 different plastics formulations. Those based on polyolefins and polyvinyl chloride, have highest utilization worldwide [3]. PVC is thermoplastic and due to its low thermal stability the use of PVC polymer is limited in industry. Several attempts have been made to enhance the thermal stability and mechanical properties of PVC in recent years [4-5]. Unmodified PVC polymer is a brittle, inflexible material with rather limited commercial possibilities. The processing of PVC in the raw form using heat and pressure resulted in severe degradation of the polymer. The utilization of PVC is based on the compounding(addition of additives with base polymer) of PVC all over the world. The method of preparing typical recipe for the compounding is known as Formulation. With the addition of additives like plasticizers, heat stabilizers, lubricants, fillers and copolymerization with other monomers, the poor properties of PVC can be improved [6-7]. Commercially, compounding PVC contains sufficient modifying components to the raw polymer to produce a homogeneous mixture suitable for processing and requiring performance at the lowest possible price [8]. The proper compounding and processing PVC resin using suitable additives produces a complex material whose behavior and properties are quite different from the PVC resin by itself [9-10]. The selection of particular additive is dependent on the end use of the PVC product like PVC-resin is not plasticized for the use in making rigid products such as water pipe, plumbing fittings, and phonograph records. For use in making piping or structural panels that require high resistance to impact, polyvinyl chloride often is blended with small proportions of rubbery synthetic polymers. The modification of rigid poly (vinyl chloride) (PVC) having relatively low toughness carried out by incorporation of a rubbery phase [11]. Various nanoscale fillers, including clay, silica, calcium carbonate ($CaCO_3$), and aluminum oxide, have been reported to enhance the mechanical and thermal properties of polymers, such as the toughness, stiffness, and heat resistance. The addition of $CaCO_3$ to PVC has been reported to improve the strength, modulus, and toughness significantly [12-13]. The yield strength and elongation at break of PVC could be increased by the addition of nano $CaCO_3$. $CaCO_3$ is the most common used filler in PVC because of its low cost. The aim of the present work is to investigate the effect of addition of calcium carbonate and stearic acid, tribasic lead sulfate and Di-octyl phthalate (DOP) on the physical and mechanical properties of polyvinylchloride (PVC).

II. MATERIALS AND METHODS:

2.1. Materials:

A. PVC Resin: grade K- 67, produced by Egyptian Petrochemicals Company. Its properties are shown in Table (1).

Table 1 : PVC Properties

Inherent viscosity	0.91 dL/gm
Mass Loss (wt%)	0.05
Porosity (DOP)	0.20 ml/gm
% Retained # 40	0
% Retained # 60	0.07
% Through # 140	4.33
Average particle size (A.P.S)	154 micron
Apparent bulk density (A B D)	0.56 gm/cm3
Residual VCM content (R-VCM)	0.39 ppm
Specific gravity (g/cu.cm@ 73° F)	1.42-1.48
Water Absorption 24 hrs @ 25° C	0.0012
Hardness, Rock well	80
Impact strength 20 C	20 kJ/m^2
Impact strength 0 C	8 kJ/m^2
Ultimate tensile stress	52 M Pa
Elongation at break	50-80%
Elastic tensile modulus	3.0-3.3 GPa

B- Calcium carbonate: Obtained from elgomhorya Company in Alexandria Egypt
C- Lubricant (stearic acid): Obtained from elgomhorya Company in Alexandria Egypt.
D- Stabilizer (tribasic lead sulfate) : obtained from Egyptian Petrochemicals Company.
E- Plasticizer (Dioctyl phthalate (DOP) : obtained from Egyptian Petrochemicals Company

2.2. Methods:

2.2.1. Preparation of PVC resin with a mixture of heat stabilizer (lead compound), lubricant(stearic acid) and fillers (calcium carbonate Caco3): (Rigid PVC)

About 100 grams of the PVC resin (k- 67) is mixed with three percentages of a mixture of stabilizer (tribasic lead sulfate, 2.2 wt%) , Lubricant (Stearic acid 0.5 wt%) and calcium carbonate as the following percentages: (10%, 12% , 15% and 20 % by weight) for calcium carbonate at a temperature of 120 C for about half an hour with continuous stirring. The composite was taken to measure the properties of PVC- CaCO3- composite [14].

2.2.2. Preparation of PVC resin with a mixture of heat stabilizer (lead compound) , lubricant (Stearic acid) and Plasticizer (Dioctyl phthalate (DOP)): (Soft PVC):

About 100 grams of the PVC resin (k- 67) is mixed with three percentages of a mixture of stabilizer (tribasic lead sulfate, 3 wt%), Lubricant (Stearic acid 0.5 wt%) and Plasticizer (Dioctyl phthalate (DOP)) as the following percentages: (60%, 70%,80% and 90 % by weight) for calcium carbonate at a temperature of 150 C for about half an hour with continuous stirring. The composite was taken to measure the properties of PVC- CaCO3- composite [14].

2.3. Testing procedures:

The principal test methods applied to measure rigid and soft PVC – composites properties are as following:

2.3.1. Physical Properties Analysis:

Several physical properties are measured such as: relative density,and hardness(shore A) for soft PVC .

2.3.2. Mechanical Properties Analysis:

The tensile stress, Izod Impact, Yield stress, % elongation at break are measured with a universal testing machine as shown in the following figures. Four different specimens were sampled from each composite for measurement. The four test results were averaged and then reported.

2.4 ASTM Testing Equipment:

2.4.1 Two Roll Mill Machine: as shown in figure (1), this machine is used to compress PVC composite into sheets to measure all the properties.

Figure (1): Two Roll Mill Machine

2.4.2 Bunch machine: This machine shown in figure 2, isused for shaping the samples to be measured into two different shapes,the dumbbell shape (Figure 2.a), and the regular shape (Figure 2.b):

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Figure (2) :Bunch machine

Figure (2.a) Dumbbell shape

Figure (2.b) Regular shape

2.4.3. LR5K PLUS (Elongation & tensile stress machine)-(ASTM-D:638) : This machineshown in figure 3,isused to measure % elongation at break, and tensile stress for both rigid and soft PVC sheets in dumbbell shape.

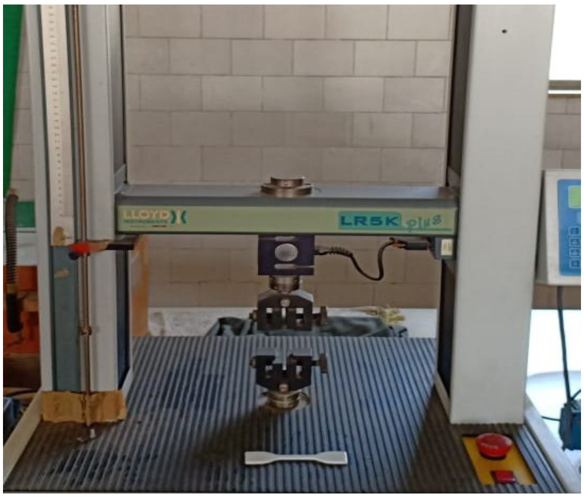

Figure (3):Elongation & tensile stress machine

2.4.4 Ceast (Hardness machine)-(ASTM-D:2240) : This machine shown in figure (4) is used to measure Hardness (shore A) for soft PVC.

Figure (4): Hardness machine

2.4.5 Ceast (Izod Impact machine)-(ASTM-D:256) : This machine shown in figure (5)is used to measure Izod Impact .

Figure (5) :Izod Impact machine

III. RESULTS AND DISCUSSIONS:

3.1 ASTM Testing For Rigid PVC:

3.1.1Effect of calcium carbonate filler on tensile stress for rigid PVC :

Fig.6 shows that the tensile stress value was increased with increasing weight of calcium carbonate at 120°C. The increase in the tensile stress value for PVC with calcium carbonate ranged from 10 % to 20% by weight. The tensile stress at break increased to maximum value (531 Kg/Cm2) and then dropped.

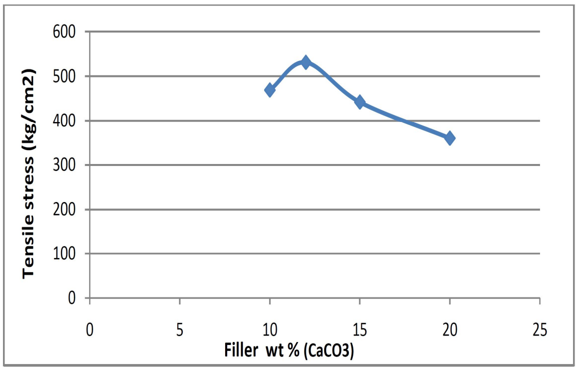

Figure 6: effect of % weight of CaCO3 at(120°C) on tensile stress at break

3.1.2.Effect of calcium carbonate filler on yield stress for rigidPVC :

Figure (7) shows thatyield stress increased to the maximum value (521 Kg/Cm2) with increasing % filler and then dropped.

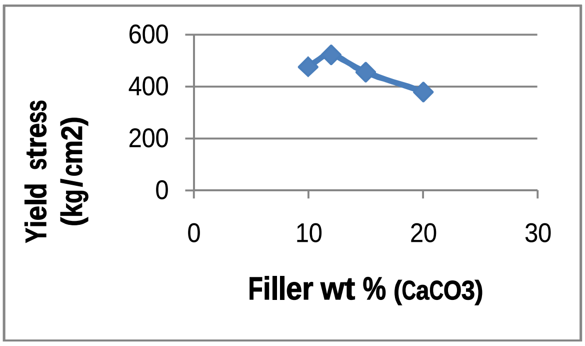

Figure 7: effect of % weight of CaCO3 at(120°C) on yield stress

3.1.3Effect of calcium carbonate on relative density forrigid PVC :

Fig.8 shows that the relative density value was increased with increasing weight of calcium carbonate(ranged from 10 % to 20% by weight) at 120°C.

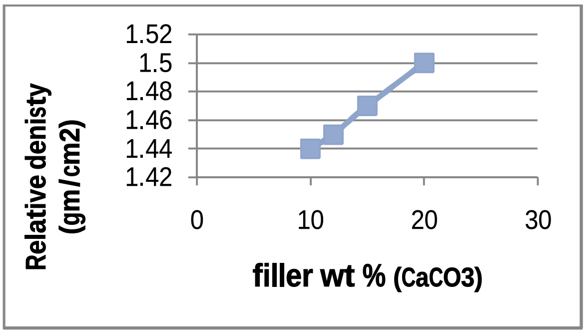

Figure 8: effect of % weight of Caco3 at(120°C) on relative density

3.1. 4Effect of calcium carbonate on %Elongation at break for rigid PVC :

Fig. 9 shows that the Elongation value was increased with increasing weight of calcium carbonate(ranged from 10 % to 20% by weight)at 120°C to a maximum value of (200 %) ,then decreased.

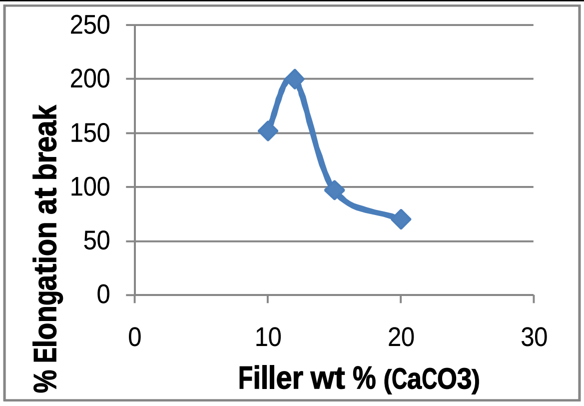

Figure 9: effect of % weight of Caco3 at(120°C) on %Elongation at break

3.1.5Effect of calcium carbonate on Izod Impact for rigid PVC :

Fig.10 shows that the izod impact value decreased with increasing weight of calcium carbonate (ranged from 10 % to 20% by weight.)at 120°C.

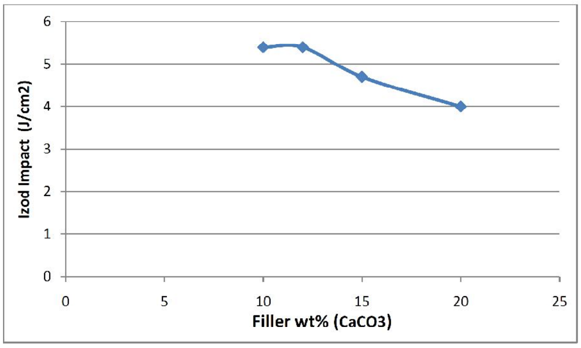

Figure 10: effect of % weight of CaCO3 at(120°C) on Izod Impact

3.2 ASTM Testing For Soft PVC :

3.2.1 Effect of Plasticizer on Tensile stress for softPVC :

Fig.11 shows that the tensile stress value was increased with increasing weight of plasticizer (ranged from 60 % to 90 % by weight) at 120°C.

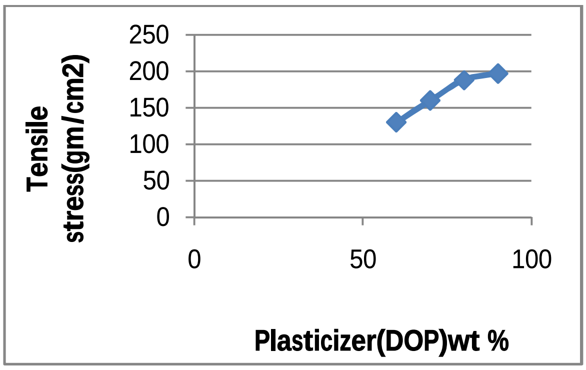

Figure 11: effect of plasticizer at(120°C) on tensile stress

3.2.2 Effect of plasticizer on %Elongation at break for soft PVC :

Fig.12 shows that the %Elongation at break value increased with increasing weight of plasticizer(ranged from 60 % to 90% by weight) at 120°C to a maximum value of (394 %) ,then decreased.

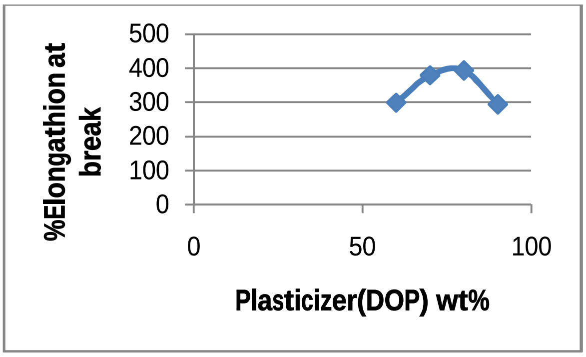

Figure 12: effect of % weight of plasticizer at(120°C) on %Elongation at break

3.2.3 Effect of plasticizer on relative density for softPVC :

Fig.13 shows that the relative density value increased with increasing weight of plasticizer(ranged from 60 % to 90% by weight) at 120°C.

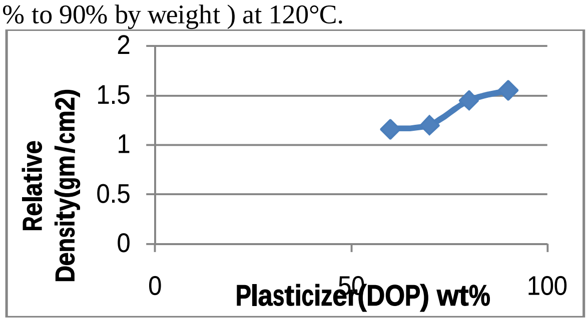

Figure 13: effect of % weight of plasticizer at(120°C) on relative density

3.2.4 Effect of plasticizer on (shore A) hardness for softPVC :

Fig.14 shows that the hardness value increased with increasing weight of plasticizer(ranged from 60 % to 90% by weight) at 120°C.

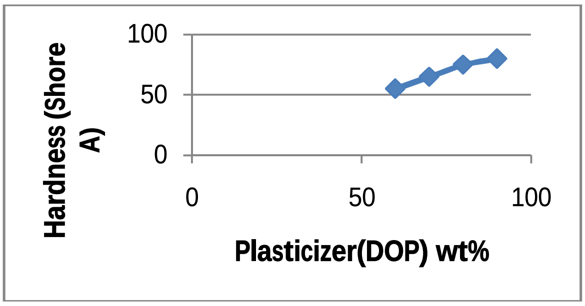

Figure 14: effect of % weight of plasticizer at(120°C) on Hardness

CONCLUSIONS:

In this study, Foursamples of poly (vinyl chloride) (PVC) are blended with different % fillers, stabilizers, % plasticizers and lubricant such as: calcium carbonate as a filler and stearic acid as a lubricant, tribasic lead sulfate as a stabilizer and Di-octyl phthalate (DOP) as a plasticizer on the physical and mechanical properties of polyvinylchloride (PVC). Based on the results of this study , the conclusions can be drawn in the following

- In case of soft PVC ,There is an increase in tensile stress, relative density and Hardness with increasing % plasticizer.
- In case of soft PVC , % Elongation at break increased with increasing plasticizer content and reached maximum value of (380 %) at 70 % weight of plasticizer and then decreased.
- In case of rigid PVC, tensile stress increased with increasing filler content and reached maximum value of (531 kg/cm2) at 12 % weight of CaCO3 filler .
- Yield stress increased with increasing filler content and reached maximum value of (521 kg/cm2) at 12 % weight of CaCO3 filler .
- On the other hand, the Izod Impact decreases with increasing filler content.
- % Elongation at break increased with increasing filler content and reached maximum value of (200 %) at 12 % weight of CaCO3 filler .
- Relative density of rigid PVC is directly proportional with % weight of filler .

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