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Study of an unknown PVC cable formulation by mechanical properties

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Abstract

PVC is a type of thermoplastic material which affected by heat due to the presence of chlorine and which is not used alone but with addition of additives such as stabilizers, plasticizers, fillers and others according to the required properties of the desired product based in suitable formulations. In this work many experiments were carried out to evaluate the additives and the type of PVC used on the formulation in cables application. The first experiments were to vary the amount of filler (calcium carbonate) and that ingredients such as PVC K67 resin, lubricant (stearic acid), stabilizer (tri-base lead sulfate), and plasticizer (Dioctyl phthalate) were constant in the formulation and then samples were tested for density, hardness, tensile strength, and sample burn test to determine the content of fillers or plasticizers. The results of the density test showed that it was 23.91wt% of the filler and in the hardness test, the plasticizers used were estimated at 52.61wt%. The tensile test results were 10.6 wt% of filler when the plasticizer value was 60wt% or 20wt% of filler with 65wt% of plasticizer weight. And it turned out that the unknown sample used PVC and high molecular weight such as pvck70-72 and not Pvck67 which we used in all experiments and the result of burning the sample gave 21.9% of the ash which is a filler. In the second experiments, the stabilizer was changed and the rest of the components were considered fixed, and the result was that the weight of the stabilizer was less than the lowest value used in the experiments 6wt% and finally. The study concluded that the sample used high molecular weight PVC, the filler percentage was 20wt%-23.9wt%, and the plasticizer was 52.61wt%-65.7wt%. This study shows that the proportions of the components of the PVC formulation can be estimated by studying the effect of fillers and heat stabilizers by using mechanical tests.

Keywords: Unknown sample; Cable formulation; Filler contents; Stabilizer; Mechanical tests; Ash content

1. Introduction

Polyvinyl chloride or commonly known as PVC, it is one of the well-known plastic materials used in pipes, chemical equipment, wires and cable [1]. PVC has a low thermal stability, and its use is limited in industry. Several attempts have been made to enhance the thermal stability and mechanical properties of PVC in the last recent years[2, 3]. Unmodified PVC polymer is brittle, manufacture of PVC in raw form, it subjected to heat and pressure then severely deteriorates its properties. The use of PVC is based on the compound (adding additives with the polymer base) of PVC worldwide. The method of preparing a typical recipe for the compound is known as the formula. With the addition of additives such as plasticizers, heat stabilizers, lubricants, fillers and copolymerization with other monomers, the poor properties of PVC can be improved [3, 4]. Consideration must be given to modifying components to be in perfect homogeneity, easy to manufacture, and economically competitive[5]. Proper treatment of PVC properties using suitable additives produces a compound whose behavior and properties are completely different from PVC itself [6, 7]. The selection of particular additive is dependent on the end use of the PVC product like PVC-resin is not plasticized (no add plasticizer) for the use in making rigid products such as water pipe, plumbing fittings. 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

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modification of rigid poly (vinyl chloride) (PVC) having relatively low toughness carried out by incorporation of a rubbery phase[8]. Various nanofillers, including clay, silica, calcium carbonate (CaCO3) and aluminum oxide, have been used to enhance the mechanical and thermal properties of the polymers, such as hardness, toughness and heat resistance. It has been studied that adding CaCO3 to PVC significantly improves strength, modulus and durability[9].The yield strength and elongation at break of PVC could be increased by the addition of nano CaCO3. CaCO3 is the most common used filler in PVC because of its low cost. The effect of adding calcium carbonate, stearic acid, tribasic lead sulfate and dioctyl phthalate (DOP) on the physical and mechanical properties of polyvinyl chloride (PVC) was studied [10] . PVC cable formulation is one of the soft PVC and has been studied with different proportions of components [11]. The objective of this work is to quantify the calcium carbonate, plasticizer and heat stabilizer of an unknown compound of PVC cable formulation. By adding proportions of calcium carbonate and maintaining the stability of the proportion of plasticizers (DOP), stearic acid and the heat stabilizer. As for checking the amount of heat stabilizer, percentages of it were changed and compared with the PVC cable formulation.

2. Material and methods

2.1. Material

2.1.1 In the first

Tests were carried out for the PVC compound for cables, which was manufactured at the Egyptian Company for Plastic Industries (El Sewedy - Egyplast) in Cairo, and the percentage of additives is not known.

2.1.2 The second

Experimental PVC formulation made and tested: PVC resin grade K- 67, Calcium carbonate, Lubricant (stearic acid), Stabilizer (tribasic lead sulfate), Plasticizer (Dioctyl phthalate (DOP), obtained from Plastic Technology Center, Alexandria, Egypt.

2.2. Methods

Two of experiments were carried out, the first experiment with the unknown sample were tested for density, hardness, tensile strength, and the complete combustion test the unknown sample only, the aim was to determine the filler or plasticizer content. The components (PVC grade K67 resin = 100g, lubricant (stearic acid) = 0.5 wt%, stabilizer (tri-base lead sulfate) = 7% wt, plasticizer (Dioctyl phthalate) DOP = 60 wt %) were considered to be fixed in the formulation and the change in the amount of filler (calcium carbonate = 20, 30, 40, 50,60wt %) see in Table (1). The second experiments were also tested by testing the color change in the oven with the passage of time to determine the amount of heat stabilizer that was used for the unknown sample (stabilizer= 6,7,8,9 wt. %) and the components (PVC = 100 g, lubricant (stearic acid) = 0.5 wt%, plasticizer (Dioctyl phthalate (DOP)) = 60 wt%, calcium carbonates = 20wt %) considered it fixed see in Table (2).

Table 1 Filler samples

No	Resin k67	DOP	CaCo3	TBLS	St	Total (gm)
Sample 1	100	60	20	7	0.5	187.5
Sample 2	100	60	30	7	0.5	197.5
Sample 3	100	60	40	7	0.5	207.5
Sample 4	100	60	50	7	0.5	217.5
Sample 5	100	60	60	7	0.5	227.5

Table 2 Stabilizer samples

No	Resin K67	DOP	CaCo3	TBLS	St	Total (gm)
Sample 1	100	60	20	6	0.5	186.5
Sample 2	100	60	20	7	0.5	187.5
Sample 3	100	60	20	8	0.5	188.5
Sample 4	100	60	20	9	0.5	189.4

The preparation and mixing were done as follows: PVC resin (k- 67) was mixed in the mixer until 50 °C, then the lubricant and plasticizer were added until the temperature reached 70 °C, and the stabilizer was added up to 90 °C, finally with calcium carbonate at 120 °C, the compound was cooled to 40 °C and leave it for 24 hours, then samples were prepared.

2.3. Testing equipment

Scales**:** As shown in Figure 1 to measuring weight.

Figure 1 The scales

Mixer**:** As shown in Figure 2: Mixer to mix PVC with additives.

Figure 2 Mixer

Miller**:** As shown in Figure 3: This machine is used to compress PVC composite into sheets to measure all the properties.

Figure 3 Two roll Mill

Compression molding and Dumbbell shape cutter: This machine shown in figure 4, is used for shaping the samples from the sheet were measured into the dumbbell shape

Figure 4 Compression molding and Dumbbell shape cutter

Physical Properties: Several physical properties are measured such as density and hardness (shore A). see Figure 5

Figure 5 (A) Hardness tester (shore A), (B) Denser

Mechanical Properties: The tensile stress, Yield stress, % elongation at break is measured with a universal testing machine as shown in the following figure 6. Four different specimens were sampled from each composite for measurement.

Figure 6 Tensile tester

Congo red test (ISO 182) in oven: Specifies a method for the determination of the thermal stability at elevated temperature of compounds and products based on vinyl chloride homopolymers and copolymers (in the following text abbreviated as PVC) which undergo dehydrochlorination (the evolution of hydrogen chloride) see Figure 7.

Figure 7 (A) Oven and (B) Muffle furnace

Muffle furnace: Test the percentage of Ash / Filler content in plastic material or finished products see Figure 7.

3. Results and discussion

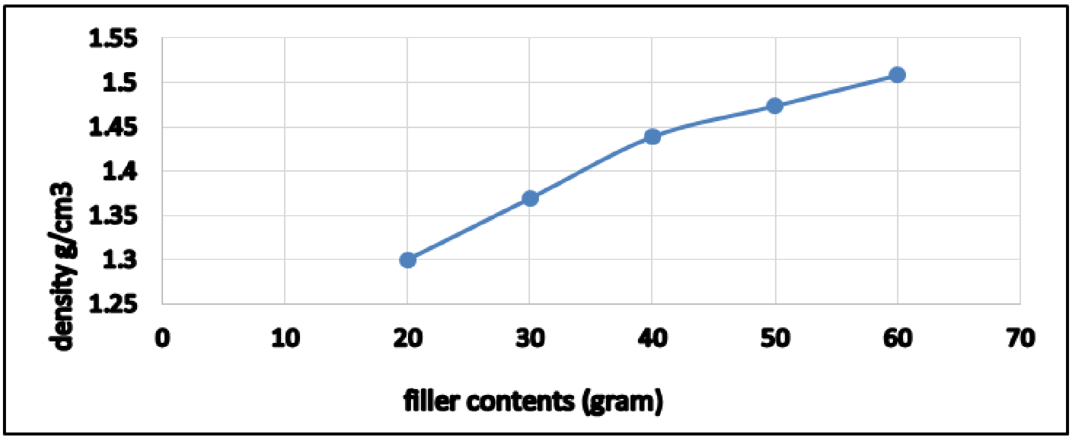

Figure 8 The effect of fillers on the density

The effect of increasing fillers on density is shown in Figure 8. Density increases. Another study showed that the density increases also by increasing the plasticizers [10]. According to the density test results, the unknow sample filler value between 20% and 30% is approximately linearly 23.91%.

The effect of the increase of filler on the shore A is shown in Figure 9. The corresponding shore hardness ranged between74-83.047. It is shown that the shore hardness increasing with increasing of filler content. While it decreases with increasing of plasticizer content. As explained previously the plasticizer softens the PVC by weakening the intermolecular interaction, while incorporating the filler the effect is completely reversed as the filler increases the hardness of the PVC.it found that addition of filler increases the hardness of the PVC and this is probably, which makes PVC breaks at low loads[12] . According to the shore test results, the unknow sample filler value more than 60wt% and this shows that the result of the hardness test in the presence of the plasticizer does not give a correct result to determine the amount of filler in the unknown sample. But it is almost inverse linear with a low value of the filler 20% the plasticizer (60wt% by weight, 74) to (Xwt%, 84.4) then X is equal to 52.61% by weight.

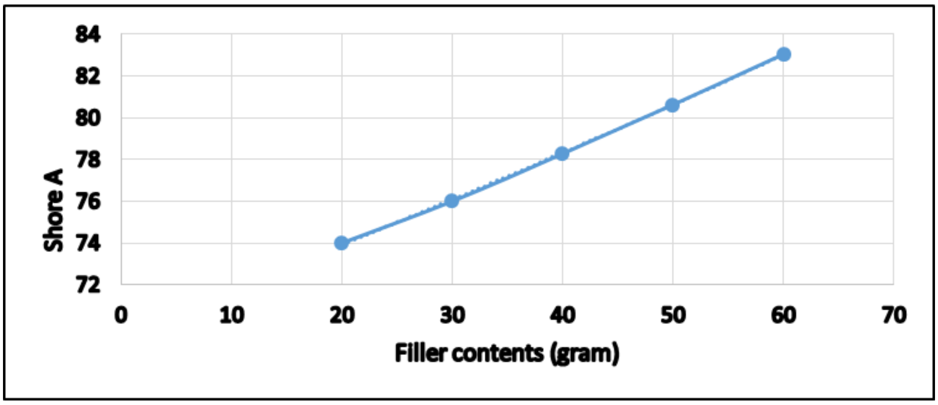

Figure 9 The effect of fillers on the hardness

In Figure 10, it is seen that the tensile strength and load at break decrease with the increase of the filler contents. The values were compared with the unknown sample with the filler, and the appropriate value was 10.6wt% of the filler, with a value of 60wt% for the plasticizer, when it contained 20wt%% of the filler, and the percentage of plasticizers was deduced from the direct relationship with the tensile strength, and the value was 65.7wt%. The cable structure was studied using PVCk-70, filler, plasticizer, tensile strength and elongation at break (PVCk-70=100g, 10wt%, 55wt%, 161 MPa. 250%) respectively [11]. The elongation ratio in Figure 11 gave oscillatory values for all experiments and was higher than the value of the unknown sample (344%), which is higher than what was studied in [11] in which the viscosity number of PVC k70 with a high molecular weight was used, so it used low fillers and plasticizers with a lower elongation result, instead of the test material PVC k67.

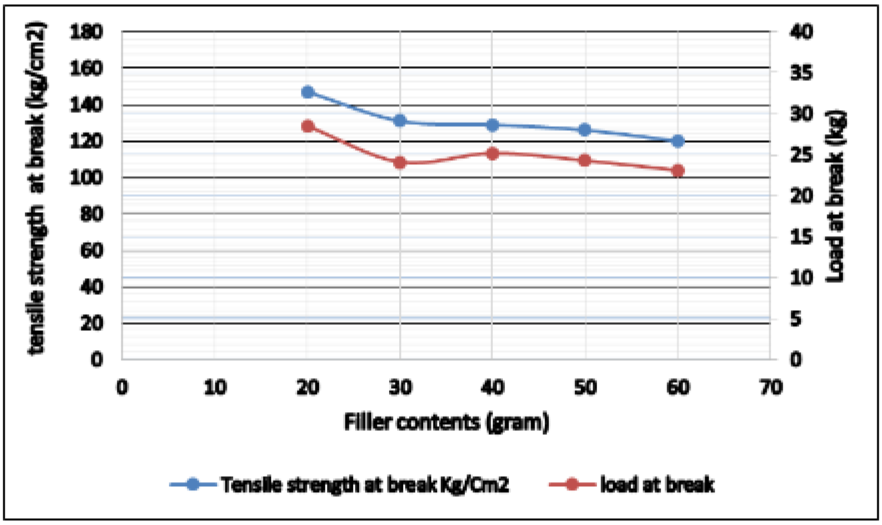

Figure 10 The effect of fillers on the land and tensile strength at break

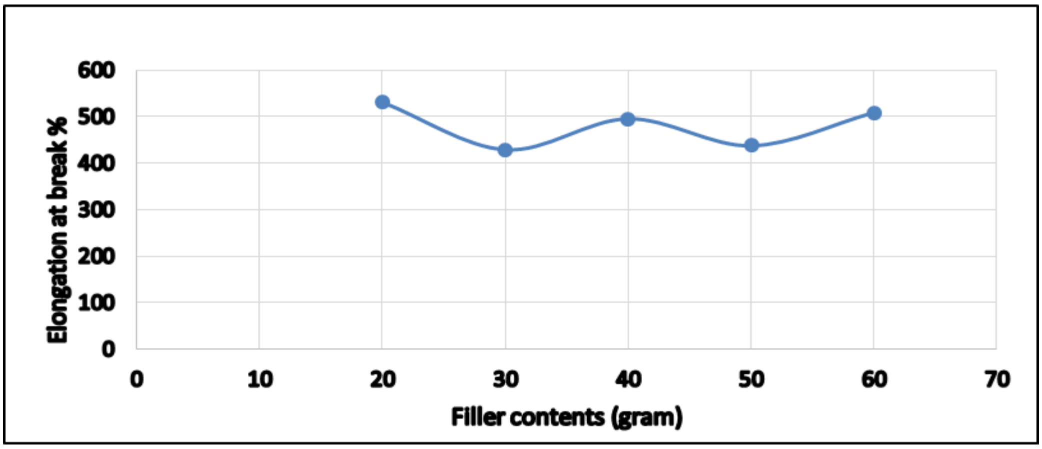

Figure 11 The effect of fillers on elongation at break

When burning the unknown sample in Muffle furnace, the resulting ash percentage was 21.9% of the sample weight before burning, which indicates the weight of the fillers is close to the previous results and considerations.

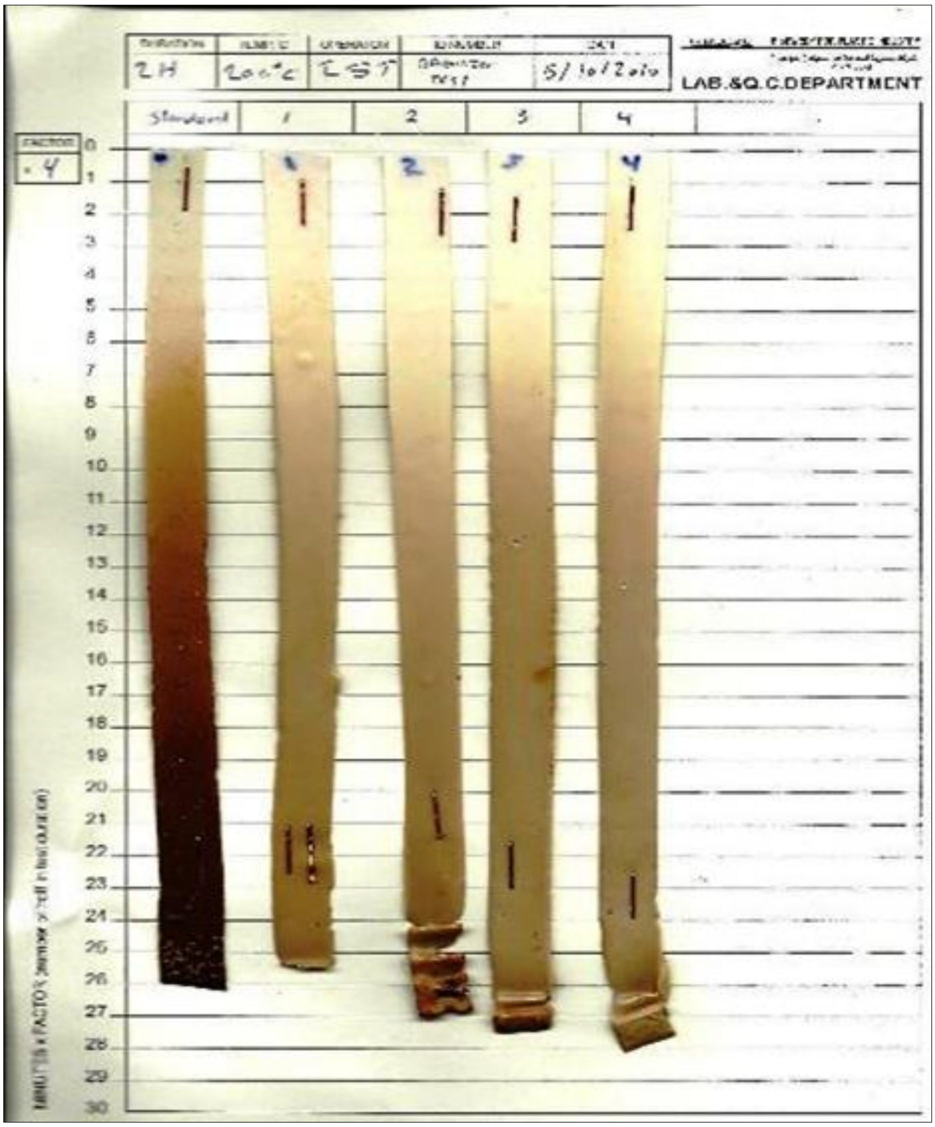

Figure 12 The results of Congo red test

The results of Congo red test shown in Figure 12 between the unknown sample (0) and other samples from table 2 according to our observation by eyes and the relation between the time and the color of the sample we found the unknown compound sample will burn in early time than the other samples. Also, by comparing between the other samples we found no big different seen between them. So, the percentage of stabilizer in the unknown compound sample is less than other samples. That's mean the percentage of stabilizer less 6wt%. The suitable value ranged (2.2%-4%) [10, 11].

Table 3 The stander sample

No	**width (cm)**	**Thickness (cm)**	**Area** $(\mathbf{cm^2})$	**Load at break Kg**	**Elongation at break (cm)**	**Tensile strength at break** $(\frac{Kg}{cm^2})$	**Elongation** %	**Density** $\frac{g}{cm^3}$	**Hardness Shor(A)**
Unknow	6.105	3.415	0.2074	33.5	222	161	344	1.327	84.4
Sample 1	6.08	3.13	0.1887	28.5	315.5	147	531	1.300	74
Sample2	6.07	3.22	0.1938	24.1	264.5	131	429	1.369	76
Sample3	6.09	3.30	0.2004	25.2	297.75	129	495.5	1.4386	78.28
Sample4	5.96	3.33	0.1982	24.3	268.75	126	437.5	1.4733	80.63
Sample5	5.98	3.21	0.1917	23.1	304.5	120	509	1.5080	83.047

4. Conclusion

In the density test, it increased by increased the filler or plasticizer, that is, it depends on the weights of the additives in the PVC compound, thus, in order to estimate the percentage of any component in a particular sample, the other components must have constant values, and the value of the estimated filler was 23.91wt%. The hardness value increases as the filler value increases or the plasticizer value decreases. It is more reliable in estimating the value of a plasticizer than a filler, especially for hard samples. The test result was linear with more than 60wt% filler for the unknown sample, which affects the poor mechanical properties, and the conclusion was to reduce the plasticizer from 60wt% to 52.61wt%, and the filler value was kept at 20wt%. The tensile test, which is an indicator of mechanical properties, the values of load and strength at break, and elongation decrease with increasing filler contents or its increase with increase in plasticizer. The filler value in the unknown sample was 10.6wt% with 60wt% plasticizer or an estimated value of 65.7wt% for plasticizer with a filler value 20wt%. The elongation of the unknown sample was less than all the tests and thus increases with the increase in the values of plasticizers or decrease fillers. When comparing the results with previous results to reduce the proportion of each of the fillers or plasticizers and the elongation ratio, by using PVC with a high molecular weight such as PVCk70-72 must be used and the strength at break is maintained as required. The result of burning the unknown sample showed that the percentage of the filler was 21.9%, and the amount of heat stabilizer used was less than 6wt%. The study concluded that the unknown sample used PVC, with a high molecular weight, and that the percentage of the filler was 20wt%-23.9wt%, and the thermal stabilizer was less than 6%, and the plasticizer was from 52.61wt%-65.7wt %.

Compliance with ethical standards

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Disclosure of conflict of interest

Four authors are involved in however no conflicts of interest.

References

[1] Ge X, Li X, Meng Y. Tensile properties, morphology, and thermal behavior of PVC composites containing pine flour and bamboo flour. Journal of Applied Polymer Science. 2004;93(4):1804-11.

[2] Wang X, Zhang Q. Effect of hydrotalcite on the thermal stability, mechanical properties, rheology and flame retardance of poly (vinyl chloride). Polymer International. 2004;53(6):698-707.

[3] Chen CH, Teng CC, Su SF, Wu WC, Yang CH. Effects of microscale calcium carbonate and nanoscale calcium carbonate on the fusion, thermal, and mechanical characterizations of rigid poly (vinyl chloride)/calcium carbonate composites. Journal of Polymer Science Part B: Polymer Physics. 2006;44(2):451-60.

[4] Unar IN, Soomro SA, Aziz S. Effect of various additives on the physical properties of polyvinylchloride resin. Pakistan Journal of Analytical & Environmental Chemistry. 2010;11(2):7.

[5] Pagé D, Cunningham N, Chan N, Carran G, Kim J. Mechanical and heat deflection properties of PVC/PMMA/montmorillonite composites. Journal of Vinyl and Additive Technology. 2007;13(2):91-7.

[6] Wang D, Parlow D, Yao Q, Wilkie CA. PVC-clay nanocomposites: Preparation, thermal and mechanical properties. Journal of Vinyl and Additive Technology. 2001;7(4):203-13.

[7] Chen CH, Teng CC, Yang CH. Preparation and characterization of rigid poly (vinyl chloride)/MMT nanocomposites. Journal of Polymer Science Part B: Polymer Physics. 2005;43(12):1465-74.

[8] Kemal I, Whittle A, Burford R, Vodenitcharova T, Hoffman M. Toughening of unmodified polyvinylchloride through the addition of nanoparticulate calcium carbonate. Polymer. 2009;50(16):4066-79.

[9] Zheng X, Gilbert M. Effects of processing on the structure of PVC/montmorillonite composites. I. Melt and solution processes. Journal of Vinyl and Additive Technology. 2011;17(4):231-8.

[10] YOUSEF NS. PVC COMPOUNDING: PREPARATION, PHYSICAL AND MECHANICAL PROPERTIES. International Journal of Mechanical and Production Engineering. 2018;6(12).

[11] Weil ED, Levchik S, Moy P. Flame and smoke retardants in vinyl chloride polymers–commercial usage and current developments. Journal of Fire Sciences. 2006;24(3):211-36.

[12] Elgozali A, Hassan M. 1EFFECT OF ADDITIVES ON THE MECHANICAL PROPERTIES OF POLYVINYL CHLORIDE Citeseer. 2008;https://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.523.4483.