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Research Article

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Experimental Investigation of the Effect of Various Additives in Physical & Mechanical Properties of PVC Compound

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Abstract

The current research about Polyvinylchloride (PVC) was compounded with some additives to improve physical and mechanical properties. PVC (K value ranging 70) was used as the base polymer. Plasticizers, fillers, stabilizers, pigments, and lubricants were mixed in standard concentration units of parts per hundred resins (phr)" with the base polymer. Cable compound and shoe compound were made in the plasticized-PVC category with primarily plasticizing additives such as dioctyl phthalate (DOP), Calcium carbonate, Stearic acid, Calcium zinc stearate. At present work is aimed to compounding of PVC with various additives and studied its various properties. The mechanical properties of the compounded samples, such as tensile strength, elongation at break, hardness, and specific gravity, were investigated experimentally. Tensile strength increased significantly from 16.62 Mpa and elongation at break 300% (The hardness (shore A) of all compounds was obtained 93. The volume resistivity was found to be 4x10^{14} Plasticizers had a direct proportional impact on elongation at break but an inverse proportional impact on tensile strength. The study provides the application of PVC compound incorporated with various additives affect its physical and mechanical properties for development of various application in electrical cable and house wiring.

Keywords: Polymer, Polyvinyl chloride, Additives, Resin, Hardness.

1. Introduction

Polyvinyl chloride, or PVC, is a building block used in a variety of products such as electronics, construction materials, stationery, chemical equipment, wires, cables, and so on. It is one of the most common thermoplastics used today and is widely produced worldwide [1,2]. There are currently 50 different basic types of plastics that are used in 60,000 different plastic formulations. Those based on polyolefins and polyvinyl chloride have the highest global utilization [3]. According to one estimate, six new plastics materials are sent to major testing laboratories in the United States every week for evaluation and approval [4]. Only low-density polyethylene has a larger global production tonnage than PVC. However, PVC has lower processability and thermal stability than other commodity plastics such as polyethylene and polystyrene [5]. PVC is a thermoplastic, and its use in industry is bound due to its low thermal stability. In recent years, several attempts have been made to improve the thermal stability and mechanical properties of PVC [6–8]. Unmodified PVC polymer is a brittle, inflexible material with limited commercial applications. Heat and pressure were used to degrade PVC in its raw form [9]. Hydrogen chloride is produced and rapidly discolors from white to yellow to brown to black. These changes were observed at processing temperatures of around 1504 C [10]. All over the world, PVC is used by "compounding" (adding additives to the base polymer). Formulation" refers to the process of preparing a typical compounding recipe. The poor properties of PVC can be improved by adding additives such as plasticizers, heat stabilizers, lubricants, fillers, and copolymerization with other monomers [1, 2]. Compounding PVC contains enough modifying components to the raw polymer to produce a homogeneous mixture suitable for processing and requiring performance at the lowest possible price [10]. The proper compounding and processing of PVC resin with appropriate additives results in a complex material with behaviour and properties that differ significantly from the PVC resin alone [11,12]. The choice of additive is determined by the end use of the PVC product, for example, PVC-resin is not plasticized for use in rigid products such as water pipe, plumbing fittings, and phonograph records. Polyvinyl chloride is commonly blended with small proportions of rubbery synthetic polymers for use in making piping or structural panels that require high impact resistance. The incorporation of a rubbery phase into rigid poly (vinyl chloride) (PVC) with relatively low toughness [13]. The addition of various properties of vinyl acetate to vinyl chloride before polymerization results in resins that are more easily plasticized than polyvinyl chloride; treatment of polyvinyl chloride with chlorine results in stiffer resins. Plasticizer proportions in commercial PVC formulations range from 15-50% by weight [3, 10]. Polyvinyl chloride decomposes and loses HCl even at low processing temperatures. In PVC, the apparent replacement of active hydrogen is assumed. Organometallic salts can inhibit the elimination of HCl and stabilize PVC, while epoxides can suppress the catalytic activity of HCl in this reaction [14,15].

PVC is modified with elastomers and special plasticizers to improve sealing properties [16-23]. These modifiers lower the glass transition temperature, increase deformability, elasticity, abrasion resistance, elastic recovery, and resistance to oils, fuels, and a variety of cleaning chemicals [16, 17, 20, 24, 25, and 26]. The physical state and morphology of a polymer have a significant impact on its mechanical properties. The elongation that occurs when a plastic is loaded (stressed) in tension is a simple measure of the differences in mechanical behaviour. Almost all plastics exhibit some elongation when stressed that is not recovered when the stress is removed. The most commonly specified mechanical properties of polymers are stiffness and breaking stress, as well as flexural modulus and tensile strength. The type and quantity of plasticizer have a significant impact on mechanical properties. Fillers will have a lesser impact on the physical properties. Unplasticized PVC is a rigid material, whereas plasticized PVC is flexible and even rubbery at high plasticizer loadings. Because of the wide variety of PVC compounds, it is important to know the physical properties of PVC resins. gaining knowledge of PVC compounding formulation. Table 1 depicts some of the properties of PVC resins. The current study examines the impact of additives, primarily plasticizers, fillers, lubricants, stabilizers, and pigments, on the physical and mechanical properties of polyvinyl chloride compounding, specifically specific gravity, tensile strength, elongation at break, volume resistivity, and hardness.

Property	Value
Appearance	White powder
K-value	60-70
Degree of polymerization (°C)	170±30
Volatile matter (%)	0.05
Foreign matter (phr)	<50
Density (g/cm^3)	1.3 - 1.6
Hardness (shore A)	40
Glass transition temp, Tg (°C)	85
Elongation at break (%)	50
Tensile strength (Kg/cm^2)	460

Table 1: Properties of PVC

2. Experimental

2.1 Materials

The preparation of PVC based compound the given chemicals are used. Suspension polymer of PVC resin (k-value 67) was procured from Shin Etsu had apparent density 0.562, Dioctyl phthalate (DOP) was 99% pure, colorless and acid value 0.1 max. Calcium carbonate was generously taken from Sukesh industries Pvt. Ltd Jaipur, Calcium zinc stabilizer was procured from Globe chemical& minerals Kanpur. And stearic acid taken from Sisco research laboratory pvt. Ltd had molecular wt. 284.49, appearance white, melting point 68-70 and density 0.845g/cm3.

3. Methodology

3.1 Method of PVC Cable Compounding

As per formulation firstly prepare the dry blend in SS Pot taking weight as per general formula given in table.2. The prepare dry blend by mixing properly with spatula on a hot plate at temp. 180°C for 1 hours after proper mixing the dried powder sample are collected properly.

4. Preparation of PVC cable sheet

The preparation of PVC cable sheet involves two stages in first stages milling process and then molding the sheet depicted in fig.1

4.1 Milling Set the temp. of two roll mill 175°C-180°C. after that add the dry blend to the mill roll the material falling through nip shall be quickly collected from the tray and returning to the moving rolls. Continuously milling approximately 5 minutes for better dispersion after that cutting the sheet and remove the milled sheet without stretching from the roller.

4.2 Sheet Molding Set the temperature of the mould 160°C-180°C. to preheat the mould after that quickly remove the mould and put the sample which previously prepared from two roll mill into it for 5 minutes. After that carefully remove the sheet from the mould and placed it into cooling chamber for few minutes after sometimes remove the sheet from the mould and preserve it for required test. (Specific gravity, thermal property, tensile strength, elongation @break & volume resistivity).

Sample	PVC resin (phr)	$CaCo_3$ (phr)	Dop (phr)	Stearic acid (phr)	C-Z stabilizer (phr)
P-1	100	10	20	0.5	3.0
P-2	100	20	30	0.5	4.0
P-3	100	30	40	0.5	5.0

Table 2: Formulation of PVC cable compound

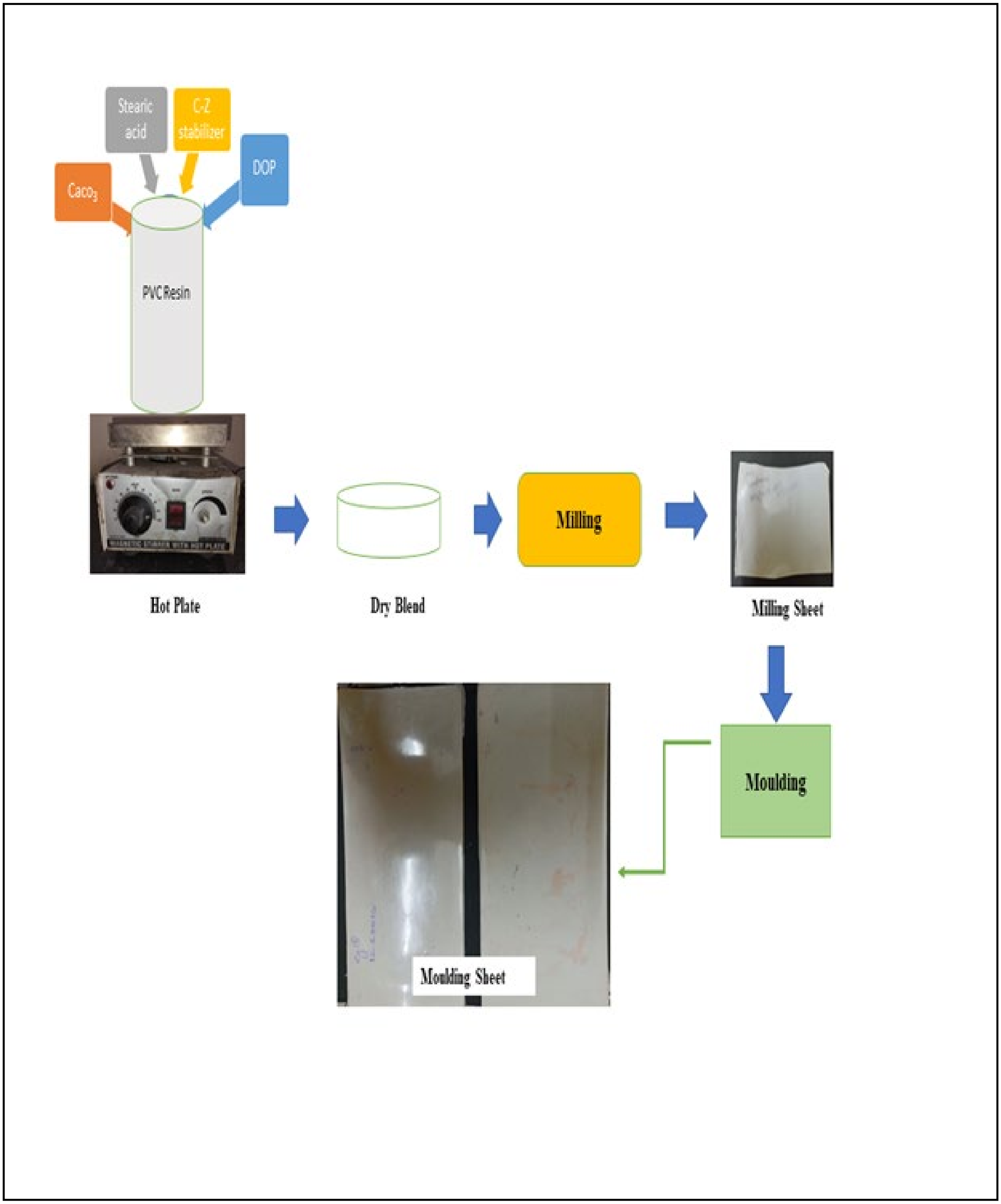

Figure 1: Preparation of PVC Cable sheet

5. TESTING

5.1 Mechanical Properties

The mechanical properties of prepared sheet were measured using a Universal Instron Tensile testing machine (Model 3382) according to ASTM D 638.

5.2 Hardness test

Shore Hardness were measured with instrument Durometer make Russell Technologies India Pvt. Ltd. (Model Leeb810A) according to ASTM D 2240.

5.3 Specific gravity Test

The specific gravity test measurement were carried out by using using Mettler Toledo instrument (Mettler-Toledo India Pvt. Ltd. Mumbai, India) according to ASTM D 729.

5.4 Volume Resistivity Test

The volume resistivity were measured with instrument VR meter make (Sataton) according to ASTM D257.

6. Results and Discussion

6.1 Tensile Properties

The tensile strength and elongation @break of PVC compound is shown in fig.2 it is clearly shows that there is decrease in tensile strength with increase in plasticizer because the plasticizer binds to polymer molecules and acts as a spacer between polymer molecules. Because of this connection, plasticizers have a significant impact on the mechanical properties of polymers. Dipole interaction is said to occur between polar groups in the polymer and polar groups in the plasticizer [10]. In this situation, the polar group in the plasticizer is represented by the chlorine atom in PVC resin and the ester group in DOP. With the addition of the plasticizer to the polymer, the bond forces of the polymer atoms weaken due to the linkage formed, and therefore free volume increases, resulting in lowering the tensile strength [27]. On the other hand, with increase in plasticizer the elongation @break increases as previously stated, the plasticizer acts as a spacer on PVC, increasing the free volume, causing PVC to become softer and weaker and allowing it to be elongated longer under low loads [27,29].

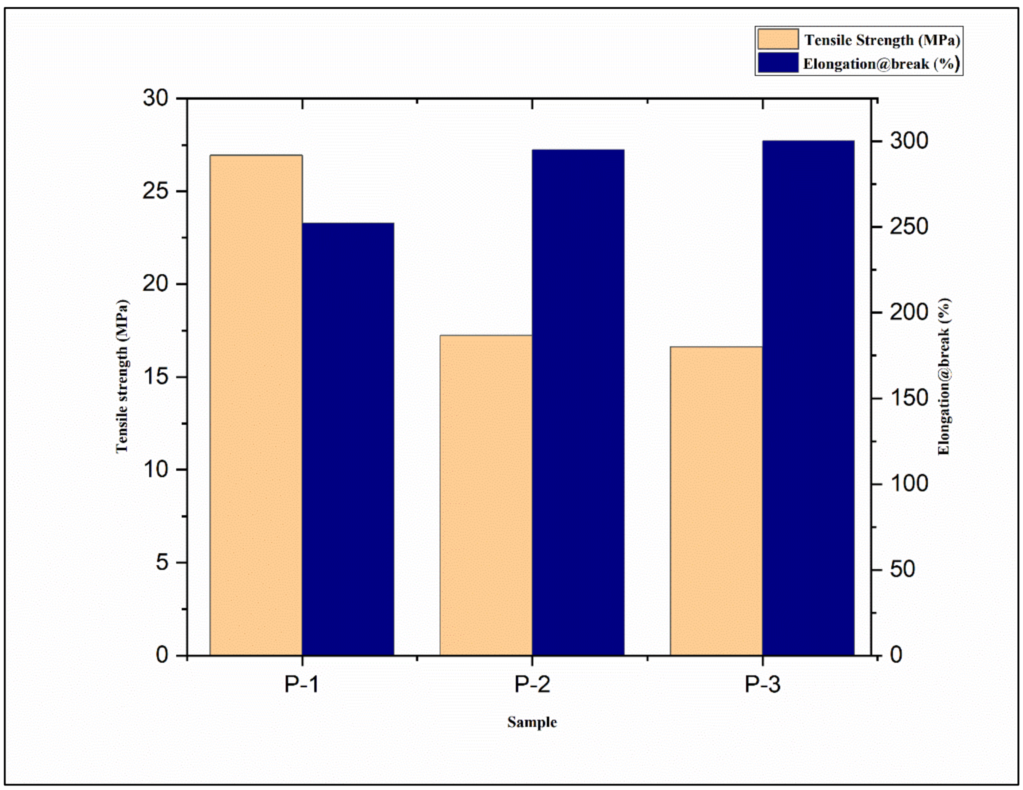

Figure 2: Tensile & Elongation @break of PVC compound

6.2 Hardness

The hardness of PVC compound was measured Shore A from fig.3 it is clearly evident that there is decrease in hardness this is due to the effect of filler and plasticizer. Shore hardness for plasticized PVC compounds is demonstrated to decrease with increasing plasticizer and filler content. As previously described, the plasticizer softens the PVC by reducing the intermolecular contact; however, when the filler is added, the effect is entirely reversed because the filler enhances the hardness of the PVC [29,30].

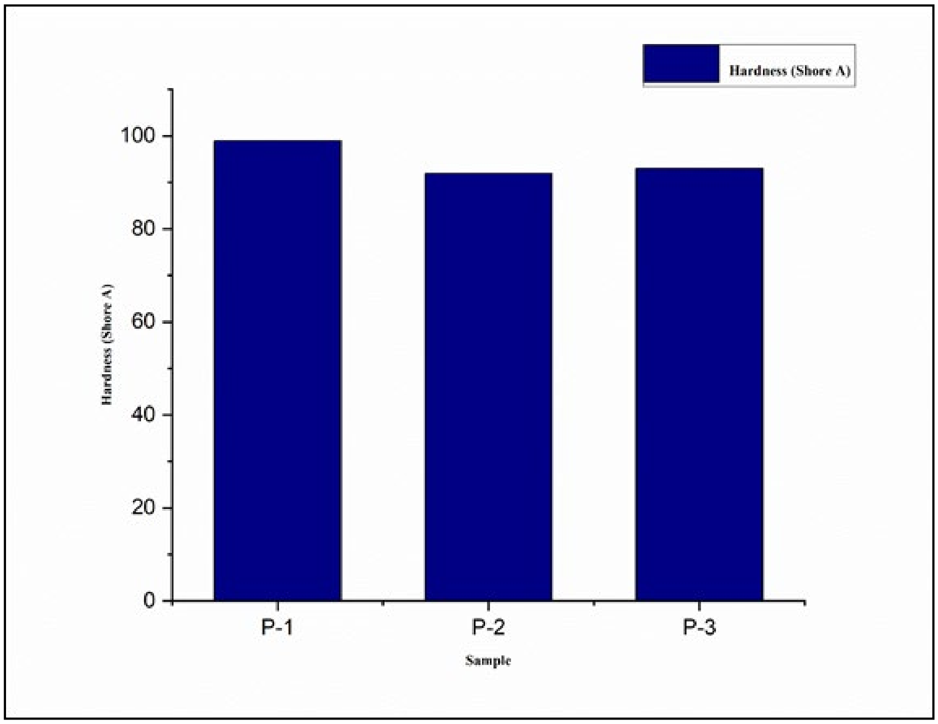

Figure 3: Hardness of PVC compound

6.3 Specific Gravity

The specific gravity of PVC compound stated in fig.4 it is shows that all of the compounds have almost similar specific gravity, which is a key factor in price and thus very important. It is also utilized in production control, including raw material production, molding, and extrusion.

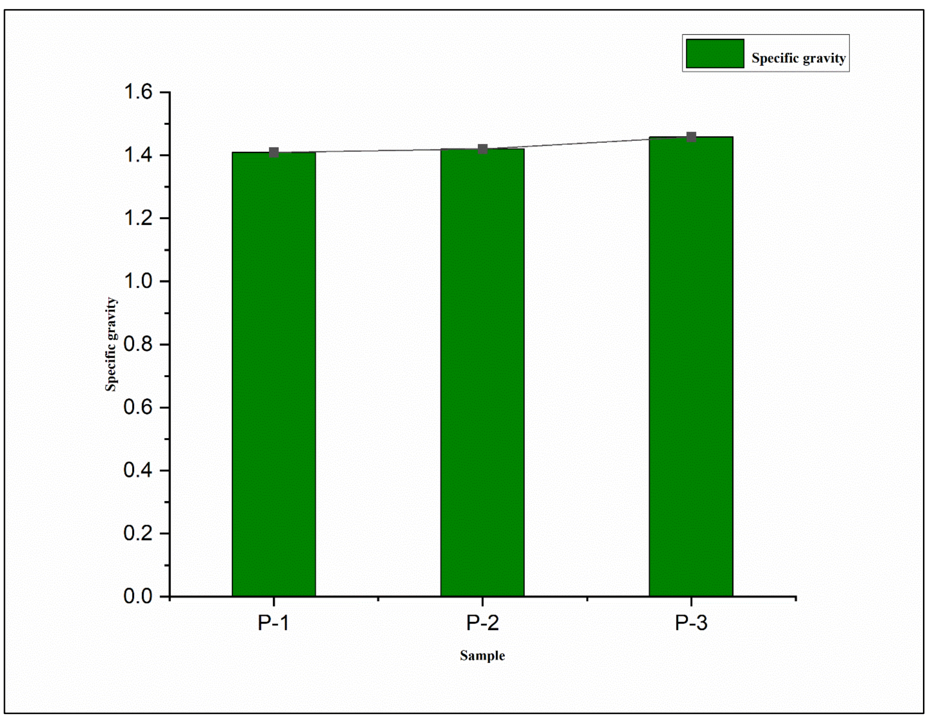

Figure 4: Specific gravity of PVC compound

6.4 Volume Resistivity

The volume resistivity of PVC compound is shown in fig.5 it is shows that there is increase in volume resistivity of PVC compound. this is due to the presence of filler in compound the volume resistivity increases with increament in filler content.

Sample	Tensile strength (Mpa)	Elongation @ break (%)	Hardness (Shore A)	Specific gravity	Volume resistivity (ohm-cm)
P-1	26.93	252.25	99	1.409	1.21×10^{16}
P-2	17.23	295	92	1.410	4.30×10^{14}
P-3	16.62	300	93	1.412	4×10^{14}

Table 3: Test results of PVC compound

7. Conclusion

The effect of different additives in PVC compound was studied successfully. From the above results it was concluded that the tensile strength lies from 26.93 to 16.62 it is slightly decrease due to incorporation of plasticizer in compound. Similarly, there is increasing in elongation @break the maximum value achieved 300%. Due to the effect of filler and plasticizer Shore Hardness of compound sightly decreases lies 93. The specific gravity of compound are slightly increase because filler is dense than plasticizer .it has significant importance in production. The volume resistivity of compound increases with increament in filler content. From the above test results it is finally observed that the effect of various additives in Physical. Mechanical and electrical properties of compound.

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