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Studies on Improving Performance of PVC Compositions for Electrical Cable Sheathing Applications

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Abstract: Flame-retardant Polyvinyl chloride (FR PVC) is by far the most widely used polymer in the wire and cable industry. Studies have been conducted on PVC compositions for use in flame-retardant low-smoke (FRLS) cable sheathing applications in electrical industry. Compositions containing varying amounts of additives were prepared. The compositions that meet the FRLS requirements of Limiting Oxygen Index (LOI) and Smoke Density Rating (SDR) were evaluated for mechanical properties like tensile strength, elongation-at-break and thermal stability. The results are satisfactory as against the required values of Min: 12.5 N/mm², Min: 150 % and > 80 minutes. The compositions are to be tested in at least two different laboratories prior to scale-up studies.

Key Words: Polyvinyl chloride, flame-retardancy, DOP, TCP, Tensometer

INTRODUCTION

Despite public safety concerns and controversies relating to environmental impact [1], PVC continues to be among the five major thermoplastic resins [2] and continues to find as widespread use as ever in transport, building, packaging, electrical, electronic and healthcare applications sectors.

PVC, first prepared in 1872 by German chemist Eugen Baumann, and plasticized by B. F. Goodrich in 1926 into the form many of us are familiar with today [2], is unique in that it is used both in its rigid (unplasticized) form as well as flexible (plasticized) form. Flexibility is achieved by incorporating plasticizers or flexibilizers together with the polymer (so that flexible PVC often contains <50% actual PVC) [3]. Rigid PVC and flexible PVC have separately earmarked areas of use. The former is used for pipe, conduit, siding, windows and injection-molded appliance-housings, while the latter find use in wire and cable coatings, wall carvings, floor coverings and upholstery cover fabrics [3].

Rigid PVC contains a high level of chlorine (~56%) and is considered to be flame-retardant with an oxygen index of about 47. Flexible PVC is made by adding generally 25-50 % of a carboxylic acid ester, such as di(ethylhexyl)pthalate (DOP) as a plasticizer to the formulation. The plasticizer is combustible and reduces the flame-retardance of the formulation as measured by the oxygen index. Typical properties of PVC resin would indicate that it is too rigid (Shore D hardness 65-90), has a very high tensile strength that can be decreased without drawbacks (35 to 60 MPa) and is fire-retardant without additives (oxygen index 47). Generally, adding plasticizers, while imparting better flexibility at room temperature and enabling easier processing, simultaneously causes decrease in the tensile strength and lowers the oxygen index [4]. The present work is an attempt to obtain PVC compositions, already found to have acceptable FRLS characteristics in our laboratory, that attain acceptability with respect to mechanical properties as well, by varying the concentrations of additives. Thermal and electrical properties (not reported here) have been recorded and found to be acceptable as per requirements.

EXPERIMENT

The PVC resin (K-70 Grade), procured from M/s IPCL, India, has been used "as received" in the experimental work. Plasticizers DOP and tricresyl phosphate (TCP), filler calcium carbonate, mineral flame-retardant additives martinal (commercially available, aluminum hydroxide for the most part) and magnesium hydroxide, a metal-containing flame-retardant zinc borate, a calcium-zinc stabilizer to reduce loss of mechanical and electrical properties, lubricants calcium stearate and stearic acid, a special additive glass and an anti-oxidant bisphenol-A are the components of the polymer matrix.

Compounds of different compositions were prepared using the a Brabender Plasti-Corder (PLE 331) that gives a twin-screw mixing action at 20-30 rpm for about 30 minutes at 180°C and cured using the Hot Press Tester (Labtech Co. Ltd., Seoul, Korea) maintained at a temperature of 175°C and pressure of 90 kg/cm^2. Using the dumbbell cutter, specimens of required dimensions were prepared and the tests carried out under standard laboratory conditions, using Tensometer (Manufacturer: Hounsfield UTM; Model: H50KM) as per ASTM D 412 specifications.

RESULTS & DISCUSSION

Compositions that showed promise, arrived at after long trials, are given in Table 1.

Table 1. Compositions of the PVC systems

Sl. No.	Components (in phr units)												Sample Code
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	
1	100	30	8	**14**	30	3	1	10	0.2	0.2	**15**	0.6	PM31
2	100	30	**9**	**12**	30	3	1	10	0.2	0.2	**14**	0.6	PM34

(a). PVC, (b).DOP, (c). TCP, (d). $CaCO_3$, (e). Martinal (f). $Mg(OH)_2$, (g). Zinc borate,
(h). Ca/Zn stabilizer, (i). Calcium Stearate, (j). Stearic acid, (k). Glass, (l). Bisphenol-A

The mechanical properties data are recorded in Table 2.

Table 2. Mechanical properties data

Designation	Properties		
	Tensile Strength or T.S(N/sq.mm)	% Elongation at Break	Thermal Stability (minutes)
PM31	14.0 – 15.6	165- 175	75-80
PM34	15.0-15.4	172.5-192.5	95-100

Both the compositions listed in Table 1 show LOI > 30% and SDR < 60%. On considering the evaluation data, the composition PM34 was selected as the final choice and repeat trials (nine times) conducted. The repeatability of this composition has been confirmed.

The results for the sample PM34 are more satisfactory. The values: T.S.:15.2 N/sq.mm, Elongation at Break: 182.5 % and Thermal Stability: 90-95 minutes are satisfactory against the minimum requirements of 12.5 N/sq.mm, 150 % and 80 minutes respectively.

The data demonstrate that small variations in concentrations of plasticizer, filler and FR additives can together bring about significant differences in tensile properties. The synergistic effect is better at 9 phr (parts per hundred resin) TCP, 12 phr $CaCO_3$ and 14 phr glass. The composition is due for verification of reproducibility of the results in two different laboratories.

CONCLUSION

On further confirmation of performance characteristics, the sample PM34 can be considered for extrusion trials and scale-up studies.

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