



# Effect of polyalkyl acrylate mixture on PVC for property modification

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**Abstract:** Poly(vinyl chloride) (PVC) belongs to a major class of commodity plastics which possess many unique properties that are suitable for a wide variety of domestic, technical and industrial products. However, due to its low impact strength and poor thermal behavior, the polymer is often mixed with other polymers to improve its properties. With this conception in view, the present study aims at improving the mechanical properties of PVC by incorporating a mixture of polyethyl acrylate (PEA) and polybutyl acrylate (PBA) in varying proportion and to assess the dynamics of mechanical behavior within the range of the PVC and polyalkyl acrylate blends under consideration. The polyalkyl acrylates are well known to be rubbery in character and exert their modifying influences in improving the toughness of the blended systems. The influence of the more rubbery PBA moieties, however, is expected to be more pronounced in improving the toughness and elongation at break (EB), with variation in PBA content. The increment in ductility is also associated with a simultaneous variation in the load bearing characteristics as manifested by modulus and ultimate tensile strength (UTS).

**Keywords:** Polyvinyl chloride, Polyethyl acrylate, Polybutyl acrylate, Mechanical properties

## I. INTRODUCTION

The inherent problems of poor impact strength and the difficult processing of poly(vinyl chloride) (PVC) have been reported to be overcome by the process of blending with certain other polymeric materials, which are referred to as impact modifiers and processing aids [1,2]. The incorporation of acrylic polymers in PVC is analogous to the rubber toughening of glassy polymers [3,4]. The present study entails the blending of two types of polyalkyl acrylates, namely poly(ethyl acrylate) (PEA) and poly(butyl acrylate) (PBA) in definite proportion, in a matrix of PVC and their characterization with reference to their mechanical properties. The polyacrylates are well known to be rubbery in character, having glass transition temperatures  $T_g$  below room temperature ( $T_g$  of PEA is  $-27^\circ\text{C}$  and PBA is  $-45^\circ\text{C}$ ). These rubbery polyacrylates, when incorporated within PVC, exert their modifying influences in improving the toughness of the blended systems [5,6]. The influence of the more rubbery PBA moieties, however, appears to be more pronounced in improving the toughness and elongation at break (EB), with increase in PBA content in the mixture [7,8]. The increment in ductility is also associated with a simultaneous improvement in the load bearing characteristics, as manifested by modulus and ultimate tensile strength (UTS) [9,10].

In the present study, PVC is chosen as the major matrix in which the mixture of polyalkyl acrylates have been incorporated. 80 parts by weight of PVC is blended with 20 parts by volume of the mixture of PEA and PBA. The mixture of PEA and PBA are incorporated in proportionate measures such that the overall dose of the mixture is maintained at 20 parts by volume. The dynamics of the mechanical parameters such as modulus, ultimate tensile strength, elongation at break and toughness are analyzed with respect to increase in polybutylacrylate content in the mixture. The mixture augments to the improvement in the mechanical properties of the base reference compound PVC wherein the influence of the PEA and PBA moieties are explicit in the corresponding figures.

## II. EXPERIMENTAL

### Materials

PVC (Reon, K value 67) from M/s Reliance Industries, Mumbai, India, was used as the matrix resin. Dioctyl phthalate (DOP) from M/s Burgoyne (India) and tribasic lead sulfate (TBLS) from M/s Kalpana Industries (Daman, India) were used as suitable plasticizers and stabilizers respectively. Poly(ethyl acrylate) (PEA) and poly(butyl acrylate) (PBA) from M/s Burgoyne (India) was purified by washing first with 2% aqueous sodium hydroxide (NaOH) solution and then by thorough and repeated washing with distilled water (to make it alkali-free as tested by litmus paper) and dried over fused calcium chloride ( $\text{CaCl}_2$ ). It was finally vacuum-distilled. Benzoyl peroxide ( $\text{Bz}_2\text{O}_2$ ) from LobaChemie (India) was purified by repeated crystallization from chloroform and was used as initiator for acrylic polymerization.



## Method

A weighed amount of purified polyalkyl acrylate was taken in a test tube and thoroughly mixed with 2% by weight (based on PEA or PBA) of recrystallized  $Bz_2O_2$ . PVC resin was weighed, such that a predetermined ratio of 80:20 with respect to the monomer was just made. The resin was taken in an air-tight dry blender and mixed with 30 parts of DOP and 2 parts of TBLS with respect to the amount of PVC resin taken. The initiator containing monomer was then added to the premix of PVC along with the plasticizer and stabilizer. Dry mixing was further continued, unless a thoroughly mixed blend of PVC and monomer was obtained. The mix was then compression-molded into sheets, by subjecting a three-piece mold under pressure and heat in two stages.

PVC resin (80 parts by weight) was taken in an air tight dry blender and mixed with 30 parts by volume of dioctyl phthalate (DOP) plasticizer and 2 parts by weight of tribasic lead sulphate (TBLS) heat stabilizer with respect to the amount of PVC resin taken. The ethyl acrylate and butyl acrylate monomer (20 parts by volume) premixed with benzoyl peroxide initiator (2 parts by weight) was added to the PVC mix and mixed thoroughly in the blender at a slightly elevated temperature unless a thoroughly mixed powder was obtained. A number of batches were prepared varying the dose of the acrylates from 4:1, 3:2, 2:3, 1:4 ratio by volume. The mixes were then moulded by compression in a compression moulding machine into sheets under heat and pressure which was then subjected for mechanical testing in Instron Universal tester. Initially, the mould (0.95 m x 0.65 m x 0.001 m) with the mixed powdery content was heated at a temperature of 80°C to initiate and propagate acrylate polymerisation. This was allowed to continue for 30 min. Subsequently, the temperature was raised to 160°C while a pressure of 15 tons/cm<sup>2</sup> was maintained for 5 minutes. The mould was then cooled down to 100°C and kept for 30 min to ensure complete polymerization. Consequently, the mould was allowed to cool down to the room temperature and the moulded sheet ejected.

## Characterization

An Instron Universal Testing Machine (Model 4204) was used for measuring the tensile properties like modulus, ultimate tensile strength, elongation at break and toughness. In the process of measurement, ASTM D638 method was followed.

## III. RESULT AND DISCUSSION

The modulus and ultimate tensile strength of PVC blended with PEA and PBA in definite ratio, as depicted in Fig 1 and Fig 2, display an upward swing with rise in polybutyl acrylate incorporation within the PVC matrix. On incorporating the polyalkyl acrylates into the linear PVC matrix, the molecular interaction between the two participating polymeric components possibly comes into play. The properties exhibited by the blended systems in varying ratio of PEA and PBA may be considered as an effect of two opposing forces operating simultaneously; the secondary valence force due to formation of H bonds through the strongly electronegative chlorine in PVC and the hydrogen of the ester group present in PEA and PBA. This appears to be predominating over the weakening dipolar forces between the adjacent PVC chains.

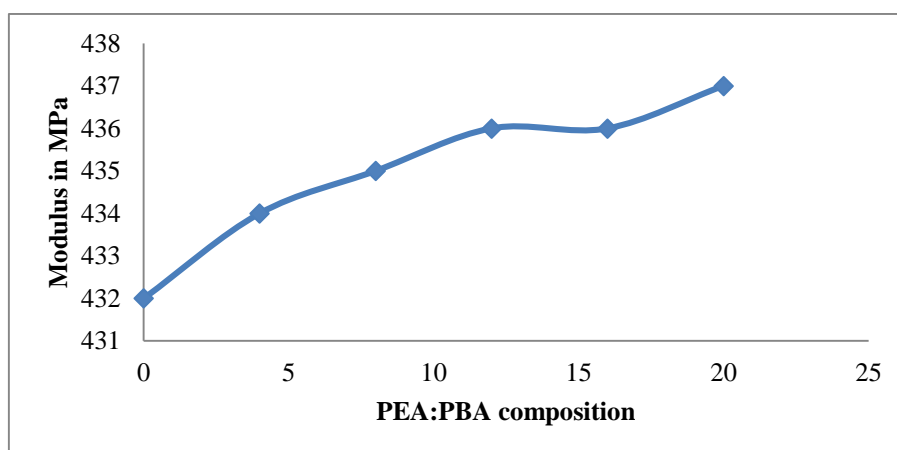


Fig. 1 Variation of modulus with PEA:PBA composition

The increases in modulus and ultimate tensile strength of the blends in definite proportion of the polyalkyl acrylates may possibly be attributed to another possible intermolecular hydrogen bonding between the  $\infty$  hydrogen of vinyl chloride chain unit with the ester carboxylate group. These two factors can be accounted for the observed miscibility in this region of acrylate incorporation. At the later stages of polyacrylate incorporation, the plasticizing influence of the somewhat rubbery polyalkyl acrylate moieties appears to play the major role. An increase in the percentage of polyalkyl acrylate ratio imparts flexibilization within the linear chains of PVC and nullifies the effect of the interaction as mentioned earlier. The observed facts in the present case simulate the “antiplasticization” phenomenon exhibited by PVC polymers at temperatures below  $T_g$ .



The effect of the even more rubbery and bulky PBA plays a more dominating role. Hence the modulus and ultimate tensile strength tends to level off at the higher proportion of PBA incorporation.

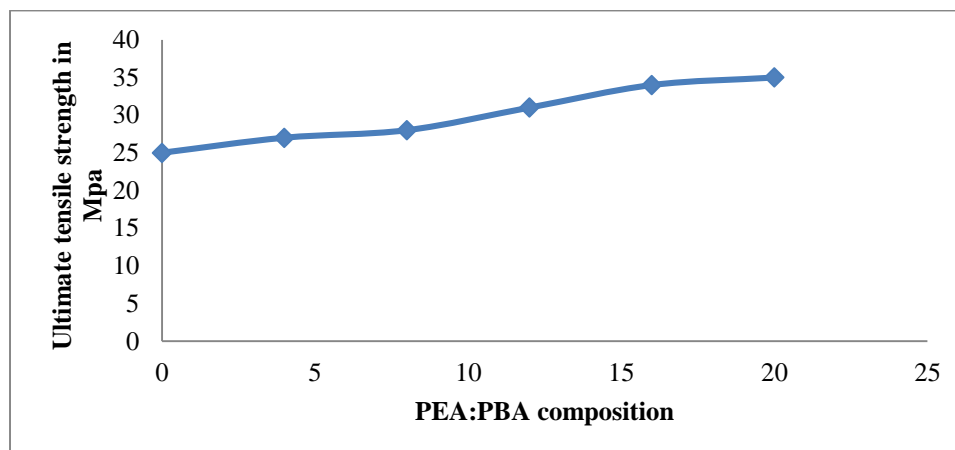


Fig. 2 Variation of ultimate tensile strength with PEA:PBA composition

The changes in elongation at break and toughness are in accordance with the changes in modulus and ultimate tensile strength, as shown in Fig 3 and Fig 4. It has been observed that there has been a steady increase in percent elongation at break. The blends exhibit higher elongation at higher doses of the polybutyl acrylates, which appear to be quite obvious because of the more rubberiness of PBA. The toughness of the blend systems also demonstrates a similar pattern like that of changes in percent elongation at break. Thus predominance of the interactive secondary valence forces over the expected softening because of the plasticizing effect of the polyalkylacrylate chains is not demonstrated but is rather followed by the classical mechanism of rubber toughening throughout the range of PEA:PBA ratio under study. Thus, though the PVC chains are expected to be thrown apart by the plasticizing influence of the polyalkyl acrylate moieties, the chains appear to concentrate because of this secondary valence force.

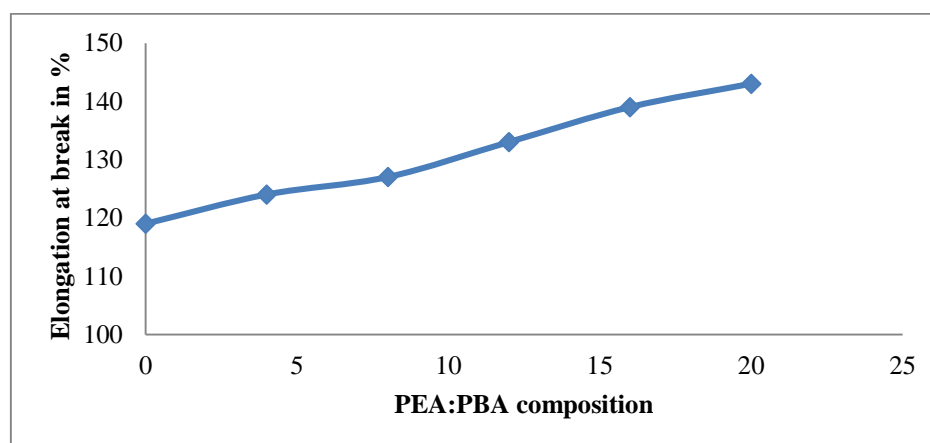


Fig. 3 Variation of elongation at break with PEA:PBA composition

It is to be noted that all the mechanical parameters studied always lie much above the corresponding values of unmodified plasticized resin (base compound). So by the incorporation of the polyalkyl acrylate polymers in definite ratio of PEA:PBA, the mechanical properties of the base reference compound PVC is modified in terms of modulus, ultimate tensile strength, elongation at break and toughness.

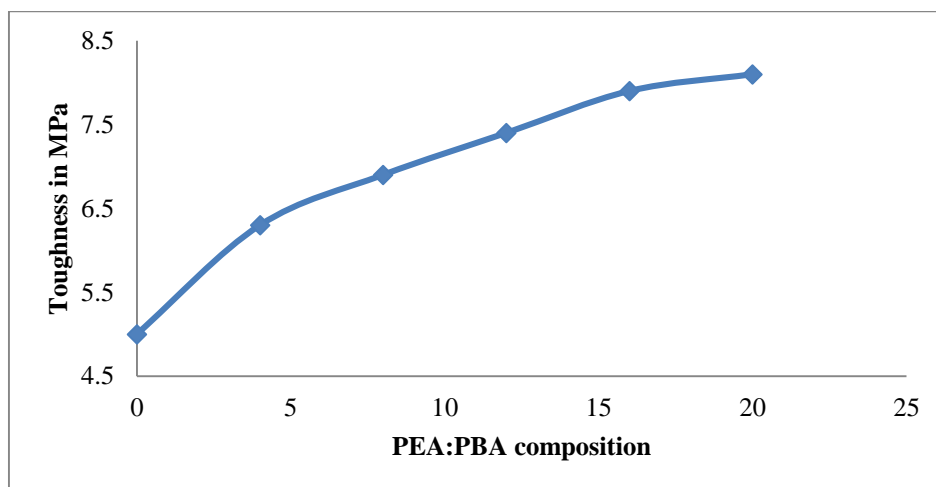


Fig. 4 Variation of toughness with PEA:PBA composition

#### IV. CONCLUSION

The systems under study reveals the effect of blend formation of PVC with PEA and PBA in definite ratio over that of the unmodified reference compound. The introduction of the acrylate moieties into the PVC matrix raises the mechanical properties. The combination of two polymers also creates a directing influence one over the other, which is explicit from the displayed figures. It is thus evident that the formation of blend has a measurable effect on the various mechanical properties which in turn modifies the base reference compound PVC.

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