

Mechanical Properties of ABS/Polycarbonate Blends

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Synopsis

The mechanical properties of extruder compounded blends of ABS and polycarbonate in the form of extruded-sheet and injection-molded bars are reported and compared with commercial products based on these components. The modulus and tensile yield strength exhibit a nearly additive response to blend composition while percent elongation at break shows a minimum vs. composition. Notched Izod impact strength is nearly constant at the level of pure ABS up to 50% polycarbonate and increases rapidly upon further addition of polycarbonate.

INTRODUCTION

Blends or alloys of polycarbonate with ABS polymers have been commercially available for some time.¹⁻⁴ They are reported to provide a useful balance of toughness, heat resistance, and ease of processing at a cost lower than that of the high performance engineering thermoplastic polycarbonate.¹⁻³ Blending with polycarbonate may be viewed as a means of boosting the performance of ABS so that it becomes a more competitive engineering thermoplastic. In addition, the notched Izod impact strength of commercially available blends are higher than those of pure polycarbonate when 0.25-in. test bars are compared owing to reduced sensitivity of fracture behavior to specimen thickness compared to pure polycarbonate.^{1,5,6}

In general, one does not expect to be able to blend arbitrarily chosen plastics and obtain good properties because of the high probability they will be incompatible.^{3,6,7} Thus, it is of interest to know something about why ABS and polycarbonate can be successfully blended into commercial products. This paper examines the relationship between mechanical properties and composition of ABS and polycarbonate blends which have been fabricated into thin sheets by extrusion and into test bars by injection molding. Since ABS is itself a complex alloy which can be chemically and physically structured in a variety of different ways,⁸ these results should not be viewed as representative of an optimized system; however, they do seem typical of some commercial products.

A subsequent paper⁹ will examine in more detail the properties and phase behavior of polycarbonate blends with styrene-acrylonitrile (SAN) copolymers which form the glassy matrix phase of ABS plastics. The interactions between polycarbonate and SAN described there are believed to be impor-

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tant factors in the property relationships reported here. The acrylonitrile content of the SAN has been found to have a strong influence on the interactions with polycarbonate and could be a useful tool for optimizing the behavior of polycarbonate/ABS products, although that issue has not been examined here.

MATERIALS AND PROCESSING PROCEDURES

The bisphenol A polycarbonate used in this study is a commercial product of the General Electric Co. designated as Lexan 131-111, which has $\bar{M}_n = 13,300$ and $\bar{M}_w = 34,200$. The ABS used is a commercial product of the Abtec Chemical Co., designated as Abson 89170, having the following characteristics: specific gravity = 1.04, notched Izod = 7.0 ft · lb/in. at 73°F, heat deflection temperature = 87°C at 264 psi (ASTM D 648), and melt index = 2 g/10 min (ASTM D 1238, Condition I). The rheological characteristics of the two polymers are indicated in Figure 1, where Brabender torque is plotted vs. melt temperature for each. The polycarbonate is more viscous for all practical processing temperatures.

All blends were made by melt mixing in a 0.75 in., $L/D = 20$ laboratory extruder. Prior to this step, pellets of the two polymers were combined in the desired proportion and dried in an air oven for 20 h at 70°C and 2 h at 85°C to remove sorbed water, which would cause degradation of the polycarbonate and defects in the product. Processing temperatures had to be carefully selected since higher temperatures are normally used for polycarbonate than are permissible for ABS. Exposure to excessive melt temperatures causes serious reduction in the toughness of ABS because of thermal instability of the unsaturated rubber particles present.¹ In view of this, the processing temperature was never set above 260°C when ABS was present, and this temperature was gradually lowered as the amount of ABS in the mixture increased. Temperatures approaching 300°C would be more convenient for polycarbonate alone.

To fabricate sheet, a slit die was attached to the extruder and the extrudate was collected by a chilled roll takeoff system. The draw ratio, defined as the ratio of the peripheral velocity of the roll to the average velocity in the die, was held constant at 10, which results in modest orientation levels.¹⁰ Typical specimens were 0.011 in. thick and 2.5 in. wide.

To fabricate injection-molded bars, a rod die was attached to the extruder, and the extrudate was passed through a cold water bath and then chopped

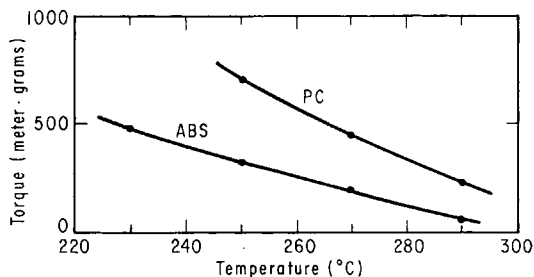


Fig. 1. Brabender torque for polycarbonate and ABS.

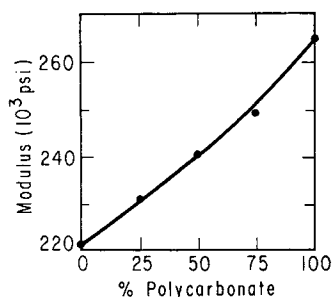


Fig. 2. Apparent modulus of ABS/polycarbonate sheet.

into pellets. These pellets were dried using the protocol described above prior to injection molding by a ram type machine using melt temperatures similar to those in the extruder. The molded specimens were in the form of dog bones (ASTM D 638) and Izod bars (ASTM D 256).

MECHANICAL PROPERTIES

Strips 0.375 in. wide were cut from the extruded sheet for mechanical testing with an Instron. The gauge section between the grips was 10 in., and this value was used in the data reduction. A crosshead speed of 0.5 in./min was used to determine the modulus. Deformation was assumed to be equal to the crosshead travel with no correction applied for any deformation which may have occurred in the grips. Yield and failure properties were measured at a crosshead speed of one inch/min.

Plots of modulus (Fig. 2) and yield strength (Fig. 3) vs. blend composition both fall slightly below the linear line of additivity connecting the values for pure polycarbonate and pure ABS. As seen in Figure 4, the percent elongation at break on the other hand deviates markedly from additivity with a pronounced minimum occurring in the middle of the composition range. Even at the minimum, however, the samples exhibited yielding and

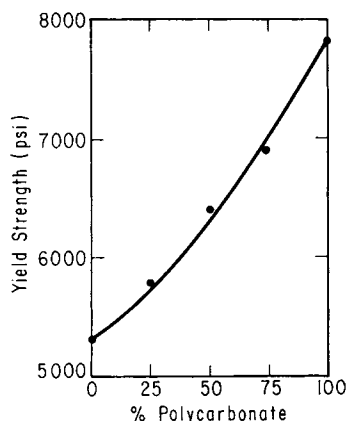


Fig. 3. Tensile yield strength of ABS/polycarbonate sheet.

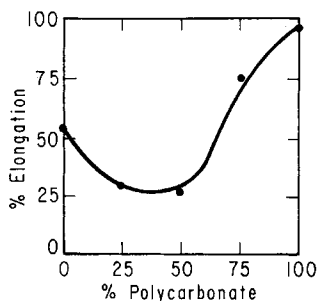


Fig. 4. Percent elongation at break for ABS/polycarbonate sheet.

extended by more than 25% prior to breaking. Thus, the blends do show considerable ductility compared to most incompatible mixtures.¹¹

Injection-molded dog-bone specimens were tested with the Instron at a crosshead speed of 0.5 in./min to obtain the modulus and the yield or failure properties. An extensometer with a 1-in. gauge section was used in determining the modulus; however, for the present elongation at break, deformation was assumed equal to crosshead travel and a value of 4.25 in. was used for the effective gauge length.

The moduli for the injection molded bars (Fig. 5) are significantly higher than those for the extruded sheet, and two factors may be cited as the cause for this. First, the injection-molded bars are no doubt more oriented than were the extruded-sheet, which would lead to higher moduli.¹⁰ Further evidence for this may be seen by comparing yield strengths of the materials processed by these two methods. The yield strengths for injection molded bars (Fig. 6) are slightly larger for all compositions compared to those given in Figure 3 for extruded sheet. Second, the moduli obtained for sheet is only an effective value since strain was not directly measured. Extra deformation in the grips, not accounted for here, does occur¹² and would tend to make the effective modulus less than the true value which would be obtained by correcting for this effect using a simple analysis of data from strips of various lengths.¹² Casual observation might lead one to think there is a larger curvature or departure from additivity of the modulus data in Figure 5 than in Figure 2, but this is primarily an illusion of the more

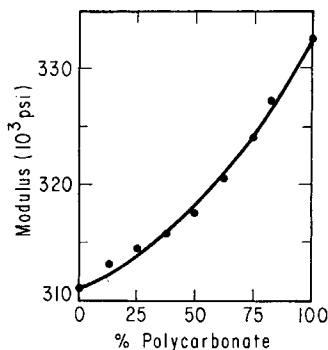


Fig. 5. Modulus of injection-molded ABS/polycarbonate blends.

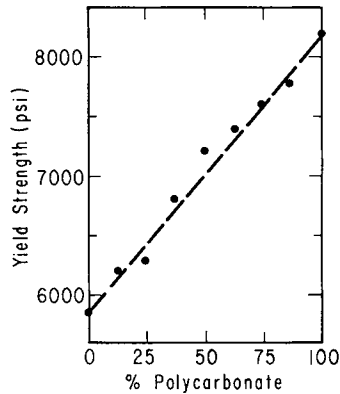


Fig. 6. Tensile yield strength of injection-molded ABS/polycarbonate blends.

expanded scale used in the former. Interestingly, the moduli for polycarbonate and ABS differ by about 43,000 psi for extruded sheet, whereas, for the injection-molded materials, they differ by about half this amount. This arises from the fact that injection molding caused a larger increase in the modulus of ABS compared to extrusion than was the case for polycarbonate. This may be surprising since polycarbonate has a higher viscosity and hence ought to have a greater orientation response to deformation than ABS. However, the two-phase nature of ABS may alter this expectation.

The yield stress for the injection molded blends is shown vs. composition in Figure 6. In the midcomposition region these data fall slightly above the dashed line drawn connecting values for pure polycarbonate and ABS.

The percent elongation at break for the injection molded materials is shown in Figure 7 as a function of blend composition. The values for pure polycarbonate and ABS are approximately the same as those for extruded sheet. However, values for the midrange blends are approximately one-third of those obtained for extruded sheet. Thus, we may conclude that the higher deformations in molding compared to extrusion tend to reduce the ductility of these blends. The same factors are probably responsible for the increase in yield strength for these blends seen by comparing the data in Figure 6 with those in Figure 3.

The Izod bars (ASTM D 256) prepared simultaneously with the dog bone specimens were notched and fractured by a 5 ft · lb hammer using a TMI

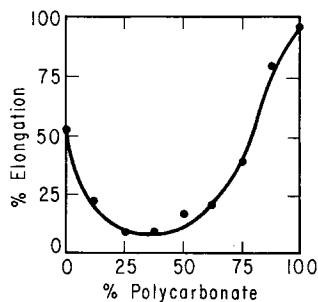


Fig. 7. Percent elongation at break for ABS/polycarbonate blends.

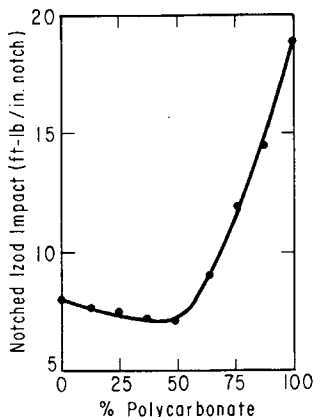


Fig. 8. Notched Izod strength for injection-molded ABS/polycarbonate blends.

Impact Tester. The results are shown in Figure 8. The impact strength decreases slightly until the blend composition reaches 50% polycarbonate. After this point, there is a rapid increase in toughness up to that for pure polycarbonate. Roughly speaking, blends having less than 50% polycarbonate have essentially the same impact strength as ABS while blends having more than 50% polycarbonate have impact strengths smoothly varying between the limits of polycarbonate and ABS. It is interesting to note that the departures from additivity are not as great for the Izod impact strength as they are for the percent elongation at break. For many of these specimens, the fracture path did not travel straight across the sample but often curved and reversed its direction. A detailed examination of the fracture mechanics for this system would be most interesting.

Some limited mechanical property data for an analogous system have been reported (4) which may be compared with that reported here on injection molded materials. The impact strength and the percent elongation at break compare very closely. The trends for tensile strength are similar but the absolute values do not compare exactly. No modulus data were given in the previous work.

SUMMARY AND CONCLUSIONS

The mechanical properties of polycarbonate/ABS blends show similar trends with composition for both extruded and injection-molded samples, although the absolute values of certain properties differ. Modulus and strength are essentially additive, but tensile elongation at break has a pronounced minimum when plotted versus blend composition. The notched Izod impact strength remains close to that of pure ABS up to 50% polycarbonate after which a steep increase occurs with further polycarbonate addition. While the ductility sensitive properties, percent elongation and impact strength for these blends fall below predictions from simple additivity, polycarbonate/ABS blends do show considerably better property relationships than many other immiscible systems. Care must be exercised during processing these blends so that the thermal stability limit of the

ABS (about 260°C) is not exceeded yet the temperature must be high enough so that the polycarbonate is not excessively viscous. The molecular weight of the latter will affect the width of this processing window.

Commercial ABS/polycarbonate alloys^{1-3,13} have room temperature notched Izod impact strengths of about 10.5 ft · lb/in. Based on the data in Figure 8, this would suggest a polycarbonate content of about 70% by weight. From Figures 5-7, this composition has a modulus of 322,000 psi, tensile yield strength of 7500, and a percent elongation at break of about 30%. The properties reported for the commercial blends lie in the following ranges: tensile yield ~ 8000-8500 psi, tensile modulus ~ 370,000-380,000 psi, and percent elongation ~ 10-15%. These compare reasonable well with the results from Figure 5-7, considering possible differences in testing conditions, ABS type, and additives that may be present in commercial products.

As mentioned earlier, a subsequent paper⁹ considers in more detail the interactions between the SAN matrix of ABS and polycarbonate.

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