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High-Impact Polystyrene. II. Physical Properties and Elastomer Content in the Latex-Suspension Method

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Synopsis

The latex-suspension technique is used to prepare a family of rubber-modified polystyrene resins possessing high-impact resistance (Izod ca. 1.5 ft-lb/in.), high gloss, high heat distortion temperature, and high tensile properties. Data are presented on the preparation of medium- and low-impact grades by physical blending with crystal polystyrene and on the preparation of ultrahigh-impact polystyrene (Izod ca. 3.5 to 6) through the incorporation of high concentrations of rubber made feasible by the latex-suspension process.

INTRODUCTION

The latex-suspension method of preparing high-impact polystyrene (HIPS) is a simple one-step process in which a mixture of the latex, monomer, catalyst, additives, suspending agent, and water is reacted at a given temperature. Although the starting elastomer is added as an emulsion, during the course of the reaction it transfers to a suspension phase and the product is recovered in the form of suspension beads. The technique has been described previously[1] and compared with conventional methods of preparing HIPS.

A family of latex-suspension polystyrene resins prepared with a hot emulsion PBD latex is now discussed: the basic formulation, physical properties, elastomer content, and cutback studies. Resultant properties are compared with commercial high-impact polystyrene.

EXPERIMENTAL

A typical formulation for latex-suspension HIPS is given in Table I.

General experimental procedure and most reagents have been described previously.[1] The catalyst *t*-butyl peracetate is available from Lucidol. FR-S 2004 polybutadiene latex (Firestone) is typified by a large particle (2750 Å mass average) and high toluene gel content (85% minimum). Polymerization is approximately 16% each cis and vinyl and 68% trans.[2] The elastomeric content of the latex was considered to be equivalent to the total solids content (actually, part of the latter is emulsifier and other additives). All percentages in formulations are based upon the sum of the styrene and elastomer contents.

RESULTS AND DISCUSSION

Selected Physical Properties

Table II shows the reproducibility of selected physical characteristics of the experimental HIPS containing 10% PBD and compares them with Cosden 825 and 850 HIPS. Experimental runs listed include both the basic formulation (Table I) and minor variations which were shown to

TABLE I
Typical 5-Liter Formulation for Latex-Suspension HIPS

Styrene, g	1350
FR-S 2004 PBD latex,[a] g	254.6
Demineralized water, g	3000
Benzoyl peroxide, g	3.75
Poly(vinyl alcohol), g	9.00
Wingstay T antioxidant, g	4.50
Temperature, °C	93
Time, hr	8
Stirrer speed, rpm	600
Atmosphere	nitrogen blanket, water-cooled condenser

[a] Latex contains 58.9% total solids.

Fig. 1. Effect of elastomer concentration on the impact resistance of experimental HIPS.

have no effect. Overall reproducibility is good and is not affected by scaleup from 5-liter flasks to 22-liter flasks. Table II shows that there is no discernible difference in the Izod value of the experimental resin between extruded and nonextruded samples. Reproducibility is also good, the mean

TABLE II
Reproducibility of HIPS Basic Formulation

Run no.	Extruded[a]	Izod,[b] ft-lb/in.	Specular gloss, %	Rockwell M hardness	Heat distortion temp.,[c] °C	Remarks
1	no	1.7	45	45	—	d
2	no	1.7	52	35	—	d, e
3	no	1.4	32	44	—	d
4	no	1.5	58	42	—	d
4	yes	1.7	71	38	—	d
5	no	1.4	75	38	—	d, e
6	no	1.7	53	28	—	d, e
7	no	1.5	57	44	—	d
8	no	(0.6)	(80)	(21)	—	d, f
9	no	1.3	57	36	—	d, f
10	no	1.3	58	31	—	d, f
11	no	1.2	61	38	87.5	f, g
12	yes	1.6	73	38	91	f, g
13	yes	1.5	70	41	91	f, g
14	no	1.2	55	—	94	d
15	yes	1.2	—	—	94.5	d
16	yes	1.6	—	—	93.5	d
17	yes	0.8	59	41	88	g
18	yes	1.1	70	39	90	g
19	no	1.2	41	43	90	d
20	no	1.4	35	43	90	d
21	no	1.3	45	42	86	d
Mean values overall		1.4 ± 0.2	56 ± 12	39 ± 5	91 ± 3	
Mean values extruded		1.5 ± 0.2	68 ± 5	39 ± 1	92 ± 2	
Mean values nonextruded		1.4 ± 0.2	52 ± 11	39 ± 5	90 ± 3	
Cosden 825[h]		1.5 ± 0.2	69 ± 4	48 ± 2	86 ± 1	
Cosden 850[h]		1.7 ± 0.1	58 ± 3	48 ± 1	93 ± 1	

[a] A 1$^1/_2$-in. extruder with an *L/D* ratio of 24/1 was used. Extrusion temperature was 375–400°F exiting the die.

[b] Samples were molded on a commercial injection molding machine manufactured by the New Britain Machine Company, New Britain, Connecticut.

[c] Heat distortion temperatures (ASTM D-648-56) were measured at 264-psi load on specimens which had been annealed for 16 hr at 70°C.

[d] Five-liter run.

[e] Per cent antioxidant varied.

[f] Per cent solids varied.

[g] Twenty-two-liter run.

[h] Cosden Oil and Chemical Company.

impact resistance being 1.4 ± 0.2 ft-lb/in. This is to be compared with Cosden 825 at 1.5 ± 0.2 ft-lb/in. and Cosden 850 at 1.7 ± 0.1 ft-lb/in.

Specular gloss values on experimental samples are shown in Table II to be improved in value and reproducibility by extrusion. The mean gloss value of the extruded experimental sample is 68 ± 5, while the unextruded sample had a mean gloss of 52 ± 11. These are to be compared with the mean values of 69 ± 4 for Cosden 825 and 58 ± 3 for Cosden 850.

Extrusion had no effect on Rockwell M hardness or on heat distortion. The annealed heat distortion temperature of the experimental material, 91 ± 3°C, is comparable with the 93°C value obtained for Cosden 850, a high heat grade. It is superior to Cosden 825 in this respect, the latter having an annealed heat distortion temperature of 86°C. However, the experimental material falls short of the Cosden material on Rockwell M hardness. Both 825 and 850 HIPS have a hardness value of 48. The value of the experimental HIPS is 39 ± 5.

The excellent elongation and good overall tensile properties of the experimental HIPS are shown in Table III. They compare well with experimentally obtained values for each of the commercial materials.

Elastomer Content

Table IV and Figure 1 summarize data on latex-suspension HIPS containing 7% to 25% PBD in the original formulation. Least-squares fit of experimentally determined Izod values in this range results in the following linear equation:

$$y = 0.303x - 1.454$$

where y is the Izod value in ft-lb/in. and x is the percentage of FR-S 2004 PBD in the composition. As is seen in Figure 1, the experimental data fit the calculated straight-line plot. The greatest deviation, 0.3 ft-lb/in., is within experimental error.

These data are compared below with the physical cutback of experimental HIPS with crystal polystyrene.

TABLE III
Representative Tensile Properties of Experimental HIPS Containing 10% PBD Compared with Cosden HIPS

Run no.	Tensile, psi	Elongation, %	Modulus, psi
22[a] Nonextruded	3893	53	2.6×10^5
11[a] Nonextruded	3637	55	2.7×10^5
11 Extruded	3727	46	2.6×10^5
Cosden 825	2870	41	3.0×10^5
Cosden 825 extruded	3200	44	3.4×10^5
Cosden 850 extruded	4400	57	2.5×10^5

[a] Run 11 is a 22-liter version of run 22, a 5-liter run. Both contain the standard formulation given in Table I.

TABLE IV
Effect of Elastomer Concentration on the Physical Properties of Experimental HIPS[a]

Run no.	FR-S 2004 PBD, %	Izod value, ft-lb/in.	Specular gloss, %	Heat distortion temp.,[b] °C	Remarks
23	7	0.8	62	—	d, f
24	7	0.7	—	—	d, f
25	8	0.7	78	—	d, f
26	8	0.7	89	—	d, f
27	9	1.4	63	—	d, f
28	9	1.2	67	—	d, f
Typical[c]	10	1.4 ± 0.2	52 ± 11	90 ± 3	d, f
			68 ± 5	92 ± 2	e, f
29	15	3.6	19	—	d, f
30	15	2.5	25	92	d, f
31	15	3.2	45	87	e, g
32	15	2.6	27	87	e, g
33	15	3.8	38	91	e, f
		3.1 ± 0.6	31 ± 13	89 ± 3	
34	20	4.8	34	88	d, f
35	25	6.2	27	88	d, f

[a] In addition to styrene and FR-S 2004 PBD latex, these runs contain 0.25% benzoyl peroxide, 0.30% Wingstay T antioxidant, poly(vinyl alcohol) varying in content from 0.30% to 2.0% based upon PBD content, suspension water, and G. E. Antifoam 72, where necessary

[b] Annealed.

[c] See Table II.

[d] Nonextruded.

[e] Extruded.

[f] Five-liter run.

[g] Twenty-two-liter run.

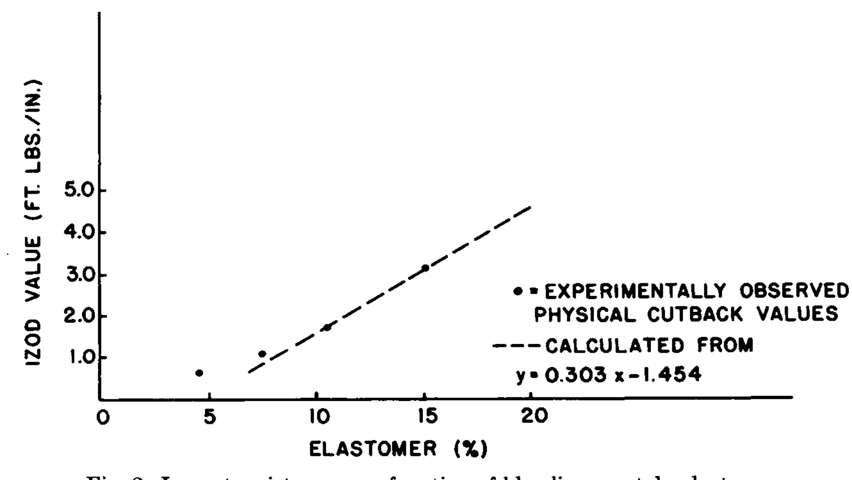

Fig. 2. Impact resistance as a function of blending crystal polystyrene with latex-suspension HIPS containing 15% PBD.

Cutback Studies

Medium- and low-impact grades of polystyrene may be prepared by physical blending with crystal polystyrene. The cutback samples are homogeneous, have excellent color, gloss which improves with cutback, and impact resistances appropriate for the degree of cutback. Data are presented in Tables V and VI and Figures 2 and 3.

TABLE V
Cutback Data for Experimental HIPS Containing 15% FR-S 2004 PBD[a] Blended with Crystal Polystyrene[b]

Run no.	HIPS, %	PBD, %	Izod value, ft-lb/in.	Specular gloss, %	Heat distortion temp.,[c] °C
31	100	15	3.2	45	87
	70	10.5	1.4	66	86
	50	7.5	0.87	67	84
	30	4.5	0.49	79	80
32	100	15	2.6	27	87
	70	10.5	1.6	58	88
	50	7.5	0.92	56	86
36	70	10.5	1.9	54	92
	50	7.5	1.1	76	91.5
	30	4.5	0.53	90	90.5
37	50	7.5	1.2	66	90
	30	4.5	0.55	82	89.5
Mean values	100[d]	15	2.9 (3.1)	36 (31)	87 (89)
	70	10.5	1.6	59	89
	50	7.5	1.0	66	88
	30	4.5	0.54	84	87

[a] These runs also contained 0.25% benzoyl peroxide, 1% poly(vinyl alcohol), 0.30% Wingstay T antioxidant, suspension water, and G. E. Antifoam #72. The material was extruded before blending.

[b] The blends were made by intimate physical mixing of the two polymers, followed by extrusion compounding and then injection molding.

[c] Annealed.

[d] Mean values for five runs taken from Table IV are given in parentheses.

TABLE VI
Physical Characteristics of Experimental HIPS[a] Containing 21% FR-S 2004 PBD Blended with Crystal Polystyrene

FR-S 2004 PBD, %	Izod, ft-lb/in.	Specular gloss, %	Rockwell M hardness
21	5.9	24	—
10	2.0	44	39
7	1.3	58	52
5	0.9	67	61

[a] This formulation (run 38) includes 0.10% benzoyl peroxide, 0.03% *t*-butyl peracetate, and 0.30% poly(vinyl alcohol).

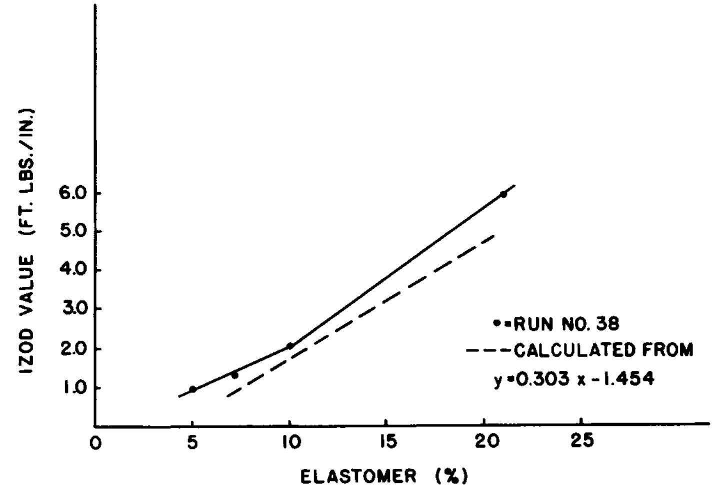

Fig. 3. Impact resistance as a function of blending crystal polystyrene with latex-suspension HIPS containing 21% PBD.

Physical cutback data on HIPS containing 15% FR-S 2004 PBD (Table V) obey the least-squares equation calculated above for chemically cutback HIPS within the range where it is applicable. If one cuts back a 15% PBD HIPS resin to 10.5% PBD (70/30 ratio), one obtains an Izod value of 1.6 ft-lb/in., as is predicted by the equation.

Table VI lists data obtained by cutting back material prepared in a 10-gallon pilot scale run (run 38) using 21% FR-S 2004 PBD and a modified dual-catalyst formulation. This resin had an Izod of 5.9 ft-lb/in. before cutback and, as is seen in the table and in Figure 3, gives excellent impact resistances after blending and results in Izod values even better, for corresponding elastomer contents, than those given in Table V. Thus, for example, blending run 38 back to 10% FR-S 2004 PBD results in a resin whose Izod value is 2.0 ft-lb/in., compared with 1.5 ft-lb/in. predicted by the above equation which was based upon a different formulation.

CONCLUSIONS

The latex-suspension technique has been used to develop a family of high-impact polystyrene resins with good impact resistance, color, heat distortion temperature, tensile properties, and gloss.

This technique permits the incorporation of high levels of elastomer. Ultrahigh-impact polystyrene has been prepared by incorporation of 15% to 25% PBD in the resin.

Physical and chemical cutback of the experimental family of high-impact polystyrene resins to produce medium-impact resins result in corresponding impact resistances which obey a least-squares equation.

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References

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