Creating Aesthetics and Functional Values in Cotton Fabrics through the Introduction of Thermobonding Amorphous Polyester Fibers into Blends

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ABSTRACT: Low-melting thermobonding PET (copolymer) fibers were used to produce heather effects in fabrics blended with cotton, which could be classified as natural 100% cotton fabrics. PET (copolymer) fibers produced at relatively low molecular weights with intrinsic viscosities of 0.57 and 0.47 were used in this investigation. These were mostly amorphous fibers that showed a low specific gravity at 1.27 g cm^{-3}. The fibers were blended with cotton to produce open-ended spun yarns without the PET component being melted. These yarns were knit into fabrics and cured. The curing was based on the thermal behavior of these fibers as observed in differential scanning calorimetry thermograms. The amount of pigmented PET copolymer needed to achieve the required heather effect was optimized by variations of the blend ratios. This approach provided another avenue for introducing additional functional properties, such as antibacterial and soil-resistance properties, to the fabric. Both the fibers and resultant fabric properties were studied extensively, along with the finishing of these fabrics. © 2003 Wiley Periodicals, Inc. J Appl Polym Sci 89: 3747–3756, 2003

Key words: amorphous; polyesters; melting point

INTRODUCTION

We have investigated the use of low-melting pigmented polyester fibers in blends with cotton to produce a heather effect in the fabric. Currently, this fabric is produced by the blending of solution-dyed PET with cotton fibers. The applications for this fabric include T-shirts, sweatshirts, casual shirting, socks, and active wear. Product quality has been a problem because of the inhomogeneous nature of two dissimilar fibers blended into yarn. A similar heather effect can be produced by the blending of a low-melting pigmented polyester with cotton and the heat-setting of the fabric. During the heat setting, the energy-activated polyester component will flow at a lower temperature than normal polyethylene terephthalate (PET) and will adhere strongly to the cotton substrate; this will result in the distribution of color throughout the fabric. In the fluid state, this material does not form a film but instead bonds with other fibers at various locations, and this makes the color more permanent. This fabric is regarded as 100% cotton fabric because the low-melting polyester component has been converted into a finishing agent after melting, and the use of costly stock-dyed cottons is eliminated. Furthermore, other functional properties, such as antibacterial, fire-retardant, and antistatic properties, can also be introduced into the fabric with a low-melting polyester.

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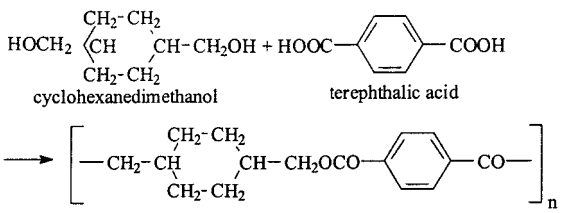
FIBER, YARN, AND FABRIC PREPARATION

The low-melting fibers used in this study were cyclohexanedimethanol (CHDM)-modified PET. The polymer was initially developed by Eastman Chemical Co. via the condensation of terephthalic acid with CHDM:



These polyester copolymer fibers were mainly amorphous, having a viscosity-related softening and flow profile. Two PETG fibers produced by Foss Manufacturing Co. were used in this study. The effect of the CHDM concentration (mol %) on the melting points is illustrated in Figure 1. The curve of the CHDM concentration versus the polymer melting point shows minima at 35%. Type 110 and 410 PETG fibers, containing approximately 35 mol % CHDM, were used in this study. The changes in the melt viscosities of these

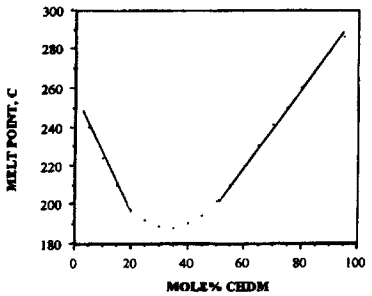


Figure 1 Effect of the CHDM concentration on the polymer melting point.[1]

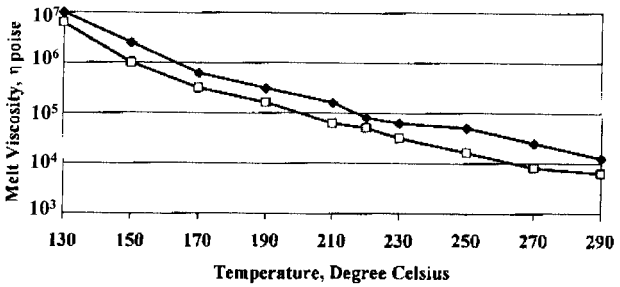


Figure 2 Viscosity–temperature relationship of PETG polymers: (♦) type 410 PETG and (□) type 110 PETG.

fibers with increasing temperature are shown in Figure 2. Type 110 PETG had a lower melt viscosity than type 410. On the basis of this melting behavior and differential scanning calorimetry (DSC) analysis, suitable heat-set temperatures for the fabrics were chosen for this investigation.

Both PETG fibers were pigmented with carbon black dispersed in linear low-density polyethylene. Type 110 fibers had a lower molecular weight and somewhat lower sticking points than type 410.

The fiber properties of both types of fibers are listed in Table I. In addition, a commercial black-pigmented homopolymer PET fiber (intrinsic viscosity (S) = 0.62) from two commercial suppliers was used. The normal black homopolymer PET control was a blend of two sources, with a fineness of 1.7 denier and a cut length of 30 mm.

DSC thermograms of both types of PETG fibers, before and after pigmentation, are shown in Figures 3–6. For both fiber types, the addition of pigments caused a slight increase in the magnitude of the main crystalline peak area. It is suggested that the pigment and dispersion aids served as nucleating agents and produced greater stress crystallization in the fiber-drawing process. However, the fibers still remained 93 and 97% amorphous, and this effectively allowed polymer flow and bonding during the heat setting by a proper selection of the temperature. The significant peaks observed near 78°C (the glass-transition temperature) were due to free-volume relaxation as the amorphous region densified, which increased with increasing temperature.

The small transition near 120°C was associated with the melting of polyethylene, which was used as a

TABLE I
Polymer and Fiber Properties of Low-Melting Pigmented Polyester

	Type 410	Type 110	PET homopolymer (black)
Intrinsic viscosity	0.59	0.47	.63
Glass-transition temperature, (°C)	78	78	120
Stick point (°C)	100–130	100–120	—
Melting Point (maximum) (°C)	180	170	250
Denier	3.6	3.6	1.7
Tenacity (g/d)	2.57	1.75	3.06
Strain (%)	51.9	43.3	41.9
Cut length (mm)	38	38	38
Specific gravity (g/cc)	1.340	1.345	1.38

TABLE II
Fabric Pilling Propensity

Black fiber concentration	10%			5%			2%		
Time cycle on tumbler	10	20	30	10	20	30	10	20	30
Black PET	3.0	2.3	1.8	3.0	2.2	1.7	3.0	2.2	1.5
Type 410 PETG	3.2	2.9	2.2	2.9	2.3	1.7	2.9	2.6	1.7
Type 110 PETG	3.2	2.4	1.8	3.1	2.0	1.5	2.7	1.8	1.3

1 = very severe pilling; 2 = severe pilling; 3 = moderate pilling; 4 = slight pilling; 5 = no pilling.

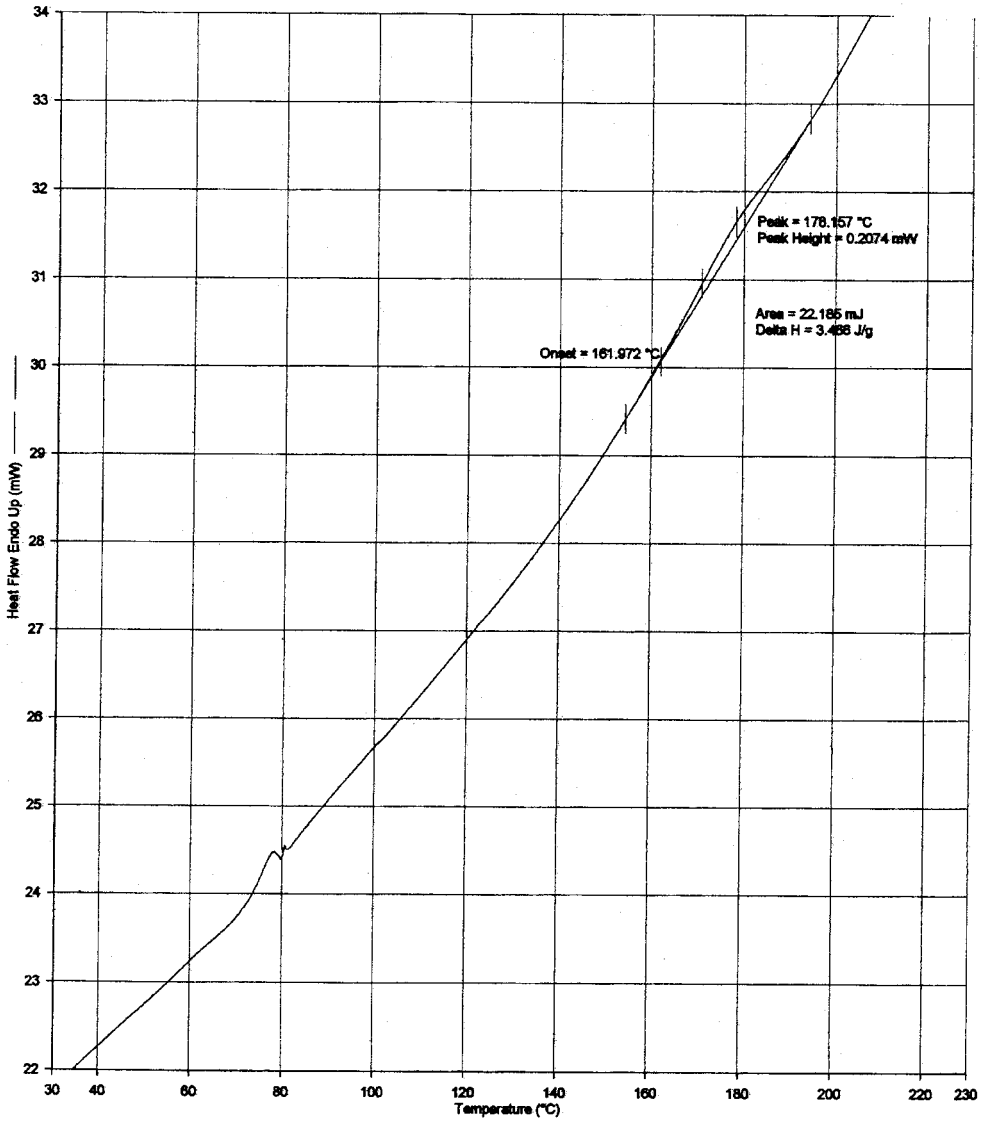


Figure 3 DSC thermogram of type 110 PETG without pigment.

pigment carrier. This peak could not be seen in the thermogram of the unpigmented, naturally colored PETG fibers. The thermogram of pigmented PET (drawn and heat-set) fibers is shown in Figure 7. As expected, the glass-transition temperature shifted to a higher temperature with a large endothermic crystal melting peak. The homopolymer PET fibers were obtained from two commercial sources and had slightly different thermal histories that contributed to the double-peak formation in the crystal melting endotherm, as shown in Figure 7.

The experimental black PETG fibers were carded separately and blended on a draw frame with cotton at three concentrations (3, 5, and 10%). The control black PET PETG was intimately blended with cotton at 2, 4, and 10% concentrations. Open-end yarn was

TABLE III
Taber Abrasion Test Data for 10% Concentration of PETG Fibers

	Number of cycles to failure		
	170	195	200
Fabric containing type 410 Black PET			247
Fabric containing type 410 PETG	251	369	350
Fabric containing type 110 PETG	170	407	281

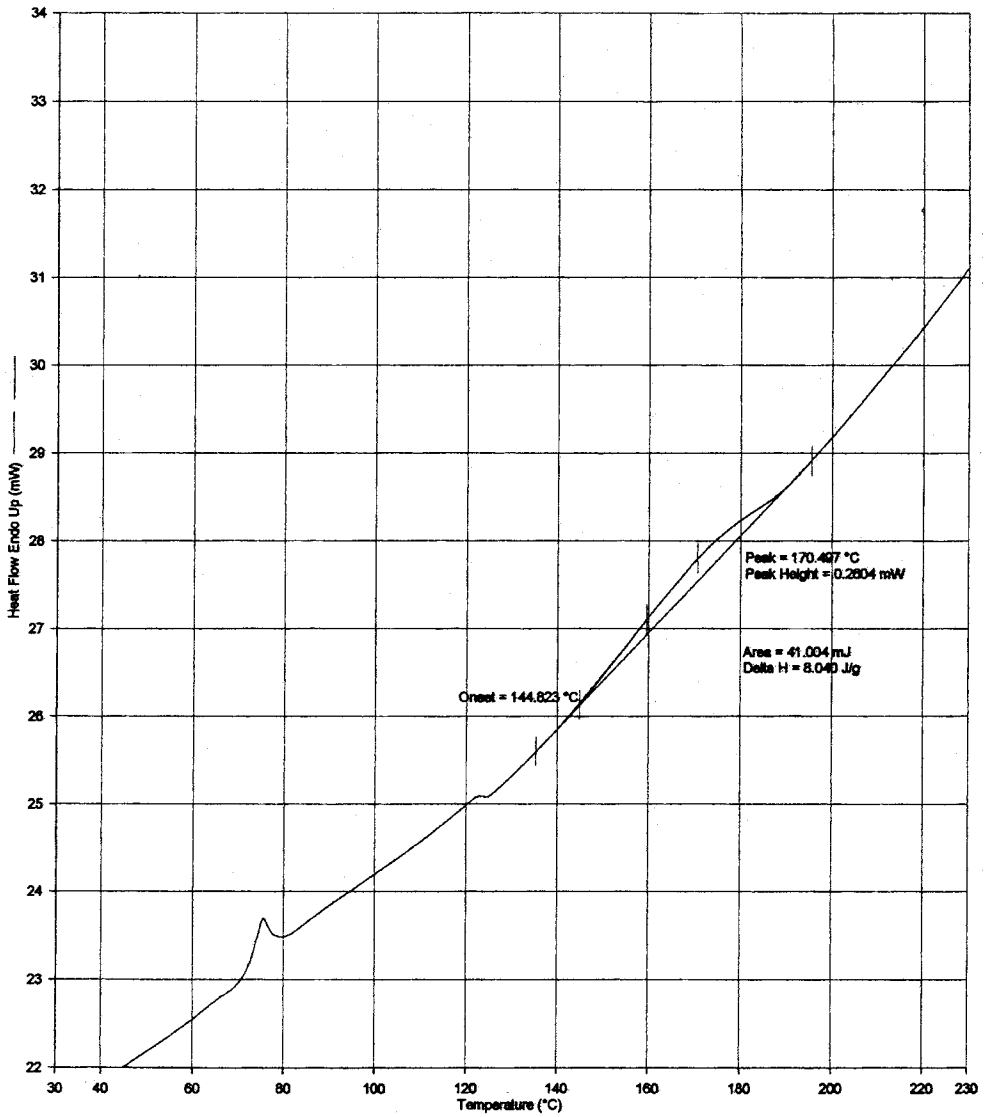


Figure 4 DSC thermogram of type 110 PETG with pigment.

spun (18/1) on a Schlafhorst Autocoro 288 SE9 at 107,000 rpm. The melting of PETG fibers during spinning was a concern as because could create fiber-fusing defects on the yarn. The problem was eliminated through process optimization. Single-jersey knit fabrics were produced on a 90-feed Monarch RL3S knitting machine. The fabric was scoured with a surfactant (Synfac G) at 60°C for 45 min to remove surface impurities. The prepared fabrics were heat-set at various temperatures (ranging from 140 to 200°C) in a tenter frame. The depth of color of the experimental fabrics was measured on a spectrophotometer with CIE Lab procedures. Color differences against a standard were expressed as ΔE.

TABLE IV
Fabric Bursting Strength

	Bursting strength (lb/in.^{2})								
	Type 410 PETG			Type 110 PETG			Black PET		
Concentration of black fiber (%)	10	5	2	10	5	2	10	5	2
	77	91	95	78	83	92	84	93	91

95% $d_{min} = 8.5$

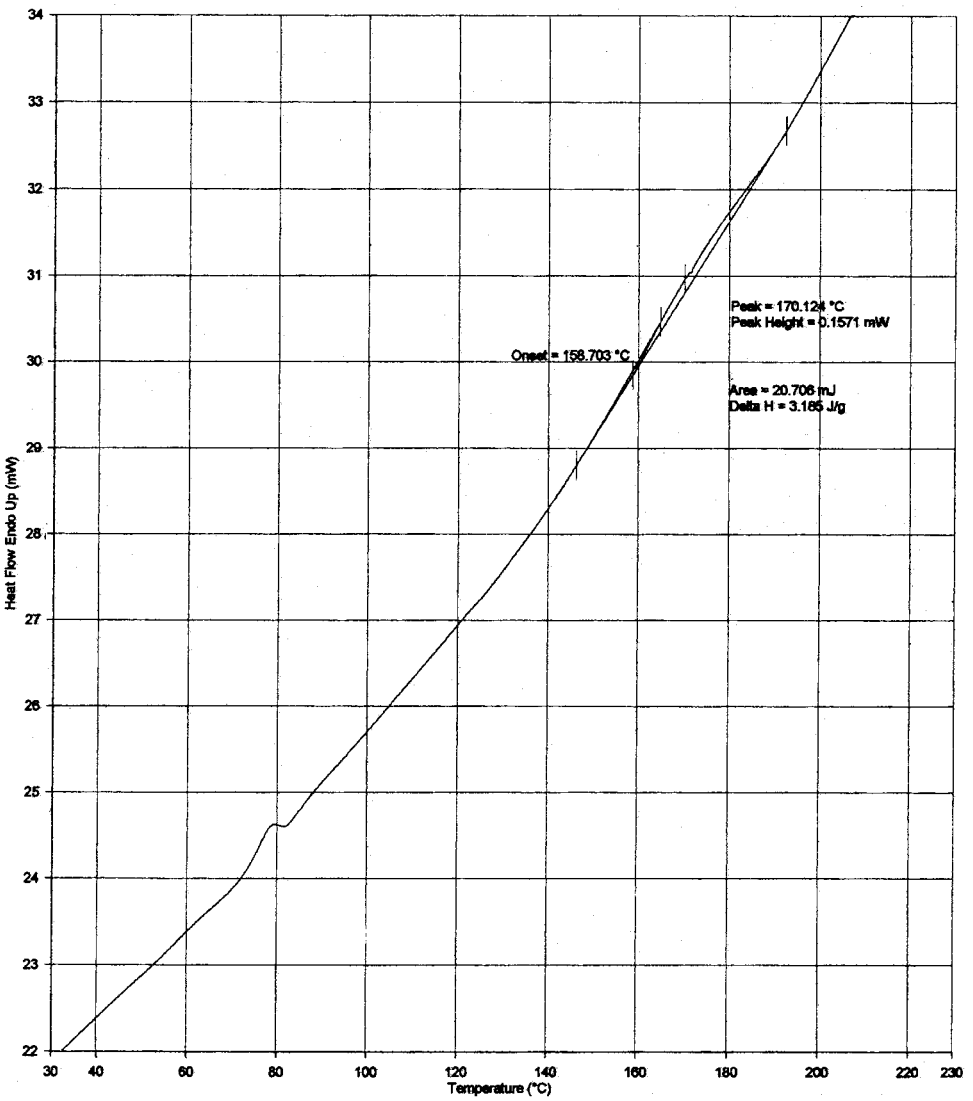


Figure 5 DSC thermogram of type 410 PETG without pigment.

FABRIC PROPERTIES AND AESTHETICS

The heat-set fabric containing low-melting PETG produced heather effects, as expected. The color differences of the fabrics produced with 2, 5, and 10% black PET and their counterparts containing PETG fibers were examined. As shown in Figures 8 and 9, the color in low-melting fabrics approached a similar depth of shade as that of the control fabric when the heat-set temperature and PETG fiber concentration increased. Furthermore, the heather effects on the fabrics containing PETG fibers were more uniform when the heat-set temperature was raised from 190 and 200°C. This phenomenon was attributed to better melting and flow and, consequently, better color distribution of the PETG fibers on the cotton substrate. Even though the PET black was blended intimately and the PETG fibers were blended by drawing, a more uniform fabric was obtained with the low-melting PETG fibers. This uniform heather effect on fabrics arising from the melt-flow characteristics of PETG at a higher heat-setting temperature was expected, following the relationship illustrated in Figure 2, which shows an increase in the melt flow of the PETG polymer as a result of increasing temperature. Photomicrographs of the heat-set fabrics containing type 410 PETG at 170, 195, and 200°C are illustrated in Figures 10 and 11. It is obvious from these micrographs that several unmelted fiber fragments were present in the fabrics heat-set at 170°C, whereas most of the PETG fibers melted at 195 and 200°C uniformly and distributed color on the cotton substrate. A similar phenomenon was observed for fabrics containing type 110 PETG fibers. The hand of these fabrics was somewhat dryer, but not harsh. For fabric containing black PET, un-

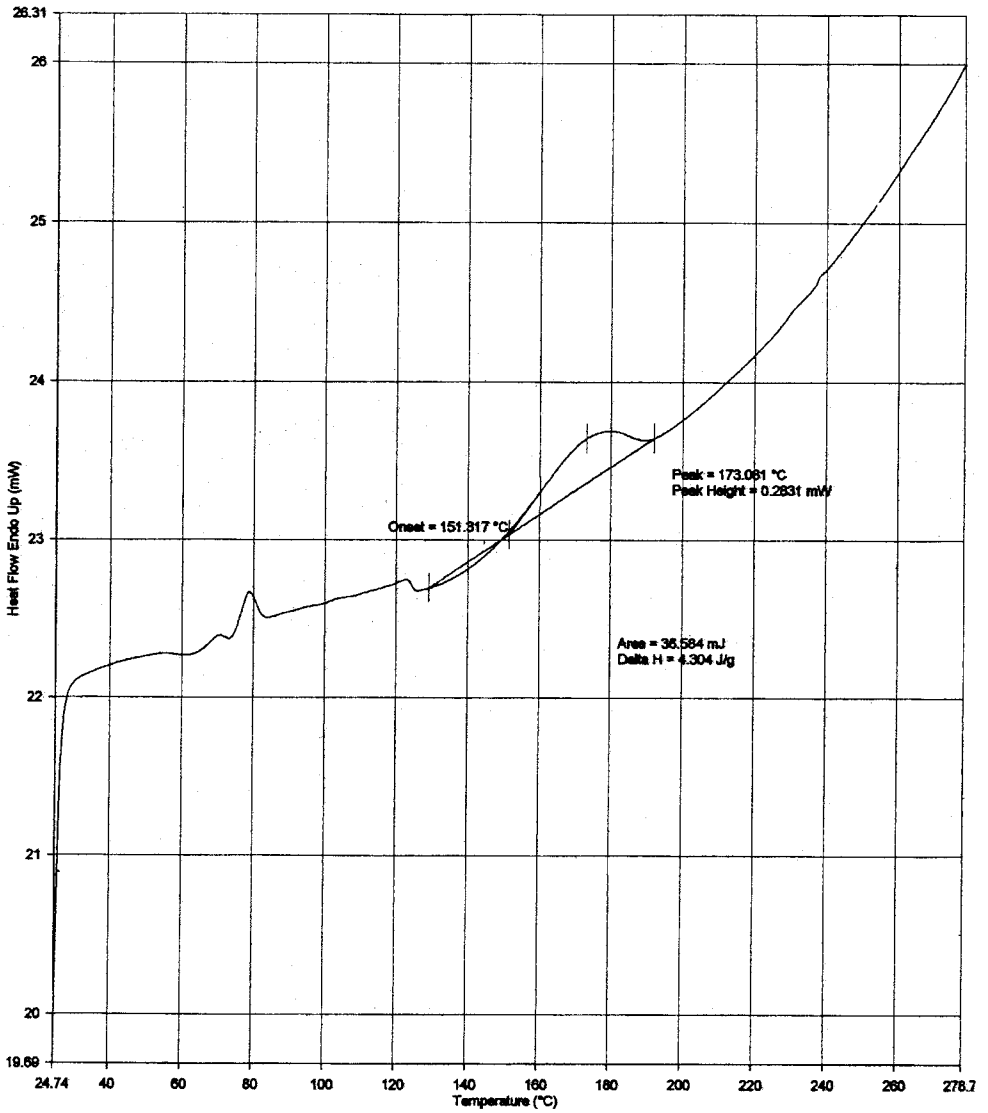


Figure 6 DSC thermogram of type 410 PETG with pigment.

evenly distributed fibers with local bunching were observed on the fabric surface (Fig. 13). Pilling (Table II) and abrasion (Table III) tests showed that the fabrics containing PETG probably had slightly greater wear resistance than their counterparts with PET black fibers. This was because the PETG fibers melted and bonded to the substrate with a more uniform distribution, whereas the black PET remained as loose fibers on the yarn surface.

A random tumble tester was used to evaluate the fabrics for pilling propensity. As shown in Table II, the pilling conditions of the PETG fiber fabrics were similar to those of the fabrics containing black PET; however, under certain conditions of manufacturing, fabrics containing PETG T 110 fibers showed lower pilling, which could be attributed to the melting and bonding to the cotton substrate of the low-melting modified PETG. Abrasion resistance, as determined by the Taber test, showed greater resistance to abrasion failure for the fabrics containing PETG fibers when the temperature was raised to 195°C and higher (Table III). The bursting strength of the PETG fabrics was measured with the Mullen burst test, and it was lower than that of the black PET fabrics when a 10% concentration was used; however, no significant differences in the bursting strength were observed at 5 and 2% concentrations of PET fibers, as shown in Table IV.

CONCLUSIONS

Our investigation shows that color-carrying amorphous polyesters can be used with cotton to enhance fabric properties. The CHDM-modified PET fibers had

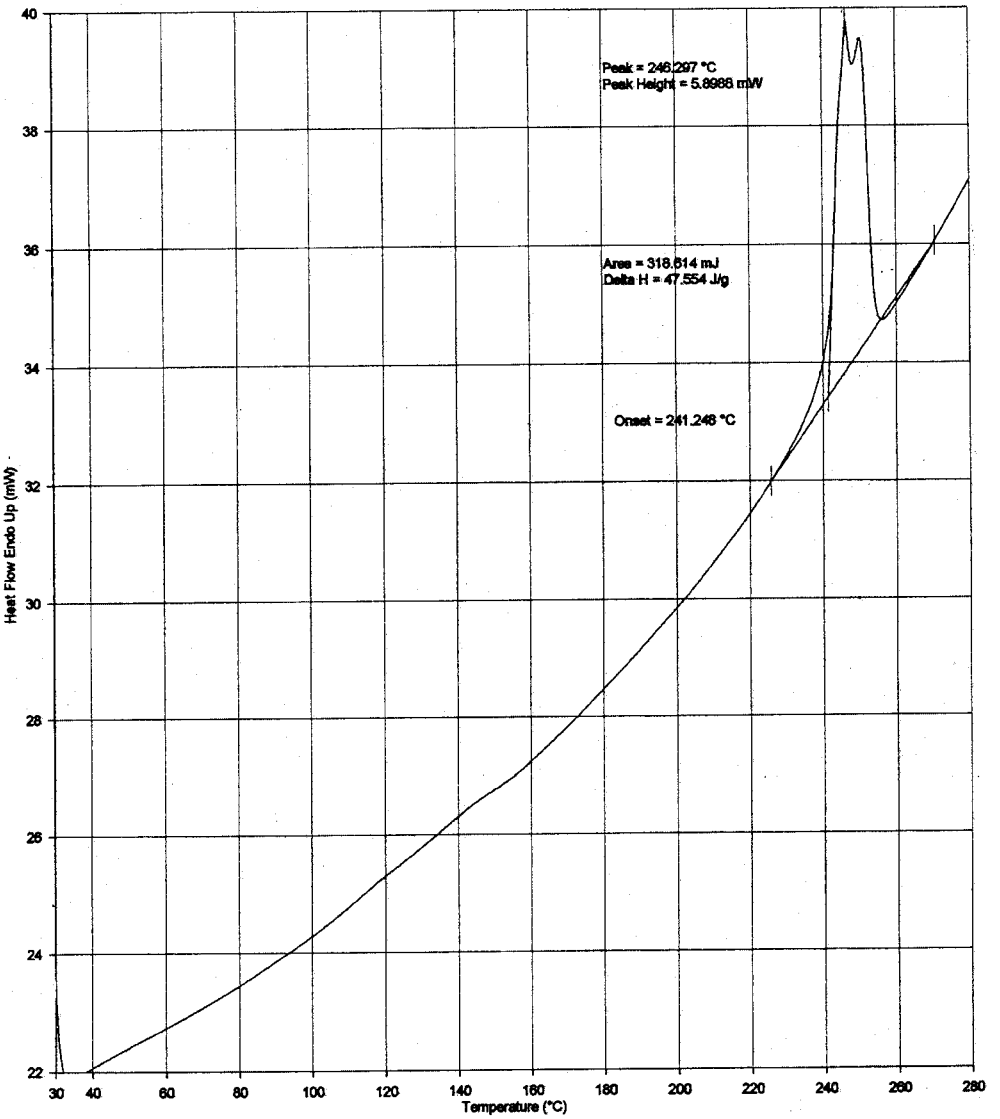


Figure 7 DSC thermogram of drawn PET with pigment.

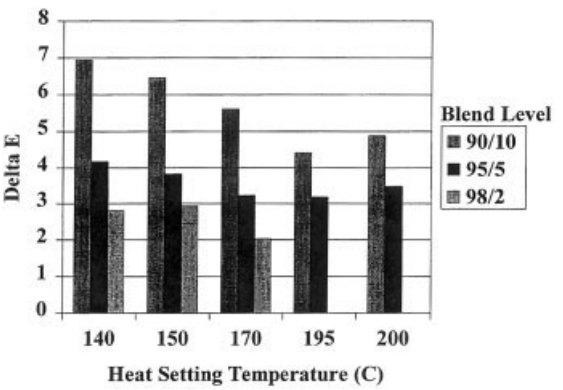


Figure 8 ΔE values of heat-set, scoured heather fabrics containing type 110 PETG fibers against a standard fabric containing black PET.

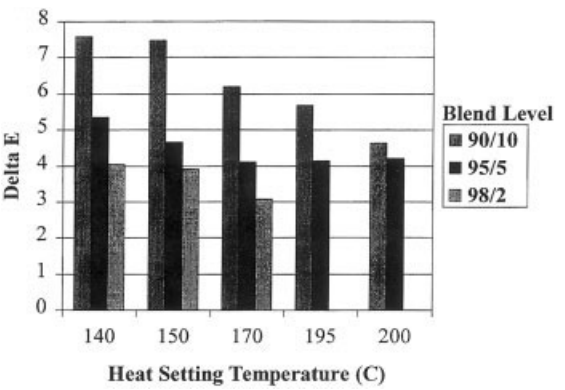


Figure 9 ΔE values of heat-set, scoured heather fabrics containing type 410 PETG fibers against a standard fabric containing PET.

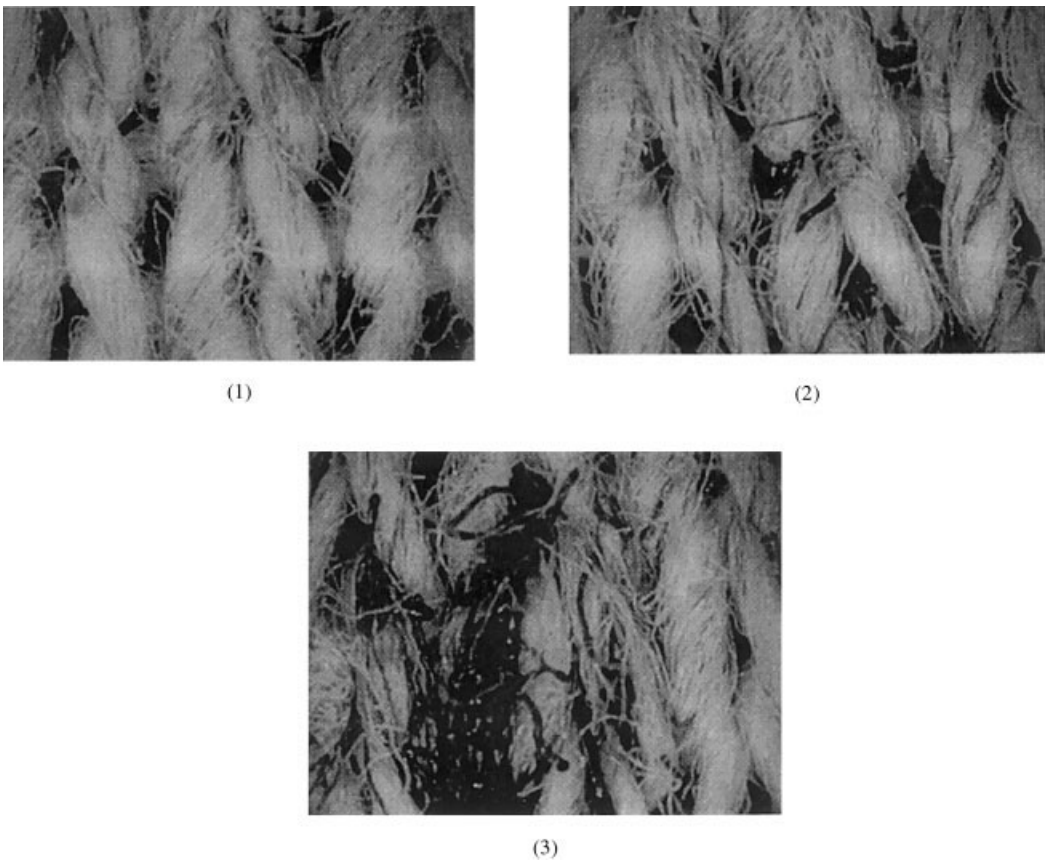


Figure 10 Fabric containing type 410 PETG (90/10) heat-set at 170°C: (1) color fiber migration, (2) black fiber melting, and (3) black fiber accumulation.

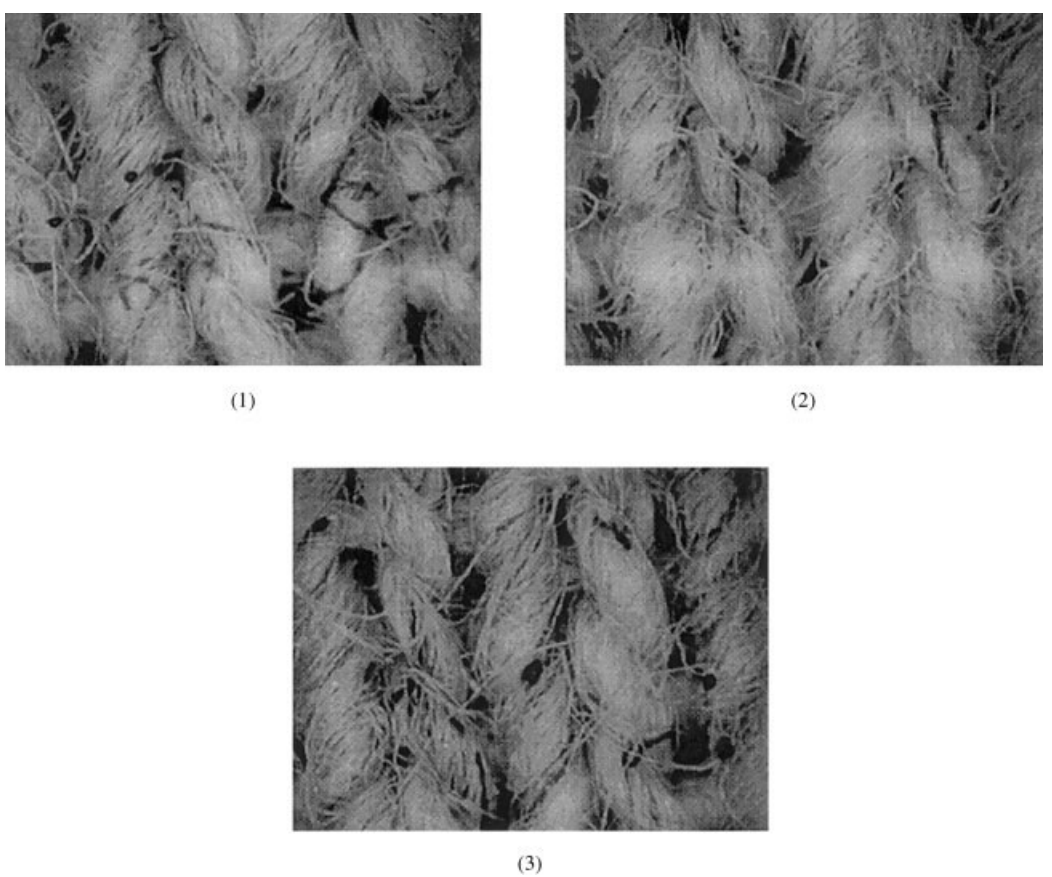


Figure 11 Fabric containing type 410 PETG (90/10) heat-set at 195°C: (1) black fiber melting, (2) color fiber migration, and (3) black fiber melting.

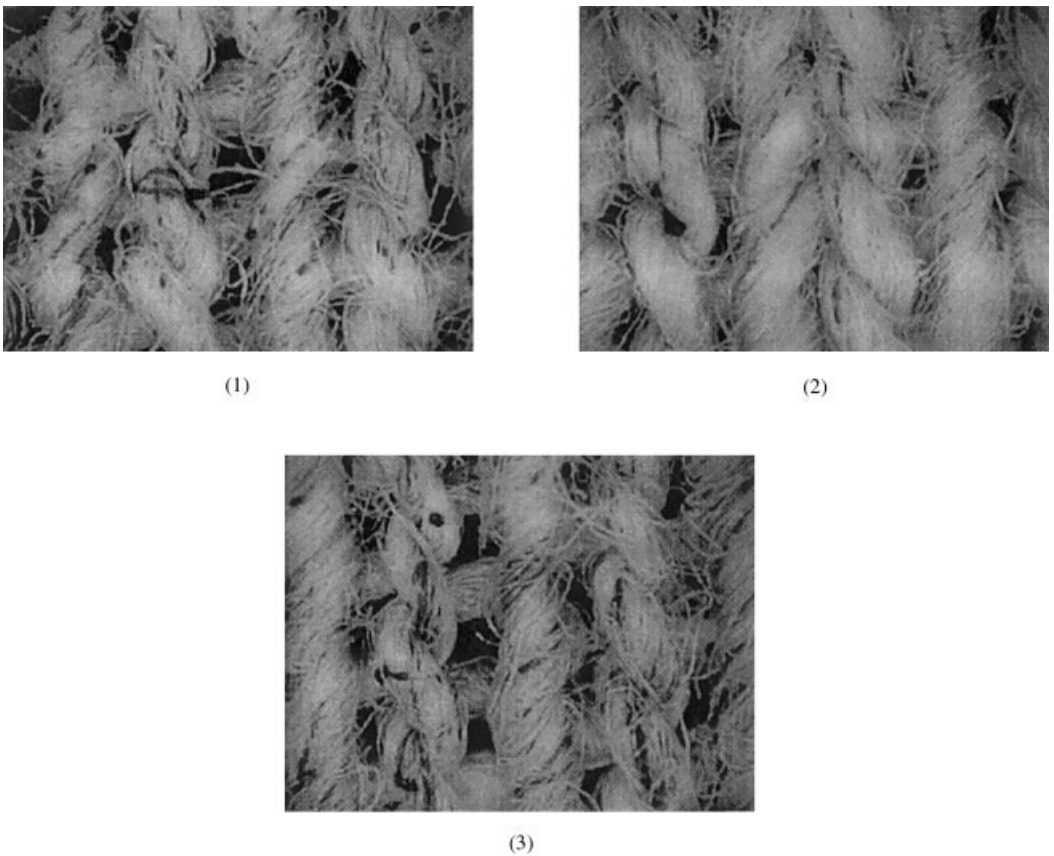


Figure 12 Fabric containing type 410 PETG (90/10) heat-set at 200°C: (1) black fiber melting, (2) color fiber migration, and (3) black fiber melting.

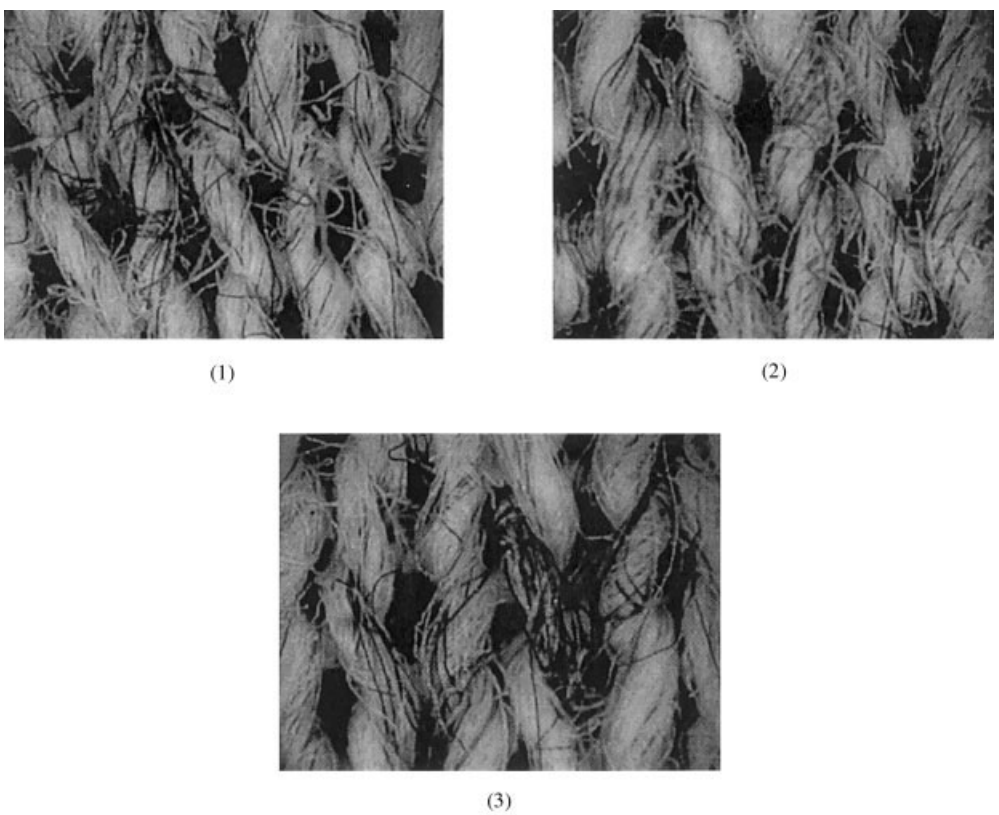


Figure 13 Heather fabric containing black PET (90/10) heat-set at 170°C: (1) high concentration of polyester fibers, (2) uniform blend of polyester fibers, and (3) nonuniform blend of polyester fibers.

rather low melting temperatures, and so the fabric could be heat-set to cure the resin on the substrate at a relatively low temperature. In a later investigation, the fabric hand was significantly improved by mechanical finishing without the alteration of other fabric properties. This method may provide an option for enhancing fabric properties by introducing antibacterial and soil-resistant finishes with this low-melting polymer.

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Reference

1. Kodel Binder Fiber for Thermobonding; Kodel Technical Literature; Kodel: 1999.