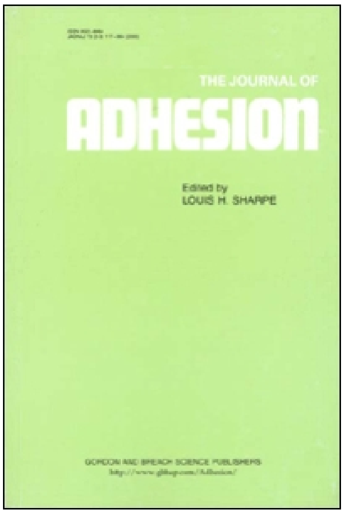

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Long Abstract

Adhesion of Trim Tape to Automotive Finishes†

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KEY WORDS Adhesion; trim tape; automotive; diffusion; peel test; coating.

INTRODUCTION

In a given application trim parts are attached to autobody surfaces by a tape comprising a neoprene core double-faced with poly(butyl acrylate) adhesive. Trim parts are received in automotive assembly plants with one side of the tape adhered in place and the other side protected by a release strip which is removed before use. The trim piece is applied with momentary pressure (0.1 MPa) from a roller to insure intimate contact. Initial adhesion must be sufficient to hold the trim part in place; functional attachment of the trim part depends on the tape adhesive for the duration of the car's use. Manufacturer's specifications do not provide for sanding of the painted surface prior to application of the trim part. It was necessary to reformulate the enamel to accommodate this by

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providing good adhesion at 30 minutes at 250°F and 60 minutes at 275°F conditions and to match the unsanded adhesion properties of a competitive product.

CHARACTERISTICS OF TRIM TAPE ADHESION

Initial adhesion is a large fraction of the ultimate value developed. Peel adhesion (180°) measured two minutes after application approximates one-half to two-thirds of that measured at 72 hours. It was found that adhesion developed is independent of application pressure so long as initial intimate contact is made. Heat hastens development of adhesion but could not be used commercially. Adhesion developed by a diffusion process should show, after an initial period of rapid increase, an approximate linear dependence on the fourth root of time according to Vasenin.[1] Average results obtained in this work and shown in Table I support a lower functional dependence as is often seen.

The peel test was conducted by affixing a thin layer of "Mylar" polyester to the tape adhesive layer opposite to that adhered to the test film; the "Mylar" was bent back over itself to form a peel angle approximating 180°. An exact angular relationship could not be achieved because of the thickness of the two layers of tape and the uncompensated juxtaposition of the Instron clamping jaws; however in all experiments the conditions were identical. One explanation for superior adhesion of the trim tape to the competitive enamel would be substrate deformation which is marked by rapid increase in peel force at a certain rate. Normalized peel forces for the proprietary and competitive finishes are shown in Table II.

TABLE I
Adhesion of trim tape to developmental automotive finish as a function of time

	Exponential dependence of 180° peel adhesion on time, hours		
Exponent	24	48	72
Experimental value, 12 determinations	1.8	1.9	2.1
Theoretical value for 0.25	2.2	2.6	2.9
% Error on theoretical	18	27	28
Calculated	0.18	0.17	0.17

TABLE II
Normalized 180° peel force as a function of peel rate for proprietary and competitive enamels

	Normalized peel force: basis 300 mm/min			
	Proprietary finish at paint bake		Competitive finish at paint bake	
Speed, mm/min	30 min × 121°C	30 min × 138°C	30 min × 121°C	30 min × 138°C
50	0.71	0.74	0.55	0.74
125	0.97	0.89	0.70	1.00
200	1.26	0.85	0.64	1.13
250	1.20	1.06	0.76	1.22
300	1.00	1.00	1.00	1.00
500	1.49	1.11	0.85	1.22
1250	2.29	1.30	0.70	1.22

The data in Table II indicate that substrate deformation does not occur for the competitive finish in the range studied; the significance of the rise in peel force for the proprietary enamel cannot be assessed with available data. It is clear that the standard and overbaked proprietary enamels are different, that standard baked proprietary and competitive enamels are different and that the standard overbaked competitive enamels are much more similar in their response than are the standard and overbaked proprietary enamels. The data are more suggestive of chemical type differences between the proprietary and competitive enamels.

Failure was within the poly(butyl acrylate) adhesive layer; the residual layer of adhesive on painted substrate was thin at low peel force and increased with peel force to the limiting case of tear within the foam core of the tape.

Relative to the competitive enamel, trim tape adhesion to the original proprietary enamel was lower at standard and overbakes and exhibited a stronger inverse temperature dependence. Given that the adhesion is diffusion controlled three factors, surface topography, mechanical properties and cohesive energy densities were identified as being possible causes of the observed differences.

Surface topography, quantified by the Wenzel ratio,[2] can play an important role in the level of adhesion developed with a given adhesive/adherend system. To determine whether any variations in surface roughness played a role in standard *versus* overbake tape adhesion to the proprietary enamel, samples were examined on two

TABLE III
Tensile strength, percent elongation, Young's modulus and energy to break for proprietary and competitive enamels

Enamel	Bake min × °C	Tensile strength MPa	Elongation at break, %	Young's modulus MPa	Energy to break MJ/m²
Proprietary	30 × 121	14.9	66.8	59.2	14.4
	30 × 138	15.6	37.6	90.7	9.53
Competitive	30 × 121	14.3	38.5	175	10.5
	20 × 138	17.4	25.3	299	7.65

Gould Surfanalyzers and a Bendix Profilometer. All instruments failed to detect topographic differences. Further, sectors of painted panels to which trim tape has been applied were examined by optical cross-section metallography. This technique clearly showed that in all cases the adhesive was in good contact with the enamel surface. It was concluded that surface roughness of the type exhibited by the proprietary enamel is not a significant factor in trim tape adhesion.

Mechanical properties, determined from free films of proprietary and competitive enamels at standard (30 min × 121°C) and severe overbake (30 min × 138°C), are shown in Table III. Examination of these data indicates consistency in the direction of property change. For both enamels, overbake *versus* standard values of tensile strength and Young's modulus increase while percent elongation and energy to break decrease. Yet the magnitudes of the properties at the two bakes show differences which were not correlatable with measured values of adhesion.

MODIFICATION OF PROPRIETARY ENAMEL

According to Voyutskii,[3] for diffusion-controlled adhesion development cohesive energy differences between adhesive and adherend are limiting. Consideration of this principle guided reformulation efforts on the proprietary enamel. As a first approach, poly(butyl acrylate) at 2% on a solids basis was added to the proprietary enamel. This small addition provided a 100% increase in both standard and overbake adhesion to a level comparable with the

TABLE IV
Initial and final 180° peel values of tape adhesion

Enamel	180° Peel Adhesion, $N/m \times 10^{-1}$ Original 30 min × 121°C	Original 60 min × 127°C	Reformulated 30 min × 121°C	Reformulated 60 min × 127°C
Proprietary	8.76	8.40	23.8	17.5
Competitive	22.8	17.2	—	—

competitive material; however, certain end use properties of the proprietary enamel were so adversely affected that it was not possible to pursue this approach.

A further and successful approach was to substitute a portion of the reactive melamine crosslinking resin with a melamine unreactive at baking temperatures. Thus the original proprietary formulation contained, on a solids basis, 40% of a single reactive melamine resin. Replacement of 10% of the reactive polymeric melamine with the non-reactive diluent gave the required increase in adhesion. Initial and final values are shown in Table IV.

It may be assumed that the poly(butyl acrylate) added at 2% on solids played a more specific role than simply reducing crosslink density, owing to its large effect at low concentration and adverse impact on certain end use properties. The use of the unreactive diluent was possible since the original amount of reactive melamine was in excess.

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