

Slip-Stick Peel Failure of a Semicrystalline Adhesive

We report some interesting findings on slip-stick adhesive failure, obtained in a study of the numerous variables affecting the 180° peel adhesion of poly(ethylene-vinyl acetate).

SAMPLE PREPARATION

180° Peel tests were performed on specimens consisting of an electropolished stainless steel substrate (centerline-average roughness values ranging from 5 to 35 μ inch), a layer of adhesive (thickness 0.1 to 1.2 mils), and a 2-mil Mylar film backing. The adhesive was cast from its xylene solution onto the Mylar, by means of a manually drawn fixed-clearance "doctor" blade, and the coated Mylar was then molded under pressure at 191°C to the substrate plates. All samples were quenched to room temperature, and some were annealed at 93°C before peel testing at various temperatures (-18° to 93°C) and rates (0.05 to 0.5 in./min).

FINDINGS

In experiments designed to test viscoelastic peel theory,^{1,2} the appearance of slip-stick failure has been shown to be contingent solely upon the value of the combination of rheological variables $r a_T$, where r is the rate of peel and a_T is the WLF shift factor. We observed our semicrystalline (approximately 60% crystalline³) adhesive to exhibit slip-stick failure under two additional contingencies of substrate roughness. First, the principal direction of substrate roughness, i.e., the direction of the machining marks remaining on the substrate and discernible even after electropolishing, apparently

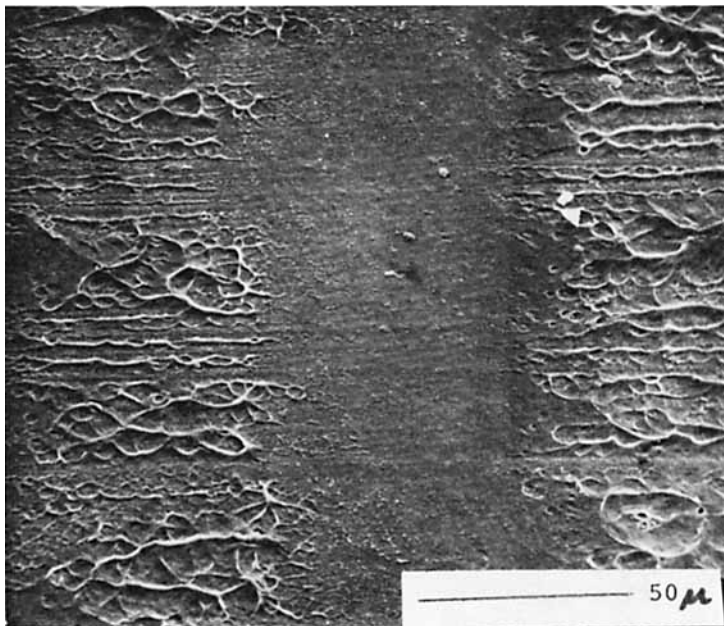


Fig. 1. Slip-stick lines on peeled substrate, 690 \times . Note the roughness striations running from left to right across the center of the picture, "connecting" the two slip-stick regions. (The gap in the center of the picture is attributed to a local drop in adhesive thickness.)

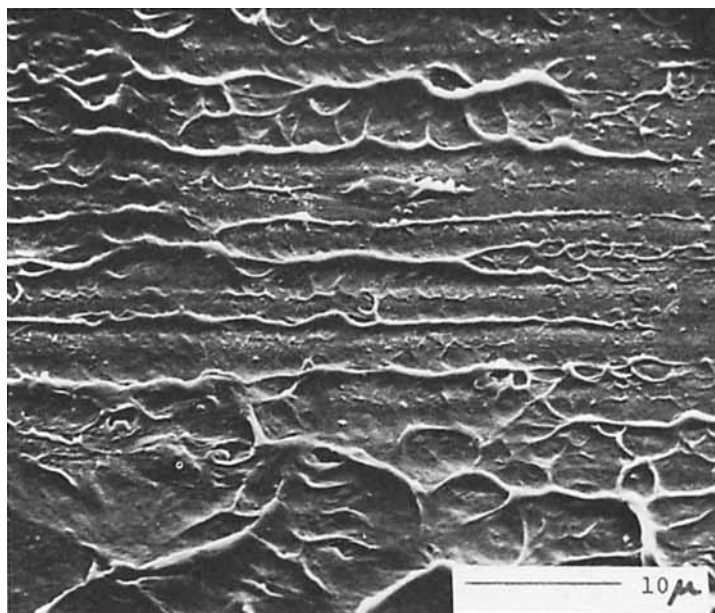


Fig. 2. Same specimen as in Fig. 1, 2620 \times .

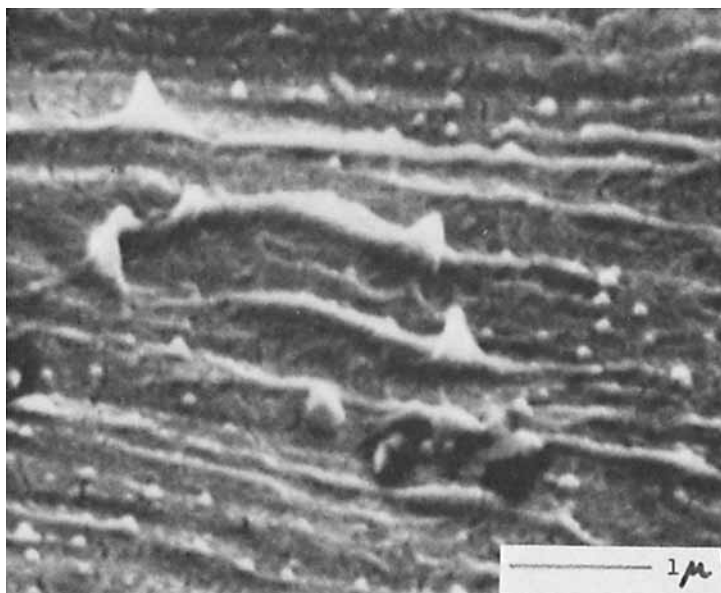


Fig. 3. Different region of same specimen as in Fig. 1, 24,800 \times . Note the location of slip-stick lines in relation to roughness striations.

had to be perpendicular to the direction of peel. Scanning electron micrographs of the peeled substrate, Figures 1 and 2, indicate that slip-stick deformation lines tended to propagate primarily along the crests and valleys of substrate roughness features. However, this direction of propagation was not always consistent, as is evident in Figure 2.

The second additional contingency was that the centerline-average magnitude of the roughness had to be considerable; all samples exhibited slip-stick on substrates of rough-

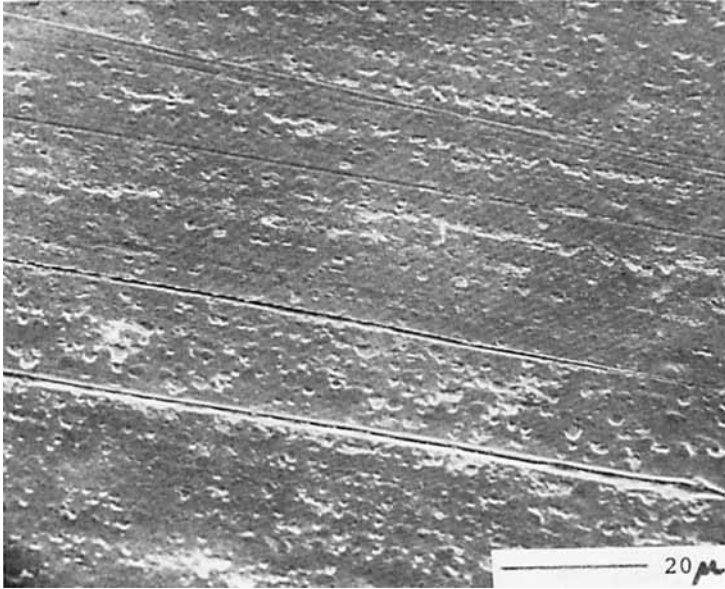


Fig. 4. Slip-stick lines on the backing of a different peel specimen, 1240 \times , morphologically similar to the phenomenon observed in other specimens, and generally visible to the naked eye.

ness greater than 20 μ inch. (Commercially available "polished" stainless steel has a roughness of about 40 μ inch, by comparison.)

In contrast to the second apparent contingency for slip-stick, microscopy (Figs. 3 and 4) revealed slip-stick lines comparable in morphology, yet greatly different in size. This indicates that, although large substrate roughness may have been necessary to initiate slip-stick, its propagation may have been considerably less contingent on roughness. Figure 4 also indicates that slip-stick polymer remnants were seen on peeled backings as well as on peeled substrates.

DISCUSSION

Our evidence suggests that substrate roughness serves to catalyze the onset of slip-stick failure in semicrystalline polymers otherwise unable, because of low molecular mobility, to undergo the periodic energy storage and release necessary for slip-stick failure. This is interesting in that, for the rubbery adhesives previously studied,^{2,4,5} substrate roughness seemed to play no corresponding role; one study even obtained slip-stick failure with substrates literally as smooth as glass.⁵ Our work suggests two broad conclusions. First, elements of peel theory previously limited in application to linear viscoelastic adhesives may be extended to more complex systems. This is of particular commercial interest in that many hot-melt adhesives are semicrystalline polymers. Second, the peculiarities of this extended application of linear viscoelastic peel theory, some of which are reported above, may merit or require further investigation, particularly regarding the relation between heterophase adhesive morphology and peel failure.

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