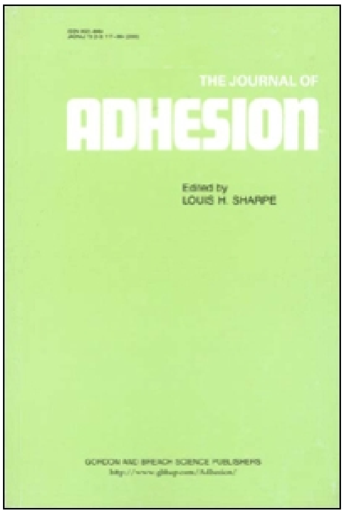


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# Stress Relaxation in Peel Adhesion

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# Stress Relaxation in Peel Adhesion

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The peeling of an adhesive joint consisting of an SBS copolymer and two Mylar film substrates proceeds by cohesive rubber rupture, and the strength increases with test rate. Stress relaxation during peeling is shown to account for this behavior and relaxation data after peeling is used to predict the rate dependence of the peel force.



## INTRODUCTION

The effect of test rate on the peel strengths of adhesive joints has been widely studied.[1–7] If the interfacial interaction of the adhesive to the substrate is sufficiently high, then the failure proceeds by rupture of the adhesive layer.[8–10] For rubbery adhesives failing in this mode, the peel strength is a measure of the cohesive tear strength of the adhesive and its value increases with detachment rate.[9,10]

This observation can be explained by considering that at low peel rates the adhesive molecules have a longer time to *relax* before detachment compared to higher rates. Indeed, an equilibrium value of the peel force has been obtained by first peeling a test-piece at some constant rate in an Instron and then stopping the crosshead (after reaching a plateau peel force) and monitoring the relaxation of the peel force until it no longer changes with time.[11]

In this brief paper, stress-relaxation after peeling is further investigated. In particular, the stress-relaxation behavior of a peeled specimen is used to predict the rate dependence of the peel force.

## EXPERIMENTAL

Mylar® polyester film (76 $\mu$m thick) was the substrate in this investigation and the adhesive layer was a plasticized SBS block copolymer (Kraton 3202). This

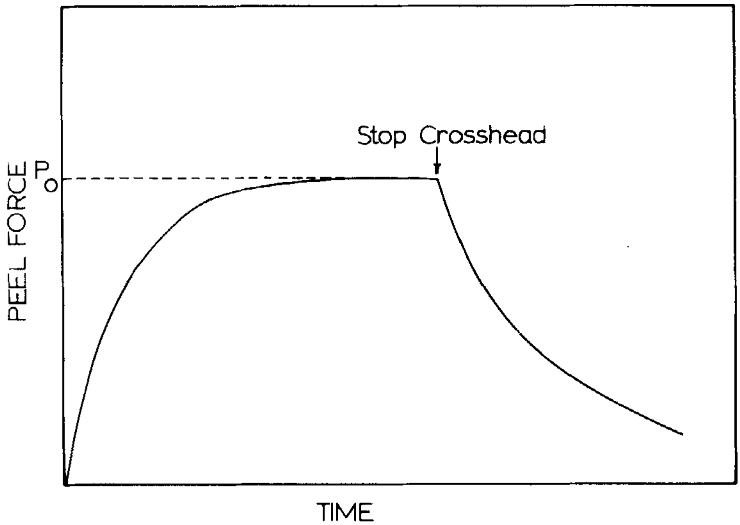


FIGURE 1 Schematic diagram showing relaxation of the peel force after steady-state peeling.



adhesive joint has been previously investigated,[7] and smooth cohesive rubber tear is the mode of failure when peeling at low rates. Furthermore, for thin rubber layers (less than about 2 mm) the peel force depends linearly on the adhesive thickness.[7]

Testpieces were prepared by compression molding a layer of the rubber between two sheets of Mylar for 60 minutes at 177°C. A spacer plate was used to obtain the desired bond thickness. After demolding, samples were cut into 25 mm wide strips and tested in a T-peel geometry at various rates. Stress-relaxation of the peel force was measured by stopping the clamp separation after reaching steady-state peeling at a specified test rate and monitoring the decrease in peel force as a function of time (Figure 1).

## RESULTS AND DISCUSSION

The peel force plotted as a function of test rate is shown in Figure 2 for a bond thickness of 0.9 mm. In all cases failure occurs by cohesive rubber fracture, and the tear force increases with rate.

The stress in the adhesive layer is a maximum at the failure point and decays rapidly in the direction of the untested portion of the bond. At a distance into the bond approximately equal to the bond thickness the stress decays to a value near zero.[12] Thus, for a rate of separation of the test piece, $R$, the adhesive layer is deformed from zero stress to a maximum stress in a time, $t$,

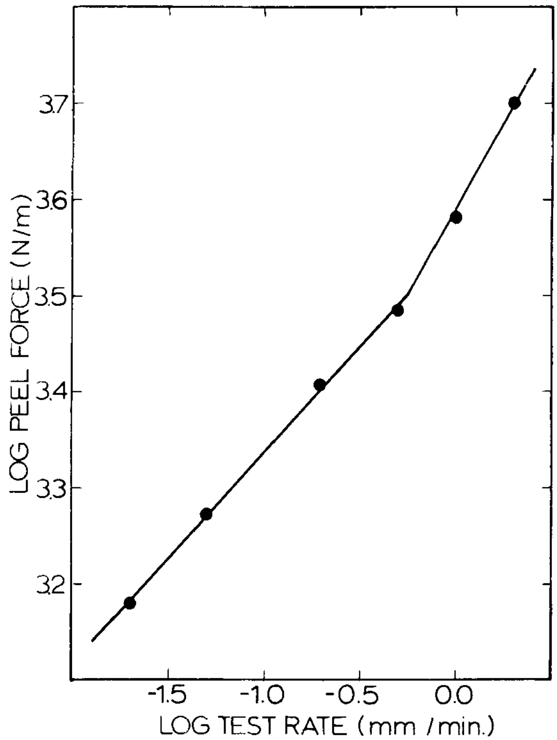


FIGURE 2 Rate dependence of the peel force for the Kraton 3202-Mylar bond tested in the $T$-peel geometry. Data points from direct measurement, solid line predicted from Eqs 3 and 4.



approximately equal to the bond thickness divided by the peel rate.[9] That is, for very slow test rates, the adhesive layer has a long time to relax before failure and hence is weak; while for more rapid rates the joint has less time to relax before failure and is resultantly stronger.

Relaxation of the peel force was measured by stopping the test machine crosshead[11] after reaching a steady state peeling force, $P_0$, of 3780 N/m at a rate of 1 mm/minute. During the test at this rate, the adhesive layer, upon entering the stressed region, relaxes for a time, $t_0 = 0.9$ mm/1.0 mm min$^{-1}$ $= 0.9$ minutes before tearing. Therefore, the total relaxation time, $\tau$, which is the total time the adhesive layer has been relaxing measured from the time it was initially stressed, is given by $t_0$ plus the time after stopping the crosshead. Results are given in Figure 3 for the peel force plotted as a function of total relaxation time. The data can be fitted quite well by two straight lines in this log-log plot,

$$P = 3700\ \tau^{-0.356} \qquad \tau < 1.5 \text{ min.} \tag{1}$$

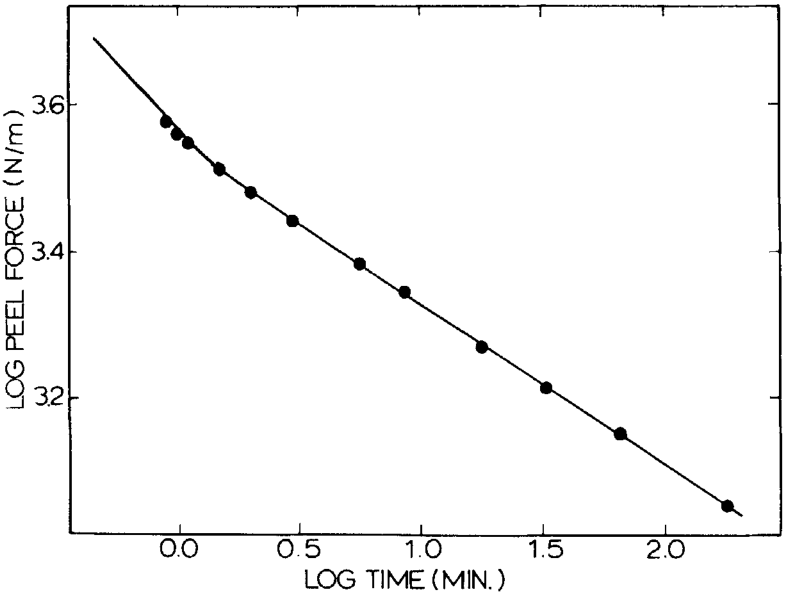


FIGURE 3 Peel force as a function of total relaxation time after $T$-peeling the Kraton 3202-Mylar bond.



and

$$P = 3500\ \tau^{-0.218} \qquad \tau > 1.5 \text{ min.} \tag{2}$$

where $P$ = peel force per unit width (N/m)
$\tau$ = total relaxation time (minutes).

For an arbitrary steady-state peeling rate, $R$, and a bond thickness of 0.9 mm, the value of $\tau = 0.9/R$ minutes. (Note: In this case, the crosshead is *not* stopped so that $t$ and $\tau$ are the same.) Substituting this into Eqs 1 and 2,

$$P = 3840\ R^{0.356} \qquad t < 1.5 \text{ min.} \tag{3}$$

and

$$P = 3580\ R^{0.218} \qquad t > 1.5 \text{ min.} \tag{4}$$

thus, these two equations, obtained from stress-relaxation measurements, can be used to *predict* the rate dependence of $P$ for the Kraton 3202-Mylar bond. The solid line in Figure 2 is calculated in this manner, and excellent agreement with the results obtained by direct measurement is found.

## CONCLUSIONS

For a soft rubbery adhesive failing cohesively in the $T$-peel geometry, the rate dependence of the peel (or tear) force can be predicted from stress-relaxation measurements of the bond. The tear strength increases with test rate because at higher rates the adhesive has less time to relax and hence responds with higher strength.

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