Viscoelastic peeling of thin tapes with frictional sliding

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Peeling is one of the most common detachment mechanisms adopted in industrial applications. However, although several experimental investigations have proven the possible occurrence of relative sliding at the interface close to the peeling front, a comprehensive model considering the effect of both the tape viscoelasticity and frictional interfacial dissipation on the peeling behavior is lacking. The present study aims at providing a theoretical framework to investigate the peeling process of a thin viscoelastic tape from a rigid substrate in the presence of frictional sliding at the interface. It shows that, under certain conditions, significantly tougher adhesive performance can be achieved compared to stuck elastic conditions with no interfacial sliding.

Keywords: Peeling, Viscoelasticity, Interfacial friction, Adhesion

1. Introduction

When the peeling process is employed to explain the adhesive strength of real systems, most of the theories rely on the Kendall' model derived for pure elastic tapes with the interfaces in completely stuck contact [1]. However, the extremely high peeling resistance exhibited by some biological systems (e.g., insects' and arachnids' toes), might also depend on the tape viscoelasticity and the occurrence of interfacial frictional sliding close to the peeling front [2]. In this study, we investigate the frictional peeling of a viscoelastic tape from a rigid substrate, aiming at highlighting the interplay between frictional sliding, bulk viscous dissipation, and peeling toughness.

2. Formulation

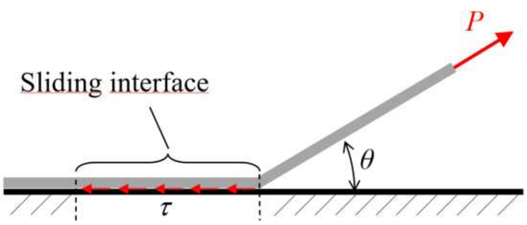

Fig1: Scheme of the peeling for a viscoelastic tape in presence of interfacial sliding.

We consider the case of a viscoelastic tape peeled away from a rigid substrate. Due to relative sliding occurring at the interface close to the peeling front, we assume a uniform shear stress distribution τ due to frictional interfacial interactions (Fig.1). Further, since the tape is sufficiently thin, we neglect any viscoelastic energy dissipation occurring due to tape bending, as well as inertial and dynamical effects.

At equilibrium, the system is governed by the power balance

$$W_E + W_I + W_S + W_E = 0 \quad (1)$$

where the terms are, respectively, the power of the external peeling force, the internal energy variation per unit time (which considers for both the elastic energy stored in the tape and the energy dissipation due to viscoelastic creep), the surface energy variation per unit time, and the energy dissipation per unit time due to frictional shear stress.

3. Discussion

We found that, since the frictional dissipation is proportional to $\cos^2\theta$, at small value of the peeling angle θ, the peeling load $\tilde{P}$ occurring in the presence of relative sliding is much higher than in the classical stuck case (i.e., with no relative sliding occurring at the interface); also note that, for $\theta \to 0$, $\tilde{P}$ diverges. Moreover, contrary to the stuck case, the sliding model results strongly affected by the peel rate showing an increment in $\tilde{P}$ values for crescent value of the parameter $\tilde{V}_0\tilde{\tau}$. Interestingly, we noted that, despite the additional loss source for the sliding case, in certain range of θ and $\tilde{V}_0$, the stuck model may also predict higher $\tilde{P}$ values.

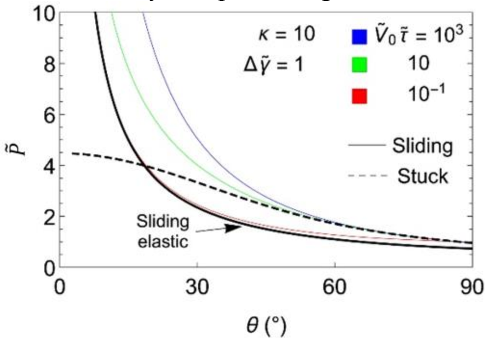

Figure 2: Comparison between dimensionless peeling load $\tilde{P}$ for stuck and sliding model at different values of the parameter $\tilde{V}_0\tilde{\tau}$ for a fixed value of dimensionless energy of adhesion $\Delta\tilde{\gamma}$ and viscoelasticity parameter $\kappa = E_\infty/E_0$.

4. References

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