Dissipation, heterogeneities and front propagation – from adhesion rupture to dynamic wetting

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Based on recent experimental and numerical examples, I will survey a few issues related to the dynamics of moving fronts, considering in parallel two related cases: adhesion rupture in soft solids and dewetting in liquids. Starting from the standard (linear viscoelastic) model(s) for dissipative cracks (which is known to be, in practice, almost universally inadequate for soft solids but works reasonably well when... there is no elasticity, ie for a dewetting newtonian fluid) I will consider the case of polyvinylbutyral/glass laminates, of the type used for safety windshields in cars. With a Tg around 25°C, polyvinylbutyral would appear as a good candidate to validate a viscoelastic crack model [1]. However, we find three major features in the low velocity delamination dynamics - blunting, macroscopic bifurcation and front instability (Fig. 1) - which are completely outside the scope of the standard model. However, they can be accounted for if a minimal dose of non-linearity is considered: the high strain rate viscoplastic component of the polymer response – a severe adaptation of the standard model. Along a different line, another source of energy dissipation in front propagation is heterogeneities, which are essential, for example, to account for wetting hysteresis in liquids and are also known to enhance interfacial toughness, in choice cases. So how do a) bulk dissipation and b) dissipation through heterogeneities couple? To bring insight into this question, I will consider a newtonian viscous liquid dewetting on a heterogeneous surface (Fig. 2). When the velocity is close to the dynamic wetting transition (liquid entrainment – the liquid equivalent to crack blunting for a soft solid), we find that heterogeneities lower the transition velocity and broaden the critical regime. I will try to provide simple arguments supporting these predictions and also show how they can explain recent observations in high speed dewetting experiments [2]. Finally, a major question is the size effect: how does this dissipation/heterogeneity coupling evolve as the size of the heterogeneities is scaled down? As a first insight into this complicated question, I will briefly present recent results of mechanical testing of polymers at small scales, demonstrating that "smaller" is not always "tougher".

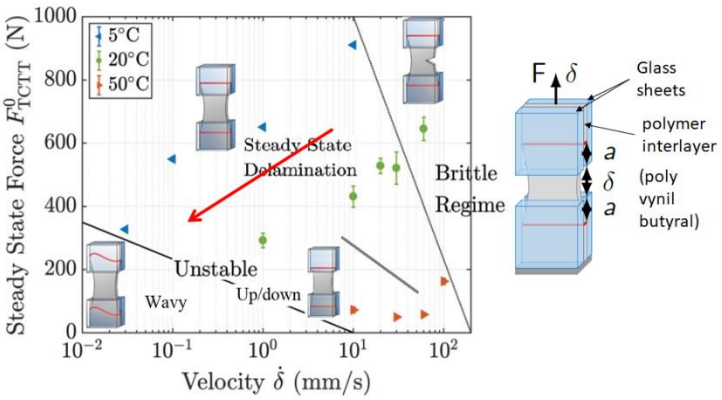

Figure 1: steady state pull- out force for delamination of a glass/polymer/glass sandwich. At low velocities, propagation stops, the front destabilizes and there is even up/down bifurcation. Beyond linear viscoelasticity, a less approximate description of dissipation in crack propagation is needed to account for these instabilities.

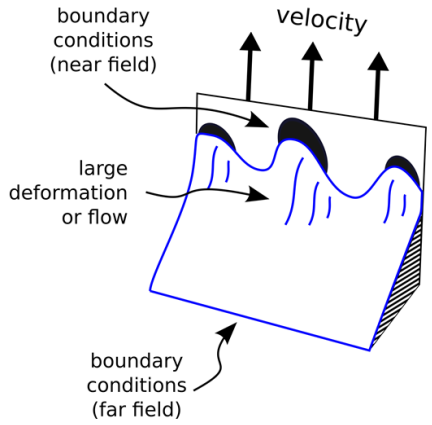

Figure 2: schematics of dynamic dewetting on heterogeneous surfaces. More local flow at the triple line affects the dynamic spectrum.

[1] P. Elzière et al., Soft Matter 13 (2017) 1624-1633; Macromolecules 52 (2019) 7821-7830.
[2] P. Hayoun et al., arXiv:1805.12030.