ADHESION PROPERTIES AND MACROSCOPIC RESPONSE OF METAL-POLYMER LAMINATES

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1. Introduction

Metal-polymer laminates are employed in several technological fields, with applications ranging from food packaging to flexible electronics. The actual material coupling is designed to meet different functional requirements, including the bearing of mechanical actions [1-3].

Specific features of these composites are the small thickness of the metal component, which may behave differently from the corresponding bulk material, and the wide deformability range of the support. The laminates can fail in a variety of modes, depending also on the adhesion level among the plies.

Models of different complexity have been proposed to evaluate the overall performances of these materials. Models are also used to recover the properties of the interfaces, which can be usually characterized only indirectly. The present contribution compares the effectiveness of different simulation tools proposed in this context.

2. Models

The material systems investigated for instance in [4] and [5] consisted of a weakly hardening metal layer supported by a strongly hardening polymer. Material interaction at the interface was simulated by an array of nonlinear springs characterized by a bilinear traction-separation law. In the analyzed situations, the overall material response does not differ substantially from that resulting from an elastic support, amenable to the effective analytical approach introduced in [6]. However, this conclusion cannot be extended to all possible combinations of stiffness, strength and thickness of the plies developed for the different applications mentioned in the Introduction, leading to the diverse failure modes represented for instance in Fig. 1.

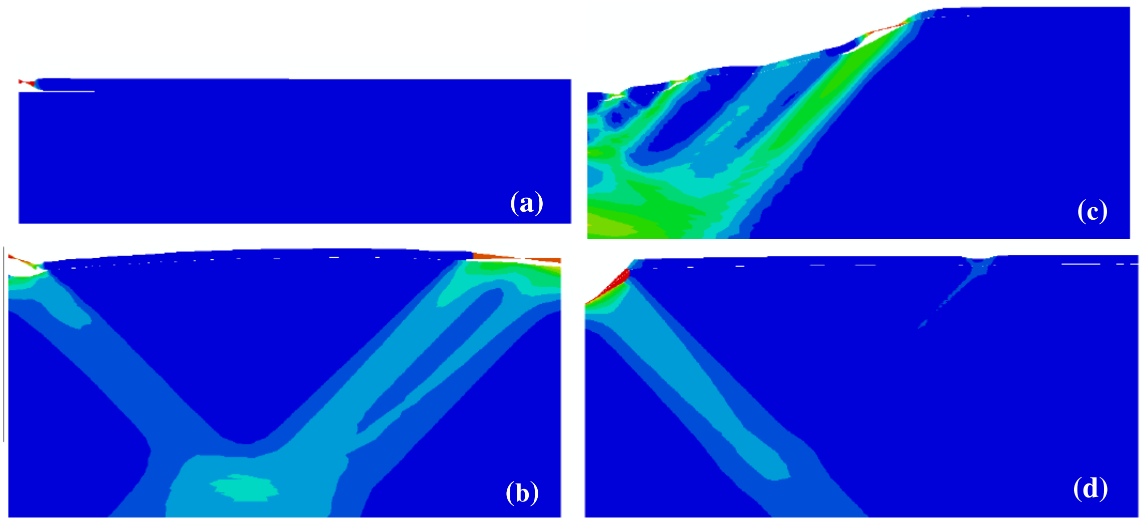

Figure 1. Final failure mode and plastic strain distribution in metal laminates for reference (graphs a and b) and high (c and d) yield limit of the support and different interface adhesion: low (a); intermediate (b and c); high in (d).

The results represented in Fig. 1 concern the simulation of the bi-layer material system considered in [5], made of a thin layer of a copper-like material deposited on a polymeric support. The mechanical response of both components have been described by the classical Huber-Hencky-von Mises elasto-plasticity model with exponential hardening rule, with the main parameters listed in Table 1. The interface among these components has been described by a bi-linear traction-separation law, considering both opening and sliding modes, with properties reported in Table 2. The study has been complemented by the consideration of larger and smaller yield limit (10 MPa and 150 MPa, respectively) of the support.

Table 1. Main material parameters [5].

	Elastic modulus (GPa)	Yield limit (MPa)	Hardening exponent	Layer thickness (μm)
Metal	100	100	0.02	1
Polymer	8	50	0.5	100

Table 2. Interface material properties.

	Weak	Intermediate	High
Normalized traction*	0.01	0.5	1
Normalized separation*	1	0.05	0.005

*Traction and separation are respectively normalized to the yield limit and to the thickness of metal layer.

3. Comparative results

In the performed analyses, failure is initiated by the necking of the metal layer. For weak interfaces, the phenomenon develops at small strain level and is accompanied by delamination as shown in Fig. 1a. Material separation in different positions, necking in multiple metal sections and strain localization in the support are rather observed as the interfacial strength is increased. These effects can be captured by numerical simulations performed in the large strain regime.

4. Closing remarks

The failure mode of metal-polymer laminates is controlled by the interplay between delamination and strain localization processes, depending on the diverse material coupling. These phenomena can be captured to various extent by different simulation tools.

6. References

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