A novel approach for the strain rate dependent modeling of woven composites

The high speed progressive failure of woven composites is investigated for automotive crash applications. The material of interest is a 2x2 twill glass fabric embedded in a polyamide 6,6 matrix, designed specifically to address the needs of this industry. A constitutive model is proposed to take into account the influence of strain rates between 0.0001 and 100 /s, which are commonly observed in high speed automotive impacts.

The originality of the model lies in its modular formulation, where rate effects are introduced as a supplementary mechanism to an otherwise rate-independent damage elastic-plastic model [1]. Key features of the latter include a unilateral, mechanism-driven, bounded rate damage model, which properly takes into account multiple independent degradation mechanisms, crack closing, and avoids spurious mesh dependency. The plasticity model is anisotropic and features a weak coupling with damage using effective stresses in the threshold criterion.

Weak couplings are also sought for viscoelasticity as it is introduced to model the rate effects of interest. For that purpose, a generalized Maxwell model is introduced where rate effects effectively act as a supplementary stress, over a quasi-static, rate independent stress. Every single component of the Maxwell model is kept linear viscoelastic, but to take into account the whole spectrum of rate dependency, a so-called spectral viscoelastic decomposition is adopted.

In order to identify each of these mechanisms independently, a two-step dedicated identification procedure is proposed, that allows characterizing viscoelasticity parameters, and then damage and plasticity parameters in a strictly sequential manner [2] (Figure 1). An inverse method is nevertheless required to calibrate the spectral viscoelastic model parameters, which presents a number of pitfalls.

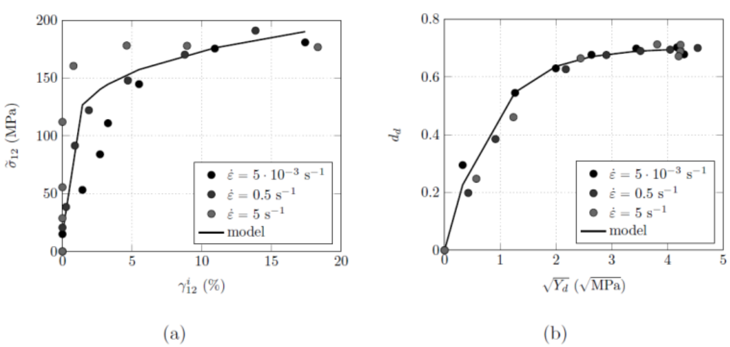

Figure 1: Evolution laws of plasticity (a) and damage (b) identified from tests performed at different strain rates

Validating the proposed models is performed in two ways. First, we show the validity of the assumption that rate effects are only weakly coupled with plasticity and damage by using a dynamic strain interruption device to interrupt tensile tests performed at different strain rates and observe if the phenomenology matches our insights [3]. Then, we compare numerical simulation on a structural specimen with the force and displacement fields measurements obtained experimentally, again at different strain rates (Figure 2). The results essentially validate our approach, yet show that plasticity does exhibit a slight strain rate dependency at the early stages of hardening (Figure 1(a)).

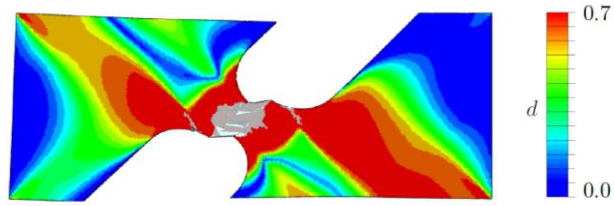

Figure 2: Damage state of the structural specimen after total failure (without using an appropriate crack propagation method)

[1] Feld & Vallino. *A pragmatic approach for the numerical simulation of laminated composites*. RCMA 25 (2), 161-180, 2015.

[2] Feld *et al. A novel approach for the strain rate dependent modelling of woven composites*. Composites Structures, *under review*.

[3] Coussa *et al. A consistent experimental protocol for the strain rate characterization of thermoplastic fabrics*, Strain 53 (3), e12220, 2017.