Characterization and prediction of static and cyclic creep behaviour in acrylic foam PSAs using an analytical model

BD Simões | EMD Fernandes | EAS Marques | RJC Carbas | S Maul | P Stihler | P Weißgraeber | LFM da Silva

Introduction

The use of pressure-sensitive adhesives (PSAs) has increased, especially in electronics, due to their strong initial adhesive force and ease of use, optimizing bonding and manufacturing processes. Now used in high-performance applications, studies enhance their durability and mechanical behaviour. PSAs, being viscoelastic, creep under load and temperature, necessitating an understanding for reliable design. This study characterizes the static and cyclic behaviour of an acrylic PSA and predicts its performance under various conditions using an analytical model. Based on experimental data, the model accurately predicts creep behaviour, incorporating temperature and stress dependence.

Theoretical and experimental details

Full creep curve modelling

The following equations were used to obtain the logarithmic strain rate and the strain values. They were for fitting purposes to generate data to feed the model and further use them to predict the creep behaviour of the single-lap joints (SLJs) under different conditions.

$$\dot{\varepsilon}(t) = \frac{d\varepsilon}{dt}(t) = exp\left[\frac{a(T,\sigma)}{(t-t_{ini})^{b(T,\sigma)} \cdot \left(t_{rup}(T,\sigma)-t\right)^{c(T,\sigma)}}\right] \quad (1)$$

$$\varepsilon(t) = \int_{t_{ini}}^{t} exp\left[\frac{a(T,\sigma)}{(\tau-t_{ini})^{b(T,\sigma)} \cdot \left(t_{rup}(T,\sigma)-\tau\right)^{c(T,\sigma)}}\right] d\tau + \varepsilon_0 \quad (2)$$

The variables a, b and c are fitting parameters, t_{ini} is the initial time, t_{rup} is the rupture time, T is the temperature in Kelvin, σ is the stress applied to the joint and ε_0 is the instantaneous strain.

Joint geometry

The material used for the substrates was poly(methyl methacrylate), or acrylic. Regarding the adhesive, a transparent acrylic transfer tape PSA was used. Quasi-static tests in SLJs at 1 mm/min determined the failure load of 76.85±6.01 N. The joint geometry is presented in Figure 1.

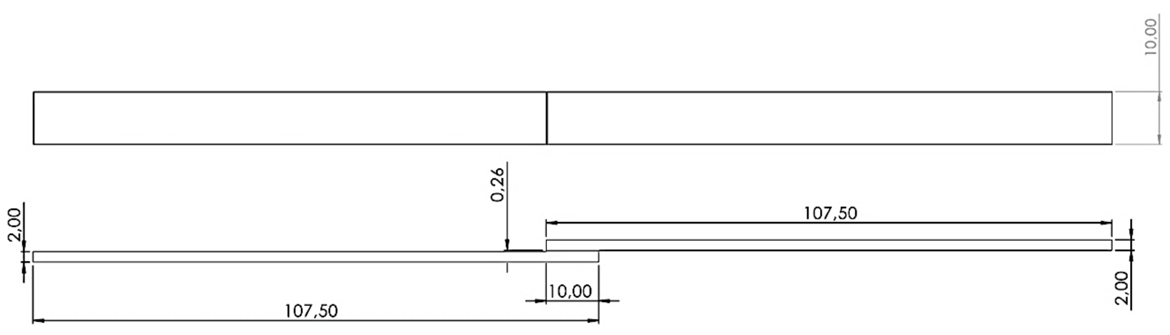

Figure 1 – Joint geometry, in mm.

Testing setup

For the static creep tests a lever-based apparatus was used to apply the defined load level (a percentage of the joint quasi-static failure load) and the displacements were measured resorting to a LVDT sensor. Regarding the cyclic creep tests, a servo-hydraulic machine was used with a trapezoidal waveform defined to control a platform that periodically supported the weight. The frequency was set at 0.04 Hz. Two photographs were taken for each cycle, one at unloaded phase and another at loaded phase, being then processed with DIC.

Results

Model fitting

The experimental results were fitted using equations (1) and (2), to obtain data to feed the model, as shown in Figure 3.

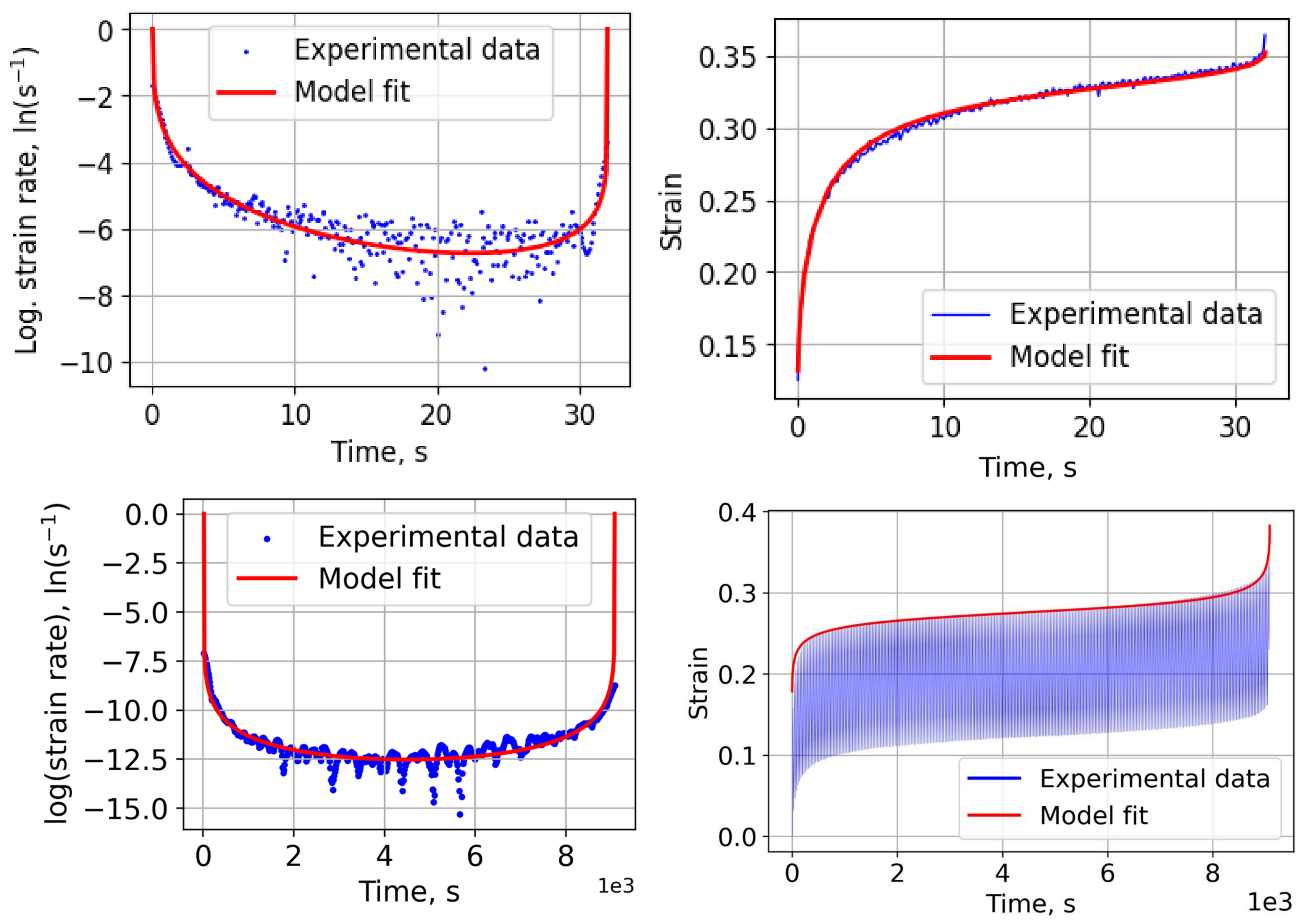

Figure 3 – Model fitting for static creep at 80% load level (A) and cyclic creep at 30% load level (B).

Model predictions

After fitting the experimental data, the model was fed with the different load levels and temperatures, for it to be able to predict other conditions. Figure 4 depicts the predicted curves produced by the model, as well as the respective experimental results.

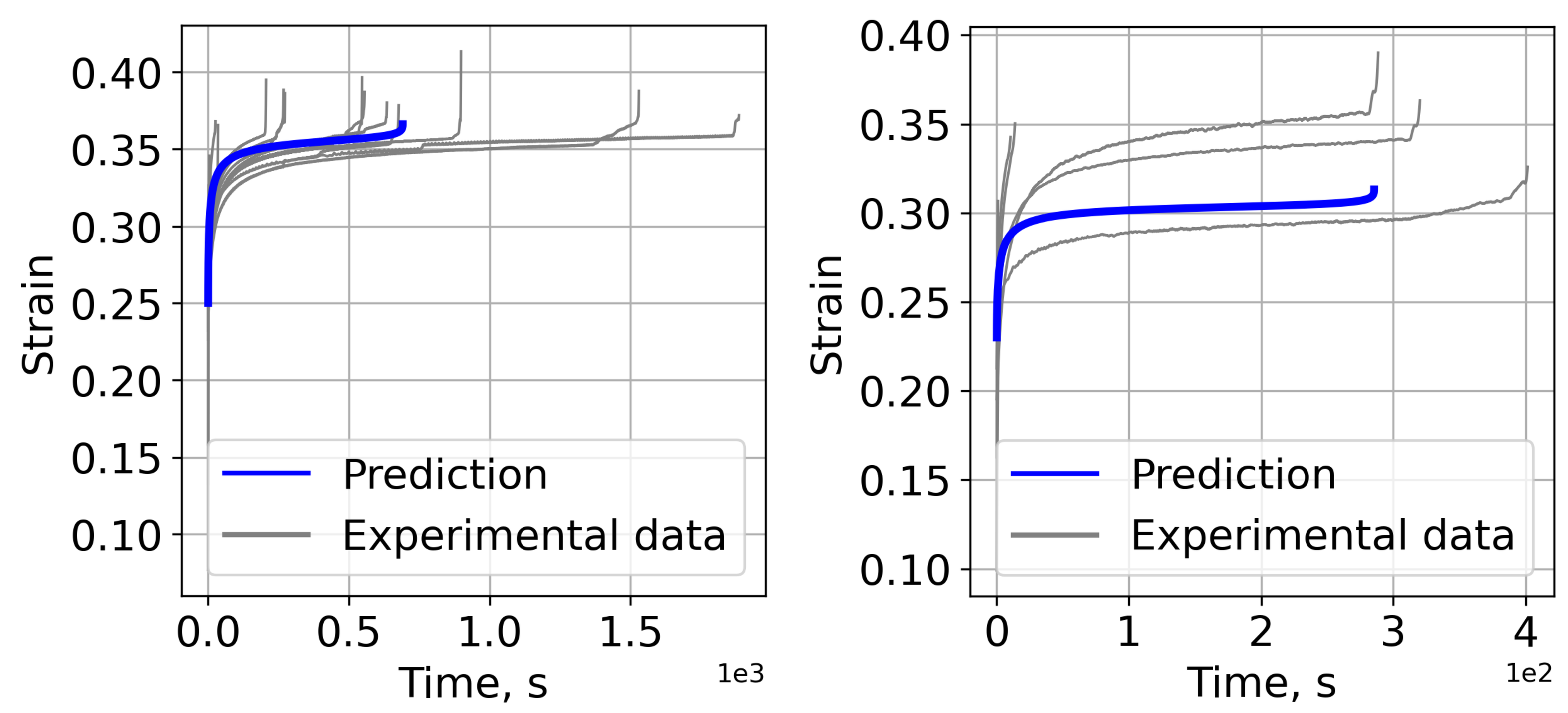

Figure 4 – Results for static creep at: 50% load level at room temperature (A) and 45% load level at 35°C (B).

Conclusions

The study successfully conducted creep tests to generate model coefficients for the PSA's creep behaviour. Despite significant data dispersion, the model showed good overall performance, though sensitivity to experimental curve shapes affected parameter correlations. The findings are promising for designing and predicting the service life of structures using PSAs, particularly in high-performance applications like the automotive sector.

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO | fct Fundação para a Ciência e a Tecnologia | Universität Rostock | BOSCH | DRMS2025 2ND INTERNATIONAL CONFERENCE ON DURABILITY, REPAIR AND MAINTENANCE OF STRUCTURES – MARCH 13-14, 2025 - PORTO, PORTUGAL