Mechanical characterization of a polyurethane using a hyper-viscoelastic constitutive model

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Abstract

The main objective of this study is to calibrate the material parameters of a hyper-viscoelastic constitutive model of a polyurethane used in rubber pad forming. Uniaxial compression, stress relaxation and free vibration tests are carried out experimentally. The hyperelastic behavior is described by the Mooney-Rivlin model, while the viscoelasticity is modelled by a series of Maxwell elements. The results show that the identified material parameters can accurately predict the mechanical behavior of the polyurethane in all tests performed.

Author Keywords. Rubber pad forming, hyper-viscoelastic behavior, Mooney-Rivlin model, Maxwell elements

1. Introduction

Increasing attention has been given to fuel cell technology in order to replace the internal combustion engines in transport applications. Since the bipolar plates (BPPs) are the primary component of the proton-exchange membrane fuel cells, comprising most of the cost, special attention is given to their manufacturing process. Rubber pad forming is one of the processes applied to manufacture BPPs (Liu and Hua 2010). The simulation of the rubber pad forming requires the accurate modelling of the mechanical behavior of the rubber material, which is both elastic and viscous (Andrade et al. 2019). In order to identify the material parameters of the constitutive model it is necessary to perform different experimental tests.

2. Experimental procedure and constitutive model

Three different mechanical tests were adopted to characterize the hyper-viscoelastic behavior of the polyurethane (PUR): (i) loading/unloading uniaxial compression tests, with three different grip velocities (0.05 mm/s, 0.5 mm/s and 5 mm/s); (ii) stress relaxation tests and (iii) free vibration tests. The PUR analyzed presents a hardness value of 70 Shore A; thus, it will be referred as PUR70. The specimen used is cylindrical (25 mm of height and 18 mm of diameter). The hyper-viscoelastic behavior was represented by the generalized Maxwell model, which is defined by an elastic spring (hyperelasticity) in parallel with *m* Maxwell elements (visco elasticity), where each of this elements is composed by an elastic spring and a viscous Newton-element in series. There are two material parameters, C_{10} and C_{01}, associated to the Mooney-Rivlin hyperelastic model as well as for each Maxwell element considered, *ak* and τ.

3. Calibration of material parameters

The nonlinear least square fitting was adopted to calibrate the material parameters, comparing the experimental and the numerical first Piola-Kirchhoff stress evolutions. The identified material parameters are listed in Table 1, showing that four Maxwell elements had to be considered to accurately capture the viscous effect. The comparison between the experimental and the calibrated curves is shown in Figure 1.

C_{10}	C_{01}	ak_1	ak_2	ak_3	ak_4	τ_1	τ_2	τ_3	τ_4
1,19882	0	10^{-5}	0,069804	0,64690	0,09290	12763,88	9,38	0,00437	726,02

Table 1: Material parameters obtained by curve fitting for the PUR70.

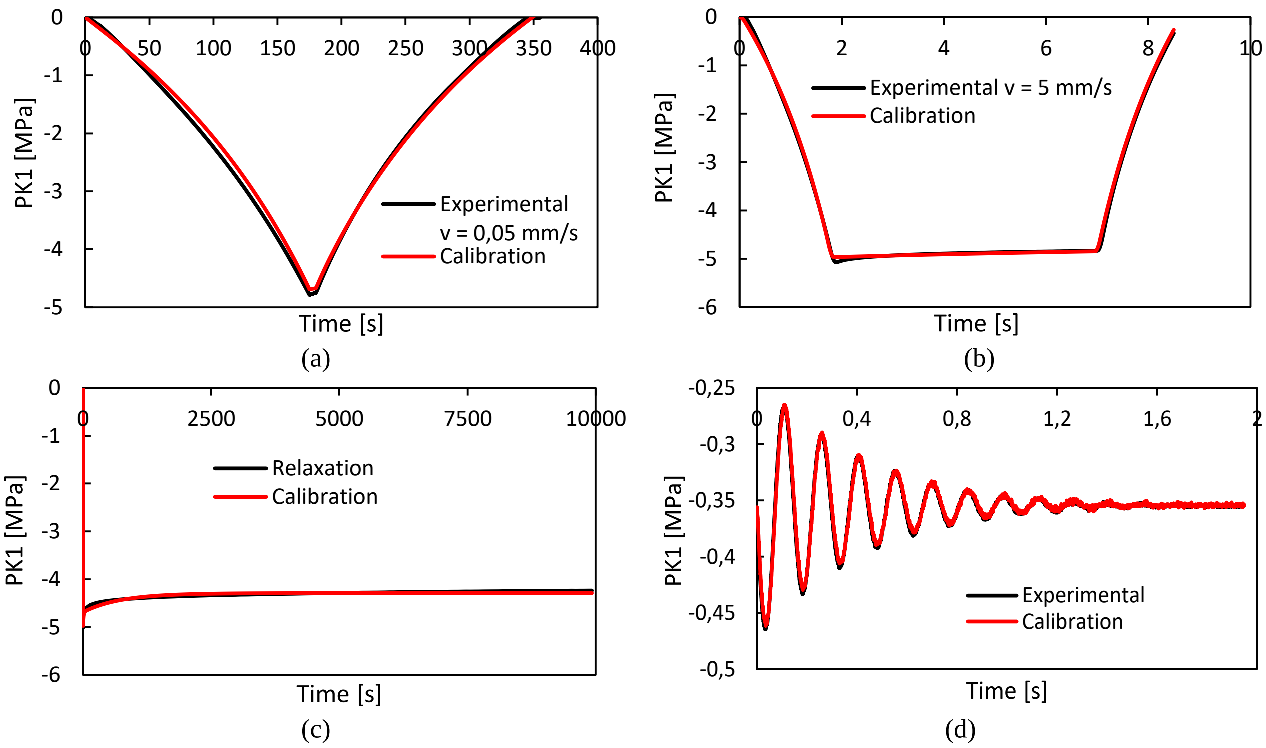

Figure 1: Comparison between the experimental and numerical first Piola-Kirchhoff stress for the PUR70: (a) uniaxial compression test v = 0.05 mm/s; (b) uniaxial compression test v = 5 mm/s; (c) stress relaxation test; (d) free vibration test.

4. Conclusions

The results show that the identified material parameters can predict very accurately the mechanical behavior of the polyurethane in all tests performed. This model will be applied in the numerical simulation of rubber pad forming of thin BPPs.

References

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