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A COMPARATIVE STUDY ON NONLINEAR MATERIAL MODELS FOR ELECTROACTIVE POLYMERS

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Dielectric elastomers (DE) are a very promising alternative to systems with moving parts and gears in many applications in mechanics, aeronautics and bioengineering. The absence of mechanisms and the simplicity of construction could reduce the weight and the cost of the devices and increase their reliability. The design process and performance evaluation require a multiphysics constitutive model able to deal with large deformations, material nonlinearities, viscoelastic effects, and electrostriction [6].

Experimental characterisation tests can be too simplistic compared to loading conditions in typical applications. Typical examples can be found in [2, 7] where uniaxial tests are considered representative of the general behaviour of DE. This is one of the factors that can lead to a poor matching between experiments and numerical simulations. For instance, static models based on experimental uniaxial test data have been used for the static inflation of a membrane, one of the most common DE applications. In multiple cases they showed a poor agreement between numerical simulations and experimental data. The maximum camber deformation calculated with these models presented errors up to 80%. The major cause of discrepancy is due to the uniaxial data considered for the fitting that do not represent the material behaviour in the specific case considered. This has been presented also by Li et al. [4] who showed how passing from uniaxial to equi-biaxial loading conditions requires the coefficients of the material model to be modified.

Another limitation of the majority of existing models is that viscoelastic effects are either neglected or modelled with a linear approach. Wissler and Mazza [7] proposed a linear viscoelastic approach based on Prony series to model the viscoelastic behaviour of the material. However, the agreement between the model and experimental results indicates that a viscoelastic linear approach is not appropriate for the performance evaluation of DE. Alternatively, Hossain [3] used the multiplicative decomposition approach to model the viscoelastic behaviour of DE for a tensile test. The results showed a good agreement for a wide range of deformation velocities.

This work proposes a dynamic, non-linear visco-hyperelastic model suitable for finite-element software implementation. It is based on a non-linear viscous model with a linear evolution law [1]. The implementation of the model has been verified against experimental uniaxial data, showing a very good agreement. Numerical simulations involving loads similar to the conditions encountered in aeronautical and biological applications, i.e. membrane inflation, are compared with dynamic experiments available in literature. The same model will be also used to evaluate the performance of tunable lenses made with dielectric elastomer actuators. The aim is to reproduce recent experimental results [5] in which the lenses are made of two transparent prestretched circular DE enclosing a fluid volume (Fig.1). The actuation of one of the membranes reduces its in-plane tension and consequently causes a redistribution of the fluid volume to obtain a new equilibrium. The focal length is hence modified by the variation of the curvatures of the two lenses. The FE model in Fig.1 is used to assess the performance of the constitutive model developed and show that it can be successfully implemented in a finite element software for the study of the various applications of DE.

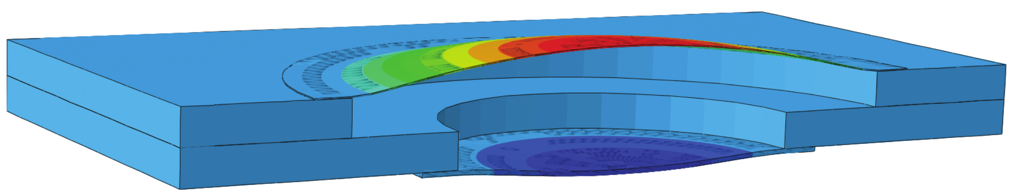

Figure 1: FE model of tunable lenses. Contour plot shows displacement under applied voltage.

REFERENCES

[1] J. Bonet. Large strain viscoelastic constitutive models. *International Journal of Solids and Structures*. Vol. **38**, 2001.

[2] J. Fox and N. Goulbourne. On the dynamic electromechanical loading of dielectric elastomer membranes. *Journal of the Mechanics and Physics of Solids*, Vol. **56**, 2669–2686, 2008.

[3] H. Mokarram, D.K. Vu and P. Steinmann. Experimental study and numerical modelling of VHB 4910 polymer. *Computational Materials Science*, Vol. **59**, 65–74, 2012.

[4] T. Li, C. Keplinger, R. Baumgartner, S. Bauer, W. Yang and Z. Suo. Giant voltage-induced deformation in dielectric elastomers near the verge of snap-through instability. *Journal of the Mechanics and Physics of Solids*, Vol. **61**, 611–628, 2013.

[5] S. Shian, R.M. Diebold and D.R.Clarke. Tunable lenses using transparent dielectric elastomer actuators. *Optical Society of America*, Vol. **21**, 8669–8676, 2010.

[6] Z. Suo. Theory of dielectric elastomers. *Acta Mechanica Solida Sinica*, Vol. **23**, 549–577, 2010.

[7] M. Wissler and E. Mazza. Electromechanical coupling in dielectric elastomer actuators. *Sensors and Actuators A: Physical*, Vol. **138**, 384–393, 2007.