Viscoelastic Mechanical Analysis at High Temperature Process of a Soda-Lime Glass Using COMSOL Multiphysics

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Abstract

Introduction: The goal of this study is to set a numerical procedure in order to study the glass forming process of soda-lime glasses used in the automotive field by means numerical simulations. In this work, using FEM analysis, the computed stresses in a simulated tensile test are compared with the ones predict by analytic relationship. This step is repeated for several temperature levels near the glass transition temperature, Tg. This is the typical temperature range for the sheet forming processes. It will be highlighted the difference by different predictive model. The constitutive relationships: In this paper, the material behavior of the soda-lime glass is studied in a range of temperature close the Tg. In such range the glass behaves as viscoelastic material. The viscoelasticity is the property of material to exhibit both viscous and elastic characteristic under deformation. For viscoelastic materials, the relationship between stress and strain depends on time. In addition to the viscoelasticity, the mechanical behavior of the analyzed glass can be assumed linear when deformations and load are small. In the following we analyze the stress relaxation properties, where a strain is produced "instantaneously" and it is maintained at the initial value while stress is "measured" as a function of time. Several constitutive models allow to evaluate the time-mechanical response of a linear viscoelastic material using linear combinations of springs and dashpots elements (Figure 1). Use of COMSOL Multiphysics: In the present study the generalized Maxwell model was implemented in COMSOL Multiphysics 3.5a by use a coupled analysis. A 3D Structural Mechanical Module is coupled with a conduction Heat Transfer Module in a transient analysis. A number of general form PDEs are added to the multiphysics analysis in order to consider the number of relaxation terms in the Prony series of the shear relaxation modulus, G(t). The relaxation times, the weight coefficients and the long term shear modulus were evaluated for a soda-lime glass at 550 °C. In this study the thermorheological simplicity assumption is done. For a material model containing multiple relaxation times, thermorheological simplicity demands that all the relaxation times have the same shift factor when the temperature is varied. Figure 2 shows the analyzed subdomain, where the geometrical symmetries were used to reduce the DOF's of the models. Results: In Figure 3 the computed stress component along the "load" direction is plotted against the time (the evaluation point is the same). A constant stain of 0.02% was applied to the ends surface of the numerical specimen. In this plot, the relaxation phenomena can be observed. Conclusion: In this paper a preliminary approach in order to analyze the mechanical behavior of inorganic glass at high temperature was showed. COMSOL Multiphysics was a suitable tool to

study the coupling of physical phenomena such as the solid structural mechanics with the thermal state of the soda-lime glass, called thermo-viscoelasticity. The acquired knowledge in the modeling of viscoelasticity has been used in a subsequent study to model a glass forming process.

Reference

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Figures used in the abstract

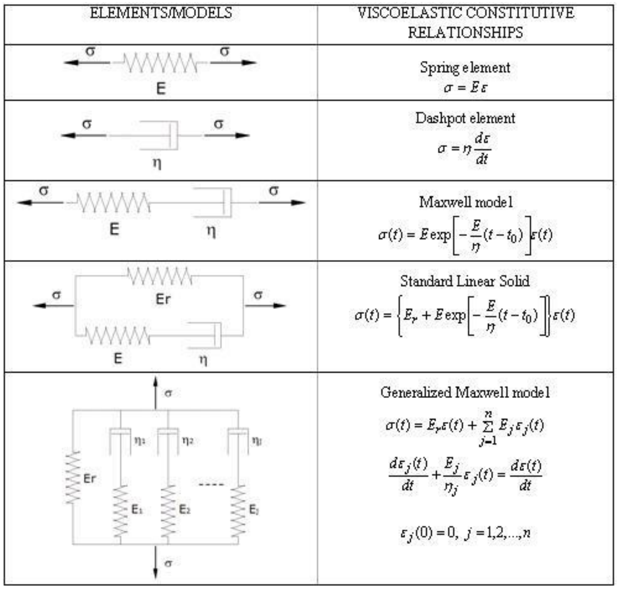

Figure 1: Base elements and viscoelastic models.

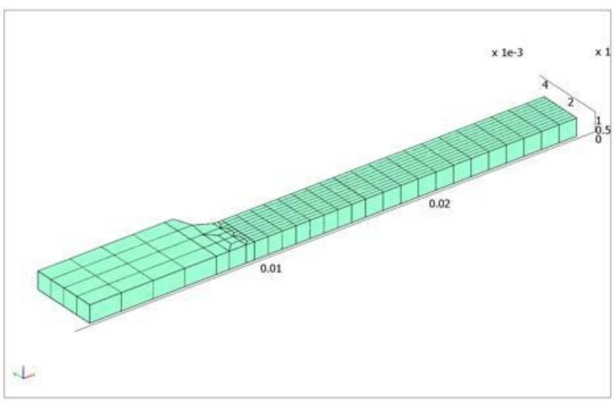

Figure 2: Tensile numerical specimen - main dimensions in millimeters.

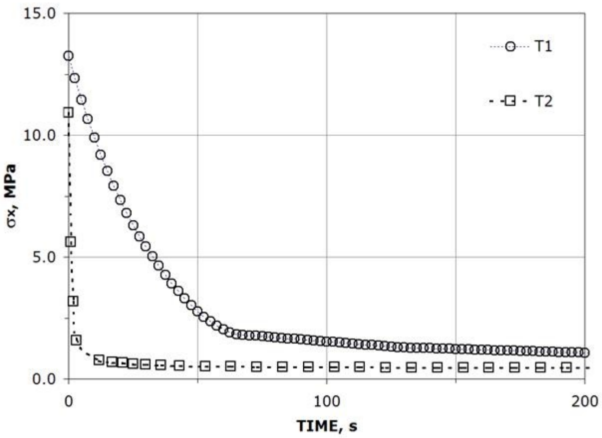

Figure 3: Analyzed subdomain, 1/4 of the original geometry.