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DEPOS 26
Deformation des Polymères Solides

An Anisotropic Modeling of the Visco-hyperelastic Behaviour of PET under ISBM Process Conditions

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ABSTRACT

The mechanical behaviour of Polyethylene Terephthalate (PET) under the severe loading conditions of the injection stretch blow moulding (ISBM) process is strongly dependent on strain rate, strain and temperature. In this process, the PET near the glass transition temperature (Tg) shows a strongly non linear elastic and viscous behaviour. In author's previous works, a non linear visco-hyperelastic model has been identified from equi-biaxial tension experimental results. In this work, the proposed non linear visco-hyperelastic model is implemented into the Abaqus environment and used to model the equal-biaxial tension tests. Despite the good agreement with biaxial test results, the model fails to reproduce the shape evolution during the free blowing of preforms. An anisotropic version of this visco-hyperelastic model is proposed and the free blowing simulation is compared with the experimental results managed in Queen's University Belfast.

KEYWORDS: Visco-hyperelastic, nonlinear behaviour, numerical simulation, experimental tests

SECTION 1 : VISCOHYPERELASTIC MODEL FOR PET UNDER ISBM CONDITIONS

The strongly hyperelastic strain rate dependant and coupled with the temperature is modeled using a Maxwell like model in finite strain. Cauchy stress tensor $\underline{\underline{\sigma}}$ can be written:

$$\begin{cases} \underline{\underline{\sigma}} = -P_e \underline{\underline{I}} + 2G\underline{\underline{\varepsilon_e}} \\ \underline{\underline{\sigma}} = -P_v \underline{\underline{I}} + 2\eta \underline{\underline{D_v}} \end{cases} \quad \text{where } \underline{\underline{\varepsilon_e}} \text{ is an Eulerian strain tensor: } \underline{\underline{\varepsilon_e}} = \frac{1}{2}\left(\underline{\underline{B_e}} - \underline{\underline{I}}\right) \tag{1}$$

$$G = G_0 \exp\left(\Lambda\left(I_1 - 3\right)^2\right), I_1 = trace\left(\underline{\underline{B_e}}\right) \quad \text{and} \quad \eta\left(\overline{\varepsilon_v}, \overline{\dot{\varepsilon}_v}, T\right) = \eta_0 h\left(\overline{\varepsilon_v}\right) f\left(\overline{\dot{\varepsilon}_v}\right) \tag{2}$$

where Λ and G_0 are constant. The reference viscosity $\eta_0(T)$ is coupled to temperature via a WLF like model with h and f specific functions identified from biaxial elongation tests [1,2]. P_e and P_v are hydrostatic pressures associated to incompressibility conditions. All leads to the constitutive equation:

$$\frac{\delta \underline{\underline{B_e}}}{\delta t} + \frac{G}{\eta} \underline{\underline{B_e}}\,\underline{\underline{\hat{B}_e}} = 0 \tag{3}$$

This model reproduces nicely the experimental results on a large range of strain, strain rate and temperature near ISBM conditions as shown on figure 1.

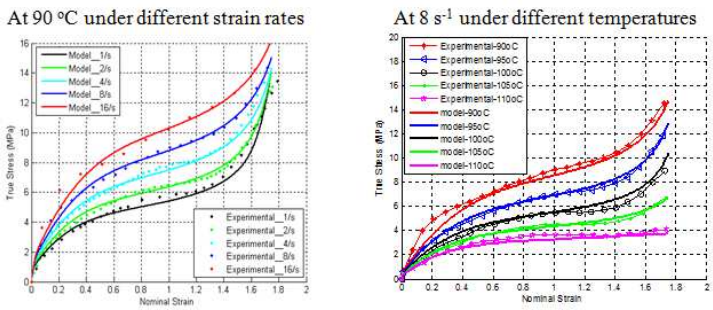

Figure 1 : Comparison between experimental results and model simulations.

SECTION 2: STRETCHING AND BLOWING SIMULATION OF A PET PREFORM

The model is implemented in ABAQUS and enables to reproduces accurately the shape evolution of a preform stretched by an internal rod and blown with internal pressure. To obtain the correct aspect ratio between length and radius of the quasi final bottle, one needs to introduce an anisotropic viscosity. We choose specific h_i function for each principal strain (i=1,2 in the surface and i=3 normal to the bottle surface) with the adjunction of the anisotropic parameter β to reproduce accurately a fine evolution of the bubble shape of the PET preform.:

$$\bar{h}_i\left(\overline{\varepsilon_v}\right)=\beta h_i\left(\overline{\varepsilon_v},\varepsilon_{vi}\right)+(1-\beta)h_{\max}\left(\overline{\varepsilon_v}\right) \text{ with } \quad 0\le\beta\le 1 \text{ for } i=1,2 \text{ and } \bar{h}_i\left(\overline{\varepsilon_v}\right)=\bar{h}\left(\overline{\varepsilon_v}\right) \text{ for } i=3 \qquad (4)$$

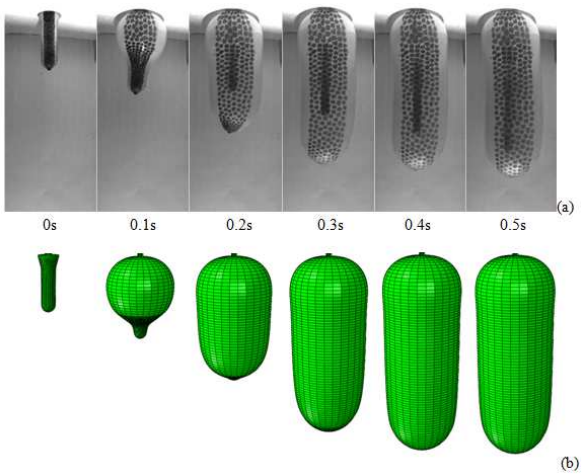

Figure 2: (a) Stretch and free blowing of a preform; (b) Abaqus simulation with model β =0,9.

Taking into account an anisotropic viscosity or elasticity has consequence on equation (3) that must be rewritten to obtain a “clean” model from a theoretical point of view. This work is actually in progress.

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