Expansion of water expandable polystyrene (WEPS)

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Introduction

During the conventional production of **EPS** foams, the physical blowing agent (e.g. pentane-isomers) is emitted into the environment. As environmental concerns grow, NOVA in collaboration with TU/e is developing a new generation PS-foam, containing no hydrocarbon blowing agent. In the new approach, the conventional blowing agent pentane is replaced by water, resulting in **WEPS**[1,2] [Figure 1 and 2]. In many cases, existing foaming processes involve more art than science, while the replacement of the common blowing agents change the expansion behaviour drastically. To predict the most common features concerning the novel expansion process, a model and an experimental expansion technique are presented.

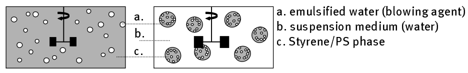

Figure 1: Schematic representation of the synthesis of WEPS

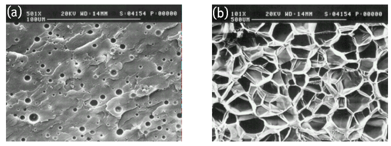

Figure 2: SEM photographs of (a) compact and (b) expanded WEPS

Model

The overall growth process involves simultaneous transport of momentum, mass and energy. At the start of expansion, the bubbles inside the foam can be considered as single spherical bubbles in an infinite sea of fluid [Figure 3].

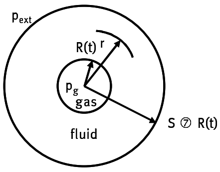

Figure 3: Schematic representation of the single bubble model

Governing equations:

Momentum equation: $$\tfrac{3}{2}\dot{R}^2 + R\ddot{R} = \frac{p_g(R) - p_{ext}}{\rho} - \frac{2\gamma}{\rho R} - \frac{3}{\rho}\int_R^{\infty} \frac{\tau_{rr}}{r}\,dr$$

Continuity equation: $$v_r = \frac{\dot{R}R^2}{r^2}$$

Normal radial stress: $$\tau_{rr}(r,t) = \int_0^t G_0 e^{(t'-t)/\lambda}\dot{\varepsilon}_{rr}(r',t')\,dt'$$

Solving these equations for respectively $\lambda \to 0$ and $\lambda \to \infty$ results in the following figures:

$\lambda \to 0$ (*Newtonian*)

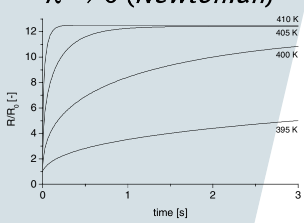

Figure 4: The relative radius as function of time for $\lambda \to 0$ at 410, 405, 400 and 395 K

$\lambda \to \infty$ (*Hookean*)

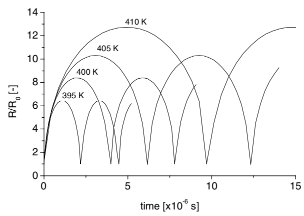

Figure 5: The relative radius as function of time for $\lambda \to \infty$ at 410, 405, 400 and 395 K

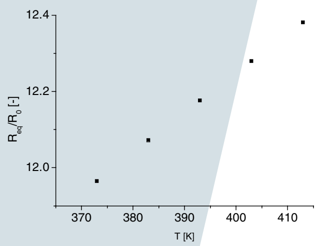

Figure 6: The relative equilibrium radius as function of temperature for $\lambda \to 0$

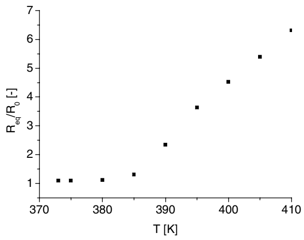

Figure 7: The relative equilibrium radius as function of temperature for $\lambda \to \infty$

Experimental

An optical technique has been developed to track accurately the foaming of a single (W)EPS bead [Figure 8]. The result for WEPS and EPS is respectively given in Figure 9a and 9b.

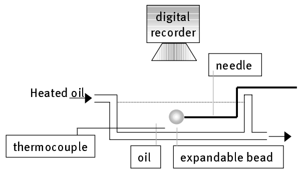

Figure 8: Schematic representation of the experimental bead expansion setup

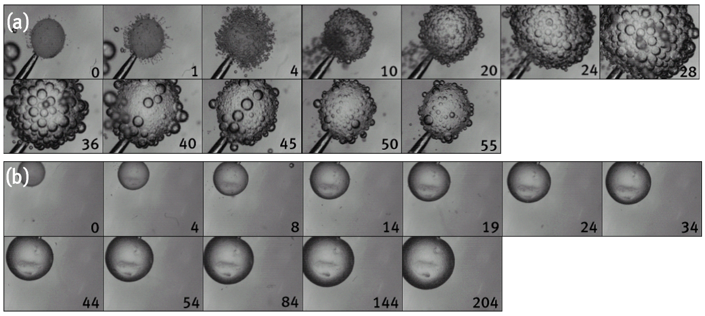

Figure 9: Photos of an expanding (a) WEPS-bead (4 wt.% water, 130°C) and (b) a commercial (NOVA) EPS-bead (7 wt.% pentane, 105°C)

From Figure 9 we can determine the (relative) volume of the bead as function of time [Figure 10].

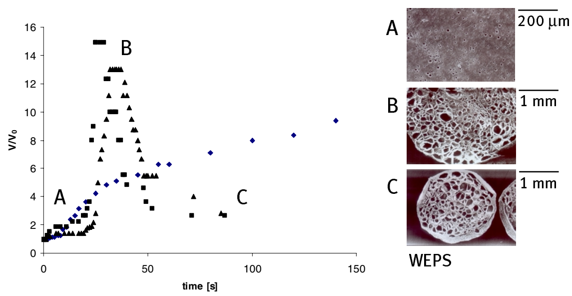

Figure 10: The relative volume as function of time for two WEPS-beads (4 wt.% water, 130°C ■, ▲), also showing cross-sections at different stages in the WEPS expansion process and one bead of a commercial EPS grade (NOVA) (7 wt.% pentane, 105°C , ◆)

Conclusion

The single bubble model is used to verify the influences of the pure elastic and the pure viscous material behaviour on the foaming. From the experimental results we can conclude that for WEPS, diffusion is of major importance during the expansion. Since we did not yet incorporate diffusion (and viscoelastic material behaviour) into the single bubble model it is too early to qualitatively compare the experimental results with the results obtained by using the single bubble model.

Reference

1. Crevecoeur J., Coolegem J., Nelissen L. and Lemstra P.J., *Polymer*, 40, 3697, (1999)
2. Crevecoeur J., Neijman E., Nelissen L. and Zijderveld J., *Eur. Pat. Appl.* 96201904.8, (1996)

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