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Simulation and Experiments for Temperature and Pressure Release Rate Superposition Principle in Physical Polymeric Foaming

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From experiments of batch CO2-polystyrene (PS) physical foaming, Muratani and Shimbo found that relationships between bubble density and depressurization time obtained in near the glass-transition temperature at different foaming temperatures can be shifted along the depressurization time to yield a master curve, which they called a time (depressurization time)-temperature (foaming temperature) superposition principle in physical foaming. In this paper, using the revised Shafi's simultaneous bubble nucleation and growth models, numerical simulations were performed to analyze and consolidate their principle. That is, the effects of temperature and pressure release rate on bubble density in physical polymeric foaming were numerically simulated. Comparison of the simulation results with experimental data elucidates that, at temperatures in near glass transition temperature and at high-pressure release rate (i.e., short depressurization time), the polymer viscosity becomes a principal factor of determining the bubble density-depressurization time relationship, and therefore, the shift factor, which is the amount that each curve is shifted, depends strongly upon the viscosity-temperature relationship. At far above glass transition temperature and at low-pressure release rate, mass transfer of physical foaming agent, i.e., diffusion of physical foaming agent (PFA) from polymer matrix to bubbles, affects the shift factor. Therefore, shift factors with two different values of activation energy are required to create a master curve for the data obtained at the different foaming temperatures ranging from near glass transition to melting temperatures.