583g The Performance of Multiple-Mode Models in Single and Double Step-Strain Flows

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Single and double step-strain flows are convenient and powerful methods to evaluate rheological constitutive equations and to examine the coupling effect among the modes in rheological models. The evaluation of several classes of multiple-mode rheological constitutive equations is presented.

The models examined include: the Uncoupled Maxwell Modes (UMM) Model, the Uncoupled Extended White/Metzner (UEWM) Model, the Uncoupled Giesekus Modes (UGM) Model, the Pair-wise Coupled Maxwell Modes (PCMM) Model, and the Pair-wise Coupled Maxwell Modes Model with the White/Metzner-like extension (PCMM-EWM), the Fully-Coupled Maxwell Modes (FCMM) Model, and the FCMM Model with the White/Metzner-like extension (FCMM-EWM Model) [1]. The parameters of all the models are obtained by fitting experimental data of a typical low-density polyethylene melt taken in small-amplitude oscillatory shear flow and steady shear flow using the Nelder and Mead's Downhill Simplex Method [2]. The same parameters are used to predict viscoelastic flow properties of the polymer melt in single and double step-strain flow through the time variation of strain.

Several types of step-strain experiments will be examined, which include single step-strain, double step-strain and reversing double step-strain experiments. We also examined the special case (second strain equals 0) of the reversing double step-strain experiments to check the performance of the models in Osaki-Kimura [3] consistency relation.

The overall performance of the models in the step-strain experiments is presented in detail. The double-step, especially the reversing double-step strain experiment is a powerful tool to examine constitutive equations critically. The FCMM-EWM Model has demonstrated a relatively good performance in both single and double step strain experiments, except that FCMM-EWM Model gives a lower prediction of the ratio between shear stress and first normal stress; but the UMM Model , well known to only fit the linear rheological properties, does give a very good prediction in both experiments. Therefore the step experiments conducted herein fall in the linear region of polymer melts, which can be proven by the fact the shear rates in step strain experiment are much below $10 sec^{-1}$. Overall, the UGM Model has shown supreme performance in all aspects of step-strain experiments.

References: 1. A. N. Beris and B. J. Edwards, Thermodynamics of Flowing Systems (Oxford University Press, New York, 1994). 2. W. H. Press, W. T. Vettuling, S. A. Tevkolsky, et al., Numerical Recipes in Fortran 77 (Cambridge Univ. Press, Cambridge, 1992). 3. K. Osaki, s. Kimura, and M.Kurata, J. Rheol. 25, 549 (1981).