MODELLING OF STRESS AND STRAIN AMPLIFICATION EFFECTS IN FILLED POLYMER MELTS

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When hard filler particles are added to a polymer melt, it is usually assumed that its zero-shear viscosity and therefore the stress increase according to Einstein's or a similar formula. In some papers one finds an alternative approach in which the local strain field is increased according to these formulas. Although both approaches provide the same increase of the shear stress in the linear limit, it can be shown that the second approach violates the energy conservation law as the macroscopic and microscopic dissipated energies are not equal anymore. In this contribution we propose a new approach, which we call the stress and strain amplification approach, to account properly for the higher deformations near the non-aggregating hard particles in a suspension with a non-Newtonian fluid as matrix. Similar to the original derivation of Einstein [1], we split the hydrodynamic amplification factor predicted by Batchelor [2] into two contributions. One, called the strain amplification factor, should hold for any kind of flow (shear, elongation) and any type of matrix (viscous, elastic, viscoelastic)

$$a_n = 1/(1-\phi)\,.$$

The other, called the stress amplification factor, depends on the flow type, and is given for a simple shear flow as

$$a_s = 1 + 0.5\phi + 2.2\phi^2\,.$$

The viscosity of the suspension can be calculated from the energy conservation law, which requires that the microscopic and macroscopic dissipated energies should be equal. This gives

$$\eta^* = a_s a_n^2 \eta(a_n \dot{\gamma})\,,$$

where the asterisk denotes the bulk (macroscopic) property of the suspension.

The stress and strain amplification approach predicts the shift of stress overshoot to lower shear rates with the increase of particle concentration. This effect was observed recently for the LDPE melts filled with layered double hydroxides [3] and cannot be explained in the frame of two other approaches, when only stress or strain is amplified. We tested the new stress and strain amplification approach using two relatively simple constitutive models: the Wagner model [4] and the original Doi-Edwards model [5]. However, it should not be difficult to apply the new approach to more elaborated integral models. A real challenge would be a further development of the stress and strain amplification approach to describe a suspension of the anisotropic hard particles with a viscoelastic polymer melt as a matrix.

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