Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713926090

S-shaped deformation profiles in sheared liquid-crystalline polymers

S. Guido[a]; N. Grizzuti[a]; G. Marrucci[a]
[a] Dipartimento di Ingegneria Chimica, Università di Napoli, Napoli, Italy

To cite this Article Guido, S. , Grizzuti, N. and Marrucci, G.(1990) 'S-shaped deformation profiles in sheared liquid-crystalline polymers', Liquid Crystals, 7: 2, 279 — 282

To link to this Article: DOI: 10.1080/02678299008029214

URL: http://dx.doi.org/10.1080/02678299008029214

LIQUID CRYSTALS, 1990, VOL. 7, NO. 2, 279–282

PRELIMINARY COMMUNICATIONS

S-shaped deformation profiles in sheared liquid-crystalline polymers

by S. GUIDO, N. GRIZZUTI and G. MARRUCCI
Dipartimento di Ingegneria Chimica, Università di Napoli, Piazzale V. Tecchio,
80125 Napoli, Italy

(*Received 25 July 1989; accepted 8 October 1989*)

A tracer particle technique has been used to investigate the deformation profiles of a liquid-crystalline polymer under shear between parallel plates. The system was an aqueous solution of hydroxypropylcellulose (HPC), the good transparency of which allows for optical observations over thicknesses of the order of millimetres, as used here. The results indicate that the deformation profile deviated considerably from linearity, whereas a linear profile was confirmed for isotropic liquids, including polymeric ones. For the HPC liquid-crystalline solution most of the deformation was concentrated close to the walls.

When a liquid is sheared between parallel plates, it is expected that, in the absence of inertial effects, the deformation profile is linear. In this preliminary communication, we show that this expectation is not necessarily fulfilled for a liquid-crystalline polymer. In particular, we have found non-linear profiles in a 50 wt % aqueous solution of hydroxypropylcellulose (HPC). The experimental set-up consists of two optical glass plates which can be made parallel to each other to within 20 μm over a distance of 10 cm. The gap can be set to any value above a few tens of microns, and one of the plates can be displaced, parallel to its major length (10 cm), with a velocity in the range 0·01–16 mm/s. Further details on the apparatus can be found in [1].

Two different samples of HPC were used in this work, having $M_w = 100\,000$ and $M_w = 300\,000$. The tracer particles used to determine the deformation profiles were glass microspheres less than 30 μm in diameter. These particles were dispersed in the sample either locally, i.e. roughly in a cross section, or uniformly throughout. In the former case, a thin filament covered with the spheres was drawn through the sample, leaving a tail of particles behind. The sample was then allotted a sufficient time for the hole created by the filament to heal completely. Alternatively, the sphere dispersion was prepared by centrifugation. Both methods gave the same results [2]. The thin filament technique could be used, and was in fact used initially, to introduce a dye, thus generating a coloured filament in the sample. Although the dye and the tracer particle techniques gave the same qualitative results, the dye technique was abandoned because of a poorer contrast under the microscope.

Under shear, the motion of a particle could be tracked by means of a microscope. If necessary, the microscope itself could be displaced micrometrically to follow the particle. Since the motion of the microscope was strictly parallel to the plates, and no change of focus was ever detected on any particle, it can be concluded that all particles move parallel to the plates. The deformation profile was determined by measuring the

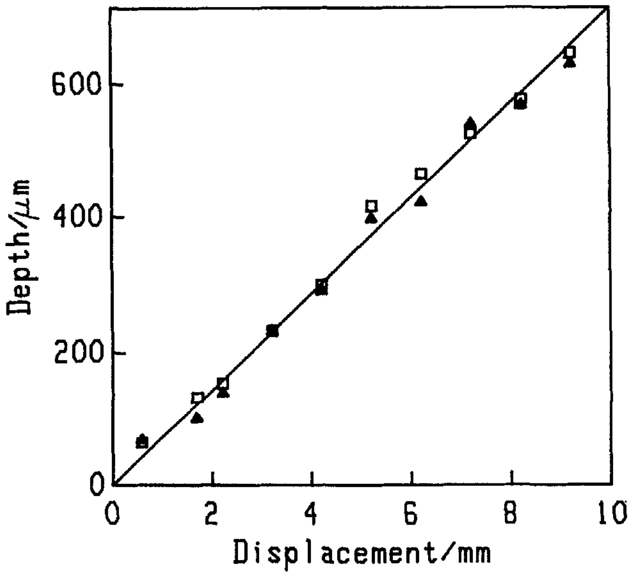

Figure 1. Two sets of results for the deformation profile of isotropic liquids; 30 wt % polyethyleneimine in water. Shear rate 1 s^{-1}.

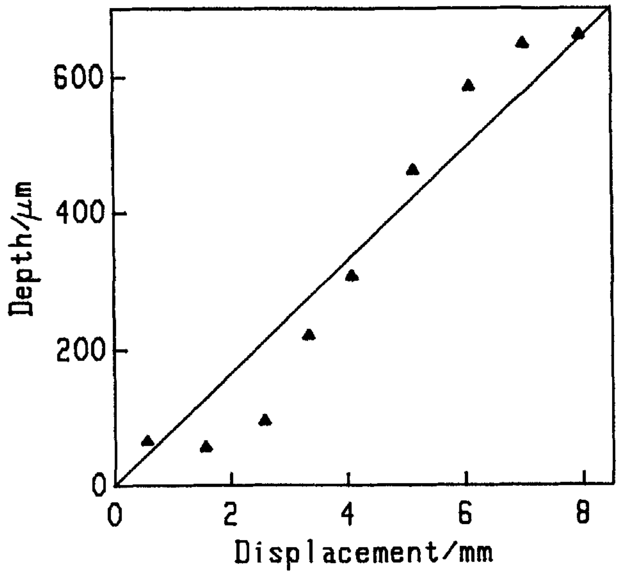

Figure 2. Deformation profile for the liquid-crystalline phase of HPC; M_w = 100 000, shear rate = 1 s^{-1}.

displacement of a set of particles, each at a different depth in the sample. At any given depth, as determined by the microscope focusing, very few particles were present in the field of view (typically only one) because the suspension was very dilute. The particle chosen could then be easily located before and after the deformation, and its displacement along the shear direction determined.

The method was first tested with some polymers forming isotropic phases, including an isotropic solution (30 wt %) of HPC itself. In all cases the expected linear profile

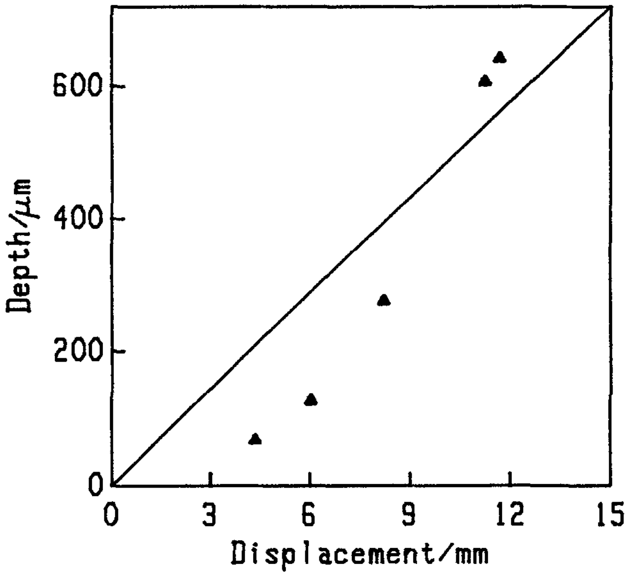

Figure 3. Deformation profile for the liquid-crystalline phase of HPC; M_w = 300 000, shear rate = 1 s^{-1}.

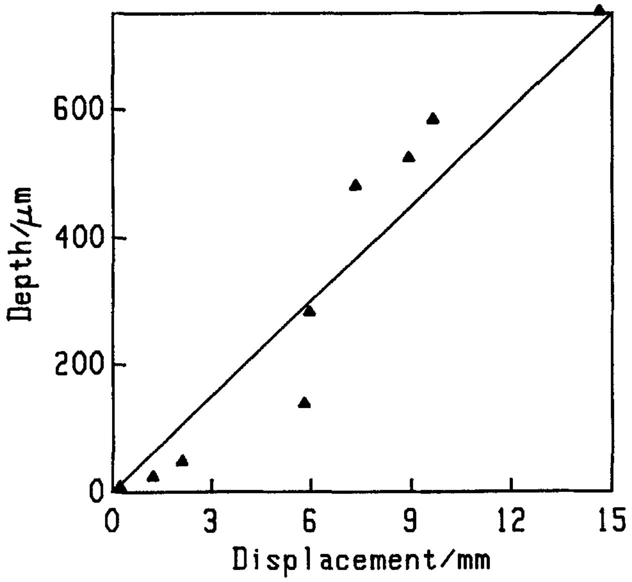

Figure 4. Deformation profile for the liquid-crystalline phase of HPC; M_w = 300 000, shear rate = 3 s^{-1}.

was in fact obtained. A typical result is shown in figure 1. Typical results for the anisotropic phase of HPC are reported in figures 2–4. In all cases, the profile is S-shaped, with the largest part of the deformation concentrated at the walls, in a thickness of about 100 μm. Comparison of figures 2–4 seems to show that the effect increases both with increasing molecular weight and shear rate. A possible explanation for this effect can perhaps be found in the presence of ordered layers of polymer near

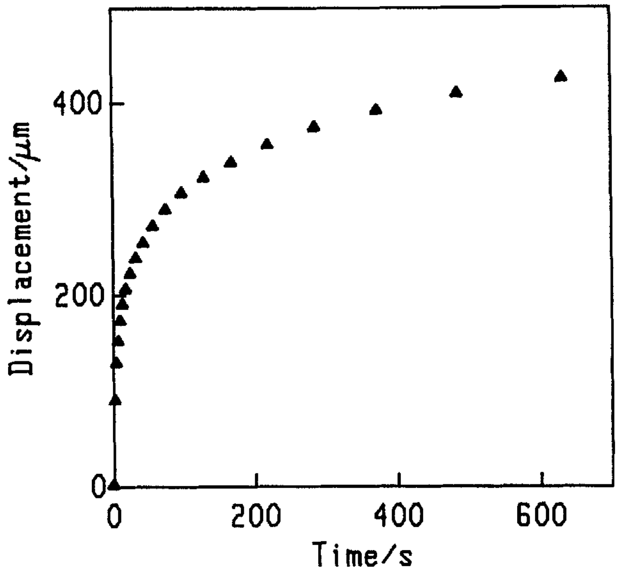

Figure 5. Displacement relaxation after cessation of shear of a particle located *c.* 100 μm from the bottom wall; M_w = 300 000, shear rate = 1 s^{-1}.

the solid walls. Evidence for such layers, of the magnitude indicated here (about 100 μm), can be found in [3]. On the other hand, it seems most unlikely that the effect is an artifact of the experiment due to, say, flow perturbations induced by the glass spheres. Thus the same S-shaped profile was observed with the dye as well.

Together with the S-shaped profile, another peculiar effect was observed. The profile relaxes partially towards the linear one several minutes after the cessation of the shear deformation. Figure 5 reports such a relaxation effect for a particle located about 100 μm from the wall. Notice that, during the relaxation, the particles sitting below the midplane move backwards, whereas particles above it move forwards. It should be stressed, however, that the amount of deformation relaxed is much less than the difference between the S-shaped profile and the linear one. In the example shown in figure 5, the particle is displaced a total of 400 μm during relaxation, whereas the difference between the S-shaped and the linear profile is about 3000 μm at the location of that particle. The deformation profiles reported in figures 2–4 were taken at the end of the relaxation process.

The question remains open as to how general the results found here are, i.e. whether or not they apply to all (or most) liquid-crystalline polymers, and in different flow conditions. Work is now under way to explore the behaviour of HPC in channel flow. Another question which poses itself is the possible influence of the non-linear profile on the formation of the well-known banded texture.

We wish to acknowledge the Ministero per l'Università e la Ricerca Scientifica e Technologica, Rome, for financial support.

References

[1] Marrucci, G., Grizzuti, N., and Buonaurio, A., 1988, *Molec. Crystals liq. Crystals*, **153**, 263.

[2] Guido, S., 1989, Chem. Eng. Thesis, Napoli.

[3] Onogi, Y., White, J. L., and Fellers, J. F., 1980, *J. Non-Newtonian Fluid Mech.*, **7**, 121.