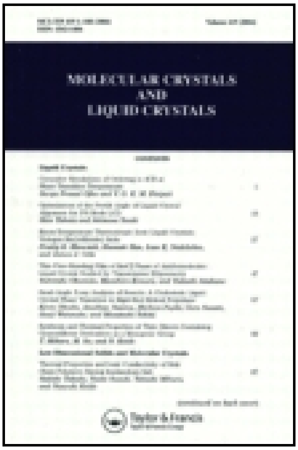

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DEVELOPMENT OF THE SHEAR FLOW INDUCED DEFORMATION IN NEMATIC LAYERS

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Abstract The results of numerical solution of the Euler-Lagrange equation for deformations of director field in sheared nematic layer are presented. The threshold behaviour is found in the special case. The maximum deformation angle versus shear stress, the director distribution in the layer and the effective viscosity are calculated. Two types of deformation are distinguished and a possibility of transition between them is found. The results obtained on the basis of catastrophe theory are confirmed.

INTRODUCTION

The shear flow alignment in nematics was investigated both experimentally[1,2,3] and theoretically[4,5,6]. Recently the qualitative analysis of the behaviour of the nematic layer based on catastrophe theory was proposed[7]. For comparison, the influence of flow upon alignment of nematics is here investigated numerically by means of resolving the Euler-Lagrange equation.

Figure 1 shows the geometry of the layer. The nematic liquid crystal is confined between two infinite parallel plates a distance d apart. It is characterized by Leslie coefficients α_i, average elastic constant k and $\alpha_3/\alpha_2>0$. The director is strongly anchored on both boundaries with surface tilt θ_1. Under the action of the constant shear τ, one of the plates moves against another and the director field is deformed.

The Euler-Lagrange equation has the form:

$$k(d^2\theta/dz^2) = \tau(\alpha_3\cos^2\theta - \alpha_2\sin^2\theta)/$$
$$/[(\alpha_3+\alpha_4+\alpha_6)/2 - (\alpha_2+\alpha_3)\sin^2\theta], \qquad (1)$$

and is integrated numerically.

RESULTS

The numerical results are presented in terms of the reduced quantities: $s=\alpha_3/\alpha_2$, $r=\eta_2/\alpha_2$, $t=\tau/\tau_0$ where $\tau_0=k\pi^2/d^2$. The values of the material constants of MBBA[8,9] were adopted, but with simplification $k=(k_{11}+k_{22}+k_{33})/3$.

The midplane orientation angle θ_m in function of the reduced stress t is shown in Figure 2 for several surface tilts. The deformation can be of type 1 if $\theta_1>-\theta_0$, where $\theta_0=\arctan\sqrt{\alpha_3/\alpha_2}$, and of type 2 if $\theta_1<-\theta_0$. For $\theta_1=-\theta_0$ the deformation has threshold character. The threshold stress τ_c is of order 0.1N/m^2 for $d=10^{-5}$m. For $\theta_1=\theta_0$ no deformation occurs. The details of the behaviour in vicinity of the threshold depend on the relation between r and s. Dashed and dotted lines denote the metastable and unstable states respectively.

Director profiles are shown in Figure 3. For very high stress the deformation saturates. The prevailing orientation is θ_0 for type 1 and $\theta_0-\pi$ for type 2. They are equivalent excepting for the thin layers adjacent to the boundary surfaces.

The changes of director field in the layer influence the effective viscosity

$$\eta = \alpha_2 d \left\{ \int_{-d/2}^{d/2} [r - (1+s)\sin\theta]^{-1} dz \right\}^{-1}. \qquad (2)$$

The $\eta(t)$ relation can have different character depending

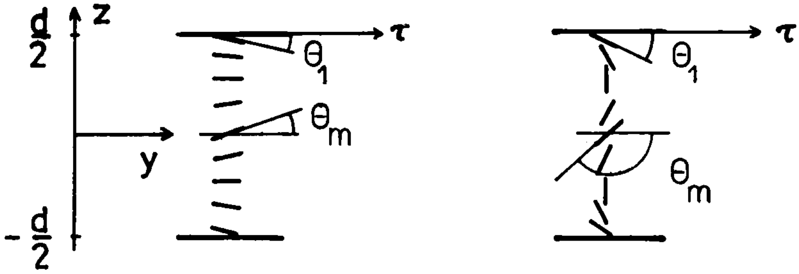

FIGURE 1. Two deformations due to simple shear.

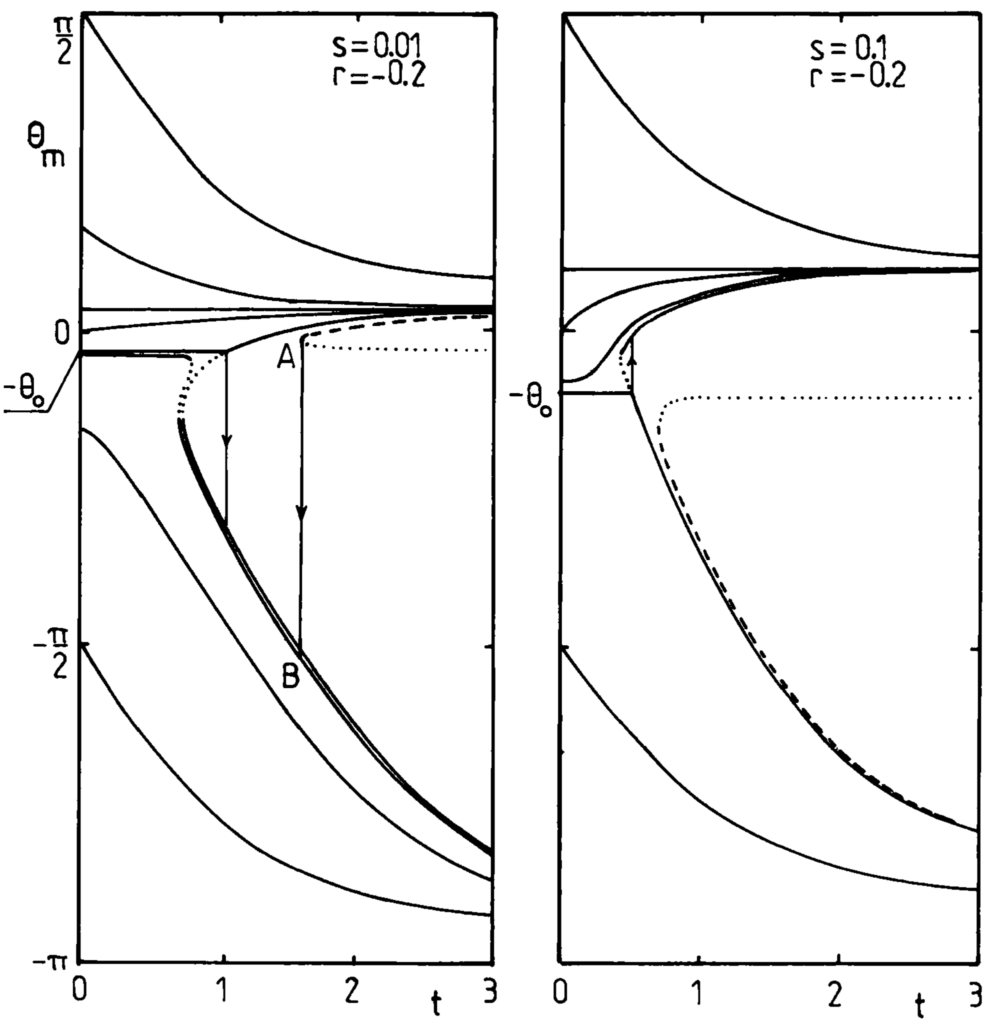

FIGURE 2. θ_m in function of t for various θ_1

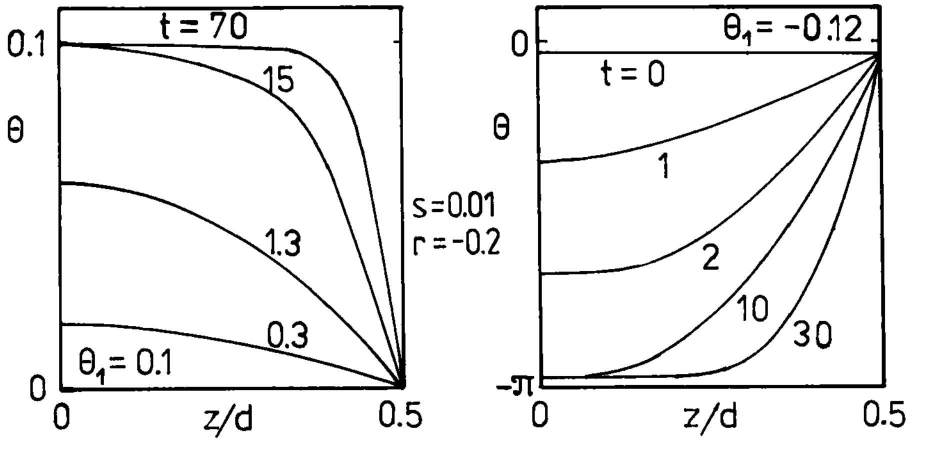

FIGURE 3. Director semiprofiles for various t.

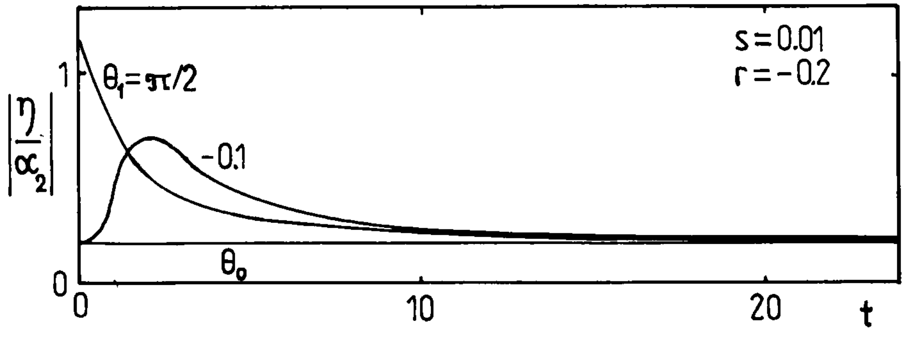

FIGURE 4. Effective viscosity versus stress.

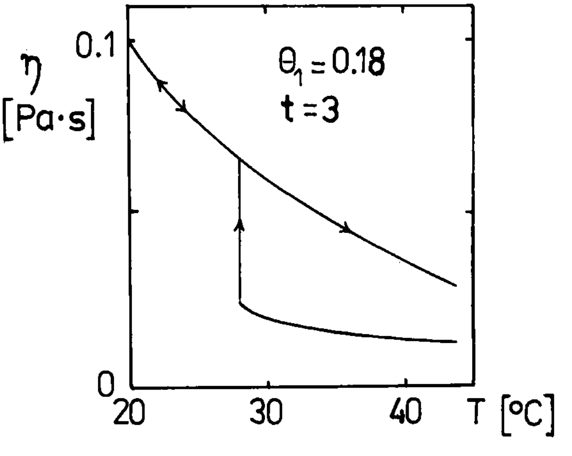

FIGURE 5. Effective viscosity vs temperature.

on the surface tilt (Figure 4). In each case the effective viscosity tends to value $\alpha_2(r-s)$ as $t \to \infty$.

There is a possibility of the rapid change of orientation from one type to another. It takes place if the deformation adopted by the layer becomes unstable, for instance from state A to B in Figure 2. Figure 5 illustrates such a transition by means of temperature changes of η at moderate stress and at constant surface orientation.

CONCLUDING REMARKS

The results are in agreement with qualitative predictions of the director field behaviour obtained from analysis based on catastrophe theory.

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