This article was downloaded by: [Tomsk State University of Control Systems and Radio]

On: 19 February 2013, At: 10:41

Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered

office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



# Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics

Publication details, including instructions for authors and subscription information:

http://www.tandfonline.com/loi/gmcl17

# Development of the Shear Flow Induced Deformation in Nematic Layers

Grzegorz Derfel <sup>a</sup>

<sup>a</sup> Technical University of Łódź, Institute of Physics, 93-005, Łódź, Poland

Version of record first published: 22 Sep 2006.

To cite this article: Grzegorz Derfel (1990): Development of the Shear Flow Induced Deformation in Nematic Layers, Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics, 191:1, 377-381

To link to this article: <a href="http://dx.doi.org/10.1080/00268949008038621">http://dx.doi.org/10.1080/00268949008038621</a>

### PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <a href="http://www.tandfonline.com/page/terms-and-conditions">http://www.tandfonline.com/page/terms-and-conditions</a>

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Mol. Cryst. Liq. Cryst. 1990, Vol. 191, pp. 377-381 Reprints available directly from the publisher Photocopying permitted by license only © 1990 Gordon and Breach Science Publishers S.A. Printed in the United States of America

DEVELOPMENT OF THE SHEAR FLOW INDUCED DEFORMATION IN NEMATIC LAYERS

GRZEGORZ DERFEL Technical University of Łódź, Institute of Physics, 93-005 Łódź, Poland

The results of numerical solution of the Euler-Lagrange equation for deformations field in sheared nematic are presented. The threshold behaviour is found in the special case. The maximum deformation versus shear stress. the director distribution in the and the effective layer viscosity Two calculated. types of deformation possibility distinguished and a of them is The obtained between found. results 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. 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  $\alpha_i$ , average elastic constant k and  $\alpha_g/\alpha_2>0$ . The director is strongly anchored on both boundaries with surface tilt  $\theta_i$ . Under the action of the constant shear  $\tau$ , one of the plates moves against another and the director field is deformed.

The Euler-Lagrange equation has the form:

$$k(d^{2}\theta/dz^{2}) = \tau(\alpha_{g}\cos^{2}\theta - \alpha_{z}\sin^{2}\theta)/$$

$$/[(\alpha_{g}+\alpha_{4}+\alpha_{g})/2 - (\alpha_{z}+\alpha_{g})\sin^{2}\theta], \qquad (1)$$

and is integrated numerically.

# **RESULTS**

The numerical results are presented in terms of the reduced quantities:  $s=\alpha_{\rm g}/\alpha_{\rm g}$ ,  $r=\eta_{\rm g}/\alpha_{\rm g}$ ,  $t=\tau/\tau_{\rm o}$  where  $\tau_{\rm o}=k\pi^2/d^2$ . The values of the material constants of MBBA<sup>8,9</sup> were adopted, but with simplification  $k=(k_{11}+k_{22}+k_{33})/3$ .

The midplane orientation angle  $\theta_{\rm m}$  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  $\theta_{0} = \arctan \sqrt{\alpha_{1}/\alpha_{2}}$ , and of type 2 if  $\theta_{1} < -\theta_{0}$ . For  $\theta_{1} = -\theta_{0}$  the deformation has threshold character. The threshold stress  $\tau_{c}$  is of order  $0.1 \text{N/m}^{2}$  for  $d=10^{-5}\text{m}$ . 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  $\theta_0$  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

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

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

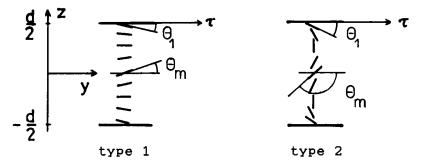
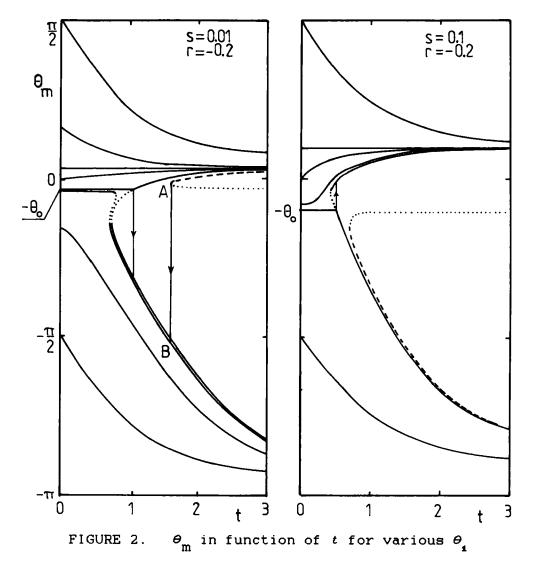


FIGURE 1. Two deformations due to simple shear.



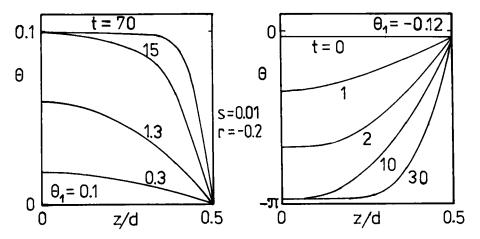


FIGURE 3. Director semiprofiles for various t.

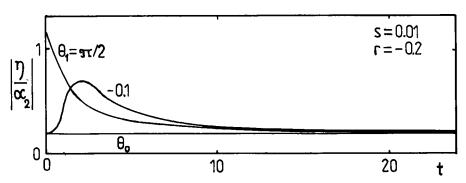


FIGURE 4. Effective viscosity versus stress.

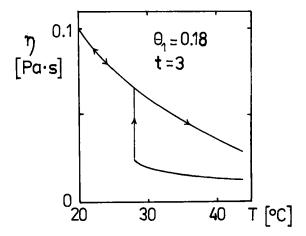


FIGURE 5. Effective viscosity vs temperature.

(Figure 4). on the surface tilt In each case the effective viscosity tends to value  $\alpha_{2}(r-s)$ as t→∞.

is a possibility of the rapid change 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  $\eta$  at moderate stress and at constant surface orientation.

## CONCLUDING REMARKS

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

### REFERENCES

- Ch. Gahwiller, <u>Molec. Crystals liq. Crystals</u>, <u>20</u>, 301 (1973).
- 2. M. G. Kim, S. Park, S. M. Cooper and S. V. Letcher, <u>36</u>, 143 (1976)
- Molec. Crystals liq. Crystals, K. Skarp and T. Carlsson, Molec. Crystals liq. <u>Crystals Lett.</u>, <u>49</u>, 75 (1978).
- 4. F. M. Leslie, <u>Arch. Rat. Mech. Anal.</u>, <u>37</u>, 222 (1968).
- 5. G. P. Mac Sithigh and P. K. Currie, J. Phys. D: Appl. <u>Phys.</u>, <u>10</u>, 1471 (1977).
- 6. P. K. Currie and G. P. Mac Sithigh, Q. J. Mech. <u>Appl. Math.</u>, <u>32</u>, 499 (1978).
- 7. G. Derfel, to be published in <u>Liquid Crystals</u>.
- De Jeu, W. A. W. H. P. Claassen Spruijt, Molec. Crystals liq. Crystals, 37, 269 (1976)
- 9. H. Kneppe, F. Schneider and N. K. Sharma, <u>J. Chem.</u> Phys., 77, 3203 (1982).