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Flexoelectric origin of oblique-roll electrohydrodynamic instability in nematics

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Abstract. We develop the theory of electrohydrodynamic instability in nematic liquid crystals by incorporating the flexoelectric terms. Using a one-dimensional linear analysis of the problem for an applied DC field, we demonstrate that for the usual materials the rolls have an oblique orientation as has been found experimentally. We also provide an experimental evidence for the strong flexoelectric influence on the director profile in the rolls.

Keywords. Nematic liquid crystals; flexoelectricity; oblique roll instability; electrohydrodynamics.

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An electrohydrodynamic (EHD) roll instability is exhibited by nematic liquid crystals with either negative or weakly positive dielectric anisotropy ($\Delta\varepsilon$) above a DC or low frequency AC threshold voltage (Blinov 1983; Chandrasekhar 1977). The first theoretical analysis of the problem was given by Helfrich (1969) for an applied DC field. It was later extended by the Orsay group (Dubois-Violette *et al* 1971; Smith *et al* 1975) to AC fields. The conductivity anisotropy ($\Delta\sigma$) of the medium gives rise to space charge densities under the action of the external field if there are bend fluctuations in a planar aligned sample. The electric force on the space charge density gives rise to EHD instabilities. The one-dimensional theories mentioned above considered only the possibility of rolls whose wavevector is along the initial undistorted orientation of the director $\mathbf{n}_0$. Recently, however, there have been a few experimental observations (Ribotta *et al* 1986; Hirata and Tako 1982) of *oblique* rolls, in which the wavevector makes an angle (α say) with $\mathbf{n}_0$, in both DC and very low frequency AC fields. Zimmermann and Kramer (1985) made a three-dimensional, linear analysis of the EHD problem. However, unrealistically, they assumed 'stress-free' boundary conditions for simplifying the analysis. They found that oblique rolls result for a certain range of material parameters, and also noted that an one-dimensional analysis would *not* lead to oblique rolls.

We must however point out that the deformation in the director field in the EHD structures gives rise to a flexoelectric polarization $\mathbf{P}$ of the medium which was not considered in the above model. The action of the external field on $\mathbf{P}$ could be expected to influence the roll structure. Some early Russian work (Ioffe 1975; Matyushichev and Kovnatskii 1975) incorporating the effect of $\mathbf{P}$ in the theory of EHD predicts the possibility of an oscillatory instability, the wavevector of the rolls remaining parallel to $\mathbf{n}_0$. In the present communication, we demonstrate that the flexoelectric terms lead to oblique rolls in an one-dimensional model itself.