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On the way of reconstruction of the liquid crystal surface anchoring potential

V.A. Belyakov [a,*], D.V. Shmeliova [b], S.V. Semenov [c]

[a] L.D. Landau Institute for Theoretical Physics, Moscow, Russia
[b] Moscow Technological University (MIREA), Moscow, Russia
[c] Russian Research Centre "Kurchatov Institute", Moscow, Russia

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ABSTRACT

We extend further the theoretical and experimental studies of the actual surface anchoring potential reconstruction by polarization microscope technique in a wedge-shaped cell with weak surface anchoring forces filled by a chiral nematic liquid crystal (in Grandjean-Cano Wedge) and present the material for the sake of the reader convenience with a short coherent survey of our previous results. To realize the theoretically predicted options of observation of large director deviation angles from the easy axes φ at a wedge surfaces (up to $\pi/2$) the experimental studies of director distribution in Grandjean-Cano zones were performed. A weak surface anchoring at one wedge surface was obtained by photo-alignment technique. A strong surface anchoring at the second wedge surface was obtained by rubbing. The measurements were performed using polarizing microscope. The experimentally found director distributions in Grandjean-Cano zones were compared with theoretical ones calculated for various model surface anchoring potentials. As a result of the present studies the ways to enlarge (compared to the previous studies) angular range of the actual surface anchoring potential restoration were proposed and it was found that the experimentally found surface potential is nicely fitted by a new model surface anchoring potential, the so called model D-potential $W_D(\varphi)$~φ^2.

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1. Introduction

It is well established (see, for example [1,2]) that the surface anchoring plays an important role in the forming different structures of liquid crystals in confine geometries. It is why, being important for the applications, studies of the surface anchoring and, in particular, attempts of a model-independent restoration of the actual surface anchoring potential are performed using various technique. One as the most promising approach looks the surface anchoring study using Grandjean-Cano wedge (a wedge-shaped cell with surface anchoring forces filled by a chiral liquid crystal).

Progress in the experimental model-independent restoration of the actual surface anchoring potential by the Grandjean-Cano wedge technique [3–5] resulting in a widening angular range of the surface anchoring potential restoration up to angle $\pi/4$ (the angle between the easy axes and director) demands further studies aimed to restore the potential in a whole range of its determination. The experimental studies [3–5] showed that the well-known Rapini-Papoular model anchoring potential (and the other proposed model potentials) failed to describe satisfactorily the experimental observations. Comparison of the theory and experiment allows to propose, so called, the model D-potential [5] as the best one in fitting the experiment in the angular range of performed measurements. Our paper reports on further theoretical and experimental studies of possible ways to describe the experimental observations obtained by polarization microscope technique in a wedge-shaped cell with weak surface anchoring forces filled by a chiral nematic liquid crystal (in Grandjean-Cano (GC) Wedge) [3,4] and aims to propose an optimal way of the further experimental investigations for the widening angular range of the surface anchoring potential restoration up to the angle $\pi/2$. Along with a weakening of the surface anchoring strength the widening angular range of the surface anchoring potential restoration can be also achieved by a proper choice of the measurement geometry (in particular, nonparallel orientation of easy axes at the wedge surfaces). We also attract attention to the fact that optical measurements at Grandjean-Cano Wedges can be efficiently used for measuring of the surface anchoring strength.

1.1. General equations

Most optical investigations on Grandjean-Cano wedge were performed for a parallel orientation of easy axes at the wedge surfaces. But, as we shall see below, a change of mutual orientation of easy axes at the wedge surfaces results in a shifting of the Grandjean-Cano zones in the wedge relative to their position in the case of parallel orientation of easy

* Corresponding author.
E-mail address: bel@landau.ac.ru (V.A. Belyakov).

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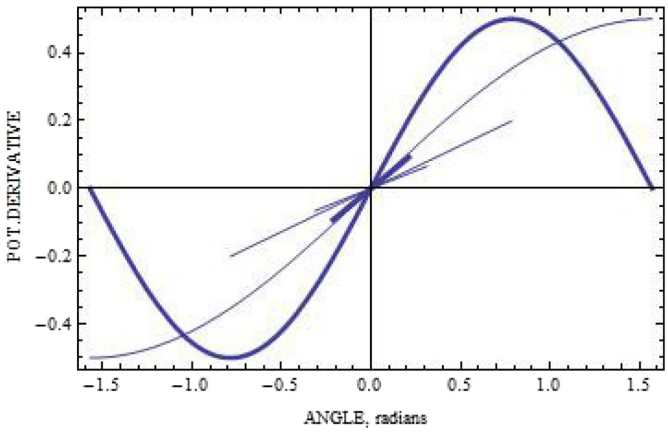

Fig. 1. Derivative of anchoring potential as an angle function (Measured [8,9,16] are straight lines and calculated are bold and thin lines for R-P and B-potential, respectively) [5].

axes at the wedge surfaces. As known [4,6,7], the positions of Grandjean-Cano zones (positions of the walls dividing neighboring zones) are with a good accuracy non-dependent on the anchoring potential shape and strength and are determined by geometrical factors (the wedge angle, equilibrium CLC pitch, mutual orientation of easy axes at the wedge surfaces). For the case of a parallel orientation of easy axes at the wedge surfaces, i.e. with an infinite anchoring strength at one wedge surface and finite (weak) at the other one, the Grandjean-Cano wedge optical problem was studied, in particular, in [3,4]. Studying here of the same problem for the case of a nonparallel orientation of easy axes at the wedge surfaces results in the following equation describing the pitch distribution in Grandjean-Cano zones and, naturally, the director orientation at the wedge surface with a finite anchoring strength.

$$dW_s(\varphi-\Delta\varphi)/d\varphi + W(S_d\varphi-2\pi l_p) = 0 \quad (1)$$

where φ is the angle of the azimuthal director deviation from the alignment (easy) direction at the surface with a finite anchoring, $\Delta\varphi$ is the relative angle between easy axes at the opposite edge surfaces, $W_s(\varphi)$ is the surface anchoring potential, K_{22} is the elastic twist modulus, d is the local wedge thickness, parameter $S_d = K_{22}/Wd$ (related to $l_p = K_{22}/Wp_0$), p_0 is the equilibrium CLC pitch, and W is the depth of the surface anchoring potential.

The Eq. (1) was solved previously [3] for the case of a parallel orientation of easy axes at the wedge surfaces ($\Delta\varphi = 0$) corresponding to the experimental measurements [3,4]. A change of $\Delta\varphi$ influences essentially the director distribution in GC wedge (see Fig. 2). The observed large angular deviations of the director from the easy axis (see also [5]) were compared with the results theoretically predicted in the framework of two model surface anchoring potentials (Rapini-Paupular (R-P) [10] and, so called, B-potential [11,12]). It was found that the well-known Rapini-Papoular model anchoring potential (and the other proposed model potentials) failed to describe satisfactorily the experimental observations (see Fig. 1) and the, so called, model D-potential [5] was the best one in fitting the experiment in the angular range of the performed measurements.

1.2. Modified D-potential

As the preceding theoretical studies showed [3–5] a non-zero value of the surface anchoring potential derivative at the edge of the potential well ($\varphi = \pi/2$) results in a jump of φ at the wall between all Grandjean-Cano zones, including the first ones. Another theoretical observation shows that a zero value of the surface anchoring potential derivative at the edge of the potential well results in a disappearance of the jump of director orientation (φ) at the wall between the first Grandjean-Cano zones if the anchoring is sufficiently weak [3,5]. Because a zero value of the surface anchoring potential derivative at the edge of the potential well ($\varphi = \pi/2$) is the value for the actual surface anchoring potential derivative following from the general physics arguments it is reasonable to modify the model D-potential in a manner ensuring for it a zero value of the derivative at the edge of the potential well. A crude modification of the model D-potential ensuring for it a zero value of the derivative at the edge of the potential well performed in [5] demonstrates a disappearance of the jump of director orientation

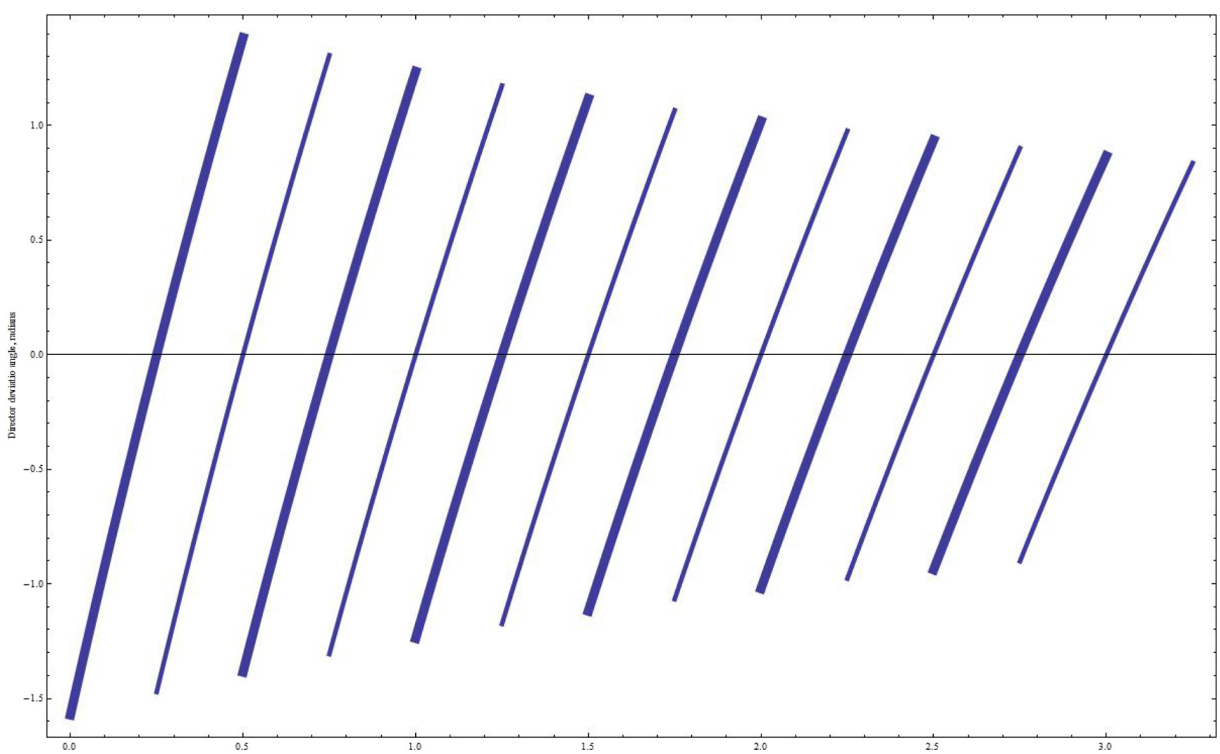

Fig. 2. Calculated director deviation from easy direction angle φ distribution in CG wedge for D-potential (bold line for perpendicular easy axes, thin one for parallel easy axes, $l_p = 1.5$).

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