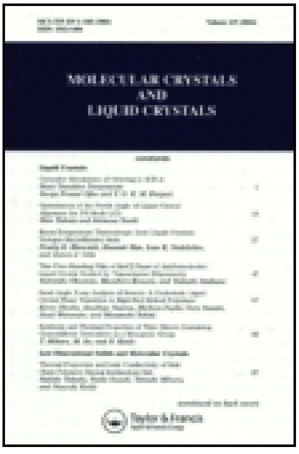

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Improved Miesowicz Viscometer

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IMPROVED MIESOWICZ VISCOMETER.[1]

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The main features of the Męsowicz torsional viscometer with automatized detection of the plate movement are described. An application of the viscometer to study the anisotropy of viscosity in nematic mixtures HALLE5 and WARSAW4 is shown as an example.

INTRODUCTION.

Męsowicz pioneered experimental studies of the viscosity anisotropy of liquid crystals more than a half-century ago [1]. His method was based on monitoring the amplitude of damped oscillations of a plate submersed in a liquid crystalline sample. With an external magnetic field applied to a sample, the nematic director of liquid crystal **n**, can be oriented with respect to the velocity vector **v**, and the velocity gradient vector ∇v, of the flow:

$$(a)\ \mathbf{n}\|(\mathbf{v}\times\nabla\mathbf{v}) \qquad (b)\ \mathbf{n}\|\mathbf{v} \qquad (c)\ \mathbf{n}\|\nabla\mathbf{v}\,, \tag{1}$$

which correspond to three Męsowicz viscosities, η_a, η_b and η_c, respectively.

Although results of Męsowicz proved to be accurate, his experimental technique has been nearly abandoned, and other techniques have been used instead [2]. This has primarily been a result of an uncomfortable procedure of monitoring the motion of the plate. The latest effort to revive the Męsowicz method was due to Siedler and Hyde [3], who used two gratings (one mobile with the plate, the other immobile) as the laser beam chopper, in order to facilitate monitoring the plate motion.

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In the present paper, we report briefly on the Mięsowicz viscometer recently assembled in our laboratory. With the optical detection system we are able to measure the viscosity coefficient in a range from a few cP to several hundreds of cP. As an example of application of the viscometer, the results for two commercially available nematic mixtures, HALLE5 and WARSAW4, are presented.

THE PRINCIPLE OF MEASUREMENT.

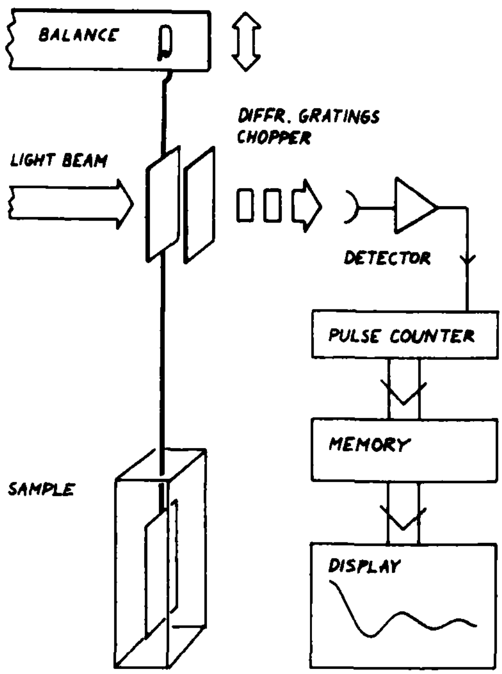

Figure 1. Schematic diagram of the Mięsowicz viscometer. The light source (a *He-Ne* laser), the temperature controlling system and the electromagnet are not shown.

Fig. 1 shows schematically the basic idea of the viscosity measurement. The viscometer plate is suspended from the arm of a sensitive balance by a thin glass rod. The balance performs very slow vertical oscillations, which decay away when the plate is submersed in a liquid. The position of the plate in time $z(t)$, is given then by solving the equation of motion of a damped harmonic oscillator:

$$\frac{d^2z}{dt^2} + 2\beta\frac{dz}{dt} + \omega_o^2 z = 0 , \tag{2}$$

where ω_o the frequency of undamped oscillations of the system, and when the motion of the plate is very slow, β is proportional to the lamelar viscosity of the sample.

Since the most frequently experimentally encountered situations are those of under- and overdamped oscillations of the plate, for us the most interesting solutions of Eq.(2) are

$$z(t) = A_o e^{-\beta t} \cos(\omega t + \phi) , \tag{3}$$

for underdamped motion ($\omega_o^2 > \beta^2$, the low viscosity sample), and

$$z(t) = A_1 e^{-(\beta-\delta)t} + A_2 e^{-(\beta+\delta)t} , \tag{4}$$

for overdamped motion ($\omega_o^2 < \beta^2$, the high viscosity sample); ϕ is the phase factor, $\delta = (\beta^2 - \omega_o^2)^{\frac{1}{2}}$, and $\omega = (\omega_o^2 - \beta^2)^{\frac{1}{2}}$.

Therefore, recording the position of the plate in time, $z(t)$, one can evaluate the parameter β by fitting an apropriate curve to experimental data. (Note that Mięsowicz used the logarithmic decrement of the damped oscillations in order to determine viscosity; the motion of his balance was, therefore, that of the underdamped oscillator.[1])

INSTRUMENTATION.

The oscillating plate is made of a square microscope cover glass, 0.2 *mm* thick and of the area of about of 4 cm^2. It is suspended by a thin glass rod, about 0.5 *mm* in diameter. The period of the free oscillations of the balance is about 14 *s* (i.e. $\omega_o = 0.45 rad/s$), and the amplitude of about of 2 *mm*.

A $0.5T$ electromagnet is used for the director orientation. At the moment only orientations in the plane perpendicular to **v** (i.e. horizontal) are available. Thus, in the presence of the magnetic field it is possible to measure η_a and η_c.

The minimum volume of a sample required is just below 5 cm^3. Temperature of the sample can be controlled in the range from the room temperatures up to 420 K, with accuracy better than 0.1 K.

Position of the plate is monitored in time by a use of the same light beam chopper as that proposed by Seidler and Hyde [3]. A pair of 100 *lines/mm* gratings are employed, one of which is attached to the support of the plate, while the second one is immobile. The gratings are parallel to each other and separated by a distance of about of 1 *mm*. The chopper is illuminated by a laser, so pulses of light are produced as the plate moves. The time interval between two sucessive pulses corresponds to the time in which the plate moved by 0.01 *mm*.

Pulses are detected by a photodiode, and sent via an interface to a Commodore-64 computer with CIA chip [4]. Pulses are counted sucessively, and the counter value is stored every 0.1 *s*.

Since the balance is not a perfect oscillator, the viscometer was calibrated with commercially available oil standards. We found that the underdamped

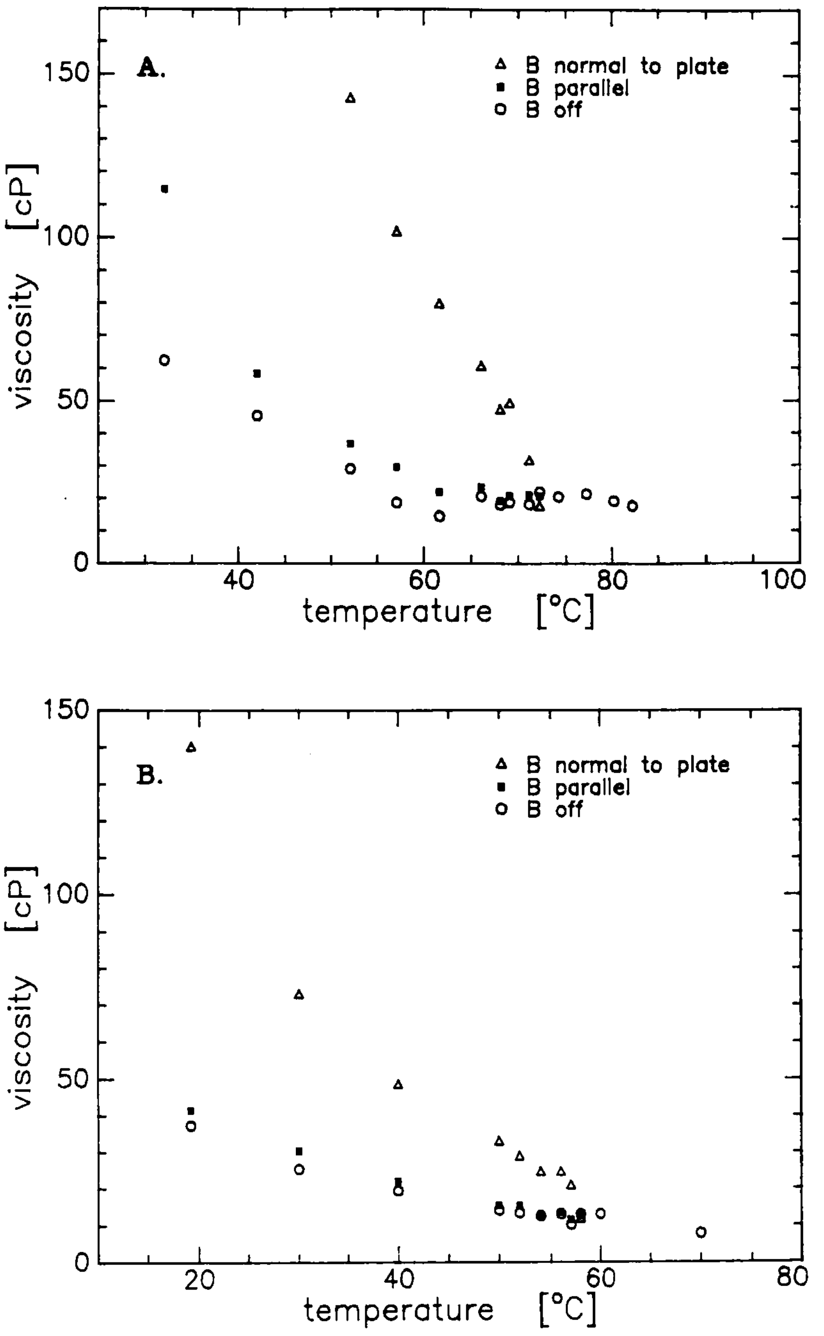

Figure 2. Viscosity coefficients of nematic mixtures (A) HALLE5, and (B) WARSAW4 at toom temperature.

regime is valid for viscosity coefficients below 200 cP. At higher viscosities the oscillator is overdamped. We have calibrated the viscometer in this regime up to nearly 1000 cP.

Detailed description of the aparatus and its performance in the underdamped and overdamped regimes will be given elsewhere [4].

APPLICATIONS.

Viscometer performance was tested by measuring the viscosity of two nematic mixtures HALLE5 and WARSAW4. Aside from measuring η_a and η_c, we also investigated the viscosity coefficient of the unoriented nematic phase, $\overline{\eta}$. Results are shown in Fig 2. As it was suggested by Mięsowicz [5], the flow induced by the moving plate is sufficient to produce the flow orientation of molecules. Thus, one might expect $\overline{\eta}$ to be close to η_b. We plan to investigate this hypotesis in the future.

ACKNOWLEDGEMENTS:

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References

[1] M. Mięsowicz, *Nature*, **136**, 261 (1935). **1936**, sec. A, 228 (1936); *ibid*, **158**, 27 (1946).

[2] W.W. Beens W.H. de Jeu, *J.Physique*, **44**, 129 (1983); M.G. Kim, S. Park, S.M. Cooper and S.V. Letcher, *Mol.Cryst.Liq.Cryst.*, **36**, 143 (1976); C. Gahwiller, *Mol.Cryst.Liq.Cryst.*, **20**, 301 (1973); S. Meiboom and R.C. Hewitt, *Phys.Rev.Lett.*, *30*, 261 (1973); J.W. Summerford, J. Boyd and B.A. Lowry, *J.Appl.Phys.*, **46**, 970 (1975); Martinoty and S. Candau, *Mol.Cryst.Liq.Cryst.*, **14**, 293 (1971); K.A. Kemp and S.V. Letcher, *Phys.Rev.Lett.*, **27**, 1634 (1971).

[3] L. Siedler and A.J. Hyde, in *Advances in Liquid Crystal Research and Applications*, L. Bata, Ed., Pergamon Press, Oxford 1980, pp. 561

[4] F. Hennel, J. Janik and J.K. Moscicki, *to be published.*

[5] M. Mięsowicz, *Mol.Cryst.Liq.Cryst.*, **97**, 1 (1983).