regarding the relations between flow birefringence and stress, previously derived on the basis of a network theory for concentrated polymer solutions, as being no longer restricted to solutions of constant viscosity.

Zusammenfassung

References
6) cf. e. g. Ferrar, W. L., Algebra p. 148, theorem 47 (Oxford 1941).

From the Institute of General Chemistry, Department of Technical Physics Warszawa 27 (Poland)*) and the Synthetic Fibres Factory, Physico-Chemical Laboratory Gorzów Wlkp., (Poland)

Mechanical Aspects of Fibre Spinning Process in Molten Polymers
Part I. Stream Diameter and Velocity Distribution along the Spinning Way

By Andrzej Ziabicki and Krystyna Kędzierska

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Introduction
Fibre spinning from molten polymers is a process in which the mechanical effects as thermal and structural ones determine fibre properties. The course of fibre formation from viscous molten polymer, the variation of stream diameter, velocity, velocity gradient, stress and viscosity are of great interest both from technological and scientific point of view.

The mechanical analysis of fibre spinning process is closely connected with other works of ours concerning fibre spinning problems — molecular orientation (1, 2) and heat transfer (3, 4). The present paper opens the series consisting of three parts; the next ones will treat the elastic behaviour of polymer melt near by the spinneret and the analysis of forces affecting the fibre formation.

A mechanical analysis of melt spinning process has not been published. Some interesting works on “wet-spinning” by Kast (5), Elsaesser (6), Sippel (7) and Pupke (8) were devoted to particular systems and did not give more general analysis of this problem which could be applied to other spinning procedures.

This work in principle deals with the melt spinning process; the general theoretical considerations and conclusions however are valid for every process of fibre formation.

Symbols used

- area of stream (fibre) cross-section
- stream (fibre) diameter
- perpendicular (transversal) velocity gradient (in shearing) elongation
- elasticity modulus tensile force
- acceleration of gravity parallel (axial) velocity gradient (in viscous traction)

*) Address for correspondence.
On the spinning way the liquid stream (fibre) is drawn; the velocity increases from $V_0$ to $V_E$ (take-up velocity) whereas the diameter decreases from $d_0$ (spinneret) to $d_E$ (final fibre diameter).

### Theoretical

In the following treatment the term "spinning" will be generally used to determine a continuous deformation process in a viscous liquid which leads to the formation of long stream (fibre) regardless of its properties. The spinning is hence a kind of viscous traction as described by an equation of Trouton (9):

$$\lambda = F/A = \eta \cdot G$$  \[1\]

an analogue to Newton equation for shearing:

$$p = P/q = \eta \cdot D$$  \[2\]

The coefficient $\lambda$ in eq. [1] is a material constant like the viscosity $\eta$ in eq. [2]. For an ideal body with Poisson ratio $\mu = 0.5$ it is:

$$\lambda = 3\eta.$$  \[3\]

In the macromolecular systems coefficients $\lambda$ and $\eta$ are no more constant and the analogy between viscous traction and shearing is not so close as in simple liquids. The differences in the velocity fields in both phenomena cause that in shearing the coefficient $\eta$ decreases with gradient $D$ whereas the coefficient $\lambda$ in traction is expected to increase with gradient $G$ due to the stable orientation of macromolecules. Such an assumption has been given by Nitschmann and Schrade (10) and Aeschlimann (11). An analysis of the rotation and orientation of elongated particles in both velocity fields given by one of us (2) seems to confirm this assumption.

The "spinnability" of liquid requires that the viscosity increases with velocity gradient. Is this condition not fulfilled the fibre must break due to the rapid thinning. However it is well known that the macromolecular fibre-forming liquids exhibit as a rule a "structural viscosity" i. e. the viscosity decreases with velocity gradient. In order to explain this divergence Schurz (12) introduced a concept of "differential viscosity" $\eta_d$:

$$\eta_d = dp/dD.$$  \[4\]

The "differential viscosity" was to be responsible for the spinnability of liquids due to its increase with the shear rate $D$. Such a treatment seems to be incorrect in principle. The *spinning* (viscous traction) should not be considered in terms of *shearing*. The