Rheological Properties and Shear Induced Texture Development of Thermotopic Liquid Crystalline Polymer Melts

T.N. Nguyen, K. Geiger, H.-G. Fritz

Universität Stuttgart, Institut für Kunststofftechnologie (IKT),
Böblinger Strasse 70, 70199 Stuttgart, Germany

* Email: geiger@ikt.uni-stuttgart.de
Fax: x49.711.6412335

Received: 27.2.2002, Final version: 27.5.2002

Abstract:
The flow behavior of two commercial liquid crystalline polymers (LCPs), trade name Vectra B 950 and Vectra L 950 supplied by Ticona, was investigated using a capillary rheometer with a special double slit die. The pressure drops in convergent and divergent wedge passage between the two slit sections, which are influenced by the curvature strains in nematic melts, were determined and compared with the pressure drops of a conventional polystyrene (PS) with flexible polymer chains. Furthermore the extensional viscositiy was determined from the pressure drop in convergent wedge passage. The development of the shear induced texture as a function of shear rate was investigated by use of a rapidly coolable double slit die with the same gap design as the double slit die used for viscosity measurement. The structural analysis was performed using polarized light microscopy.

Zusammenfassung:
Das Fließverhalten von zwei kommerziellen flüssigkristallinen Polymeren Vectra B 950 und Vectra L 950 wurde mittels einer speziellen Doppel-Flachschlitzdüse am Hochdruckkapillarrheometer untersucht. Die Druckverluste im konvergenten und divergenten trapezförmigen Fließkanalübergang zwischen den beiden Düsenabschnitten, die durch mikroskopische Krümungsverformungen in der nematischen Schmelze beeinflusst sind, wurden ermittelt und mit den Druckverlusten von einem konventionellen Polymer Polystyrol (PS) mit flexiblen Molekülketten verglichen. Weiterhin bietet dieses Düsensystem die Möglichkeit für die Ermittlung der Dehnviskosität anhand der Druckverluste im konvergenten trapezförmigen Fließkanalübergang. Die scherinduzierte Mikrostruktur der beiden LCP-Schmelzen wurde unter dem Polarisationsmikroskop in Proben, deren Mikrostruktur mittels der kühlbaren Düse mit äquivalenter Düsengeometrie zu der Doppelflachschlitzdüse durch unterschiedliche Schergeschwindigkeiten erzeugt und durch schnelles Abkühlen fixiert wurde, analysiert.

Résumé:
Le comportement en écoulement de 2 polymères cristaux liquides (LCPs) commerciaux, noms de marché Vectra B950 et Vectra L950 fournis par Ticana, a été étudié à l'aide d'un rhéomètre capillaire équipé d'une fente double spéciale. Les chutes de pression, dans le conduit en coin convergent et divergent entre les deux sections de fente, qui sont influencées par les déformations dans les fondus nématiques, ont été déterminées et comparées avec les chutes de pression d'un polystyrène conventionel possédant des chaînes polymères flexibles. De plus, la viscosité en extension a été déterminée à partir de la chute de pression dans le conduit en coin convergent. Le développement de la texture induite par le cisaillement, en fonction de la vitesse de cisaillement, a été étudié au moyen d'une fente double qui peut être rapidement refroidie et possédant la même configuration d'entrefer que la double fente utilisée pour la mesure de la viscosité. L'analyse structurale a été conduite à l'aide de la microscopie en lumière polarisée.

Key Words: liquid crystalline polymers (LCPs), capillary rheometer, convergent flow, shear induced texture, polarized light microscopy

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org

The texture development as a function of shear rate for Vectra B 950 is shown in Fig. 12. A worm texture is found for the plateau region of the viscosity curve. Compared to the shear thinning first region, the reduction of size of diclination loops is clearly weaker. A new organization of new defect nucleated from thread texture dominates here. It is obvious that the newly emerging loops by reform of nucleated threads are distributed isotropicaly with regard to macroscopic considerations. At high shear rate in the pseudo-plastic third region, an ordered texture is visible.

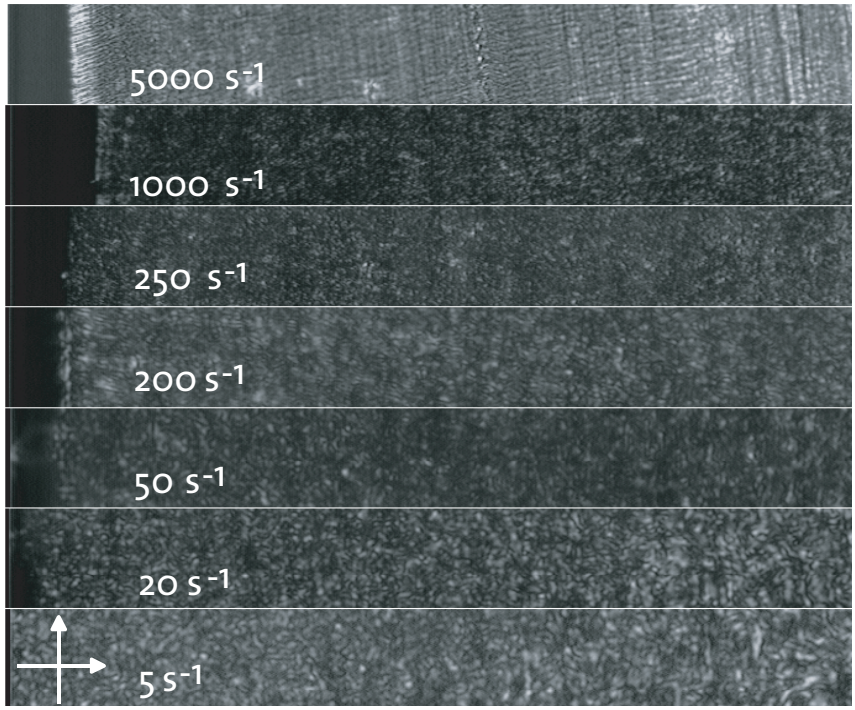

Figure 12: Shear induced texture development subjected to shear rates for Vectra B 950 (between crossed polarizers).

4 CONCLUSION

Two commercial LC polymers of the Vectra family (Vectra L 950 and Vectra B 950) were investigated concerning their flow behavior and their microstructure development as a function of shear rate. LCP melts typically show a flow curve with three regions, which relate closely to the change of texture for respective shear rate ranges. The high modulus LCP resin Vectra B 950 exhibits a more pronounced "three-region-viscosity curve" than the more flexible low viscous Vectra L 950. The shear thinning flow behavior in the first region at low shear rate corresponds to the thread texture consisting of ± 1/2 integertwist disclinations. This is especially pronounced for the melt of Vectra B 950, for Vectra L 950 the texture is finer. In the plateau region for Vectra B 950, a worm texture is found and at high shear rates in the pseudo-plastic third region, the worm texture is changed into an ordered texture. Pre-shearing of both melts leads to a narrower plateau region in the viscosity curve (second region), and accordingly to a decreasing viscosity in the pseudo-plastic third region. Both LCP melts show an apparent geometry dependence of the flow behavior due to increasing viscosity with smaller gap size of the rectangular slit dies. In contrary to conventional polymers with flexible chains, the pressure drop of LCP melt flowing through a convergent wedge passage is clearly larger than the pressure drop in divergent wedge passage because of the difference of their particular splay and twist curvature strains. Comparison of the elongational flow behaviour determined in the wedge passage, of the shape of the plateau region, of the enhancement of the pressure drop in convergent wedge as well as of the shear induced texture for both LCP melt let to conclude that the mesogens of Vectra B 950 are stiffer and less mobile than the mesogens of Vectra L 950, and that the anisotropic Frank elasticity represented by ratio of the splay constant K_{11} to the twist constant K_{22} is considerably larger for Vectra B 950 than for Vectra L 950.

ACKNOWLEDGMENTS

The authors are grateful to the German Science Foundation (DFG) for the grant Fr 562/24-2 ''Shear Induced LCP-Texture" and to TICONA GmbH for supply of materials. The authors also thank Prof. M. H. Wagner for valuable remarks and discussion.

REFERENCE

[1] Geiger K: Einfluß der mechanisch/thermischen Vorgeschichte auf die rheologischen Eigenschaften von LCP-Schmelzen, 12. Stuttgarter Kunststoffkolloquium Session 7.1: 1-18 (1991).

[2] Frayer PD and Huspeni PJ: Processing preshear and orientation effects on the rheology of an LCP melt, J. Rheol. 34 (1990) 1199.

[3] Nuel L and Denn MM: Effect of processing and particulate fillers on the rheology of a nematic polymer melt, Rheol. Acta 30 (1991) 65.

[4] Ide Y and Ophir Z: Orientation development in thermotropic liquid crystal polymers, Polym. Eng. Sci. 23 (1983) 261.

[5] Moldenaers P, Fullers G and Mewis J: Mechanical and optical rheometry of polymer liquid-crystal domain structure, Macromolecules 22 (1989) 960.

[6] Gotsis AD and Baird DG: Rheological properties of Liquid Crystalline Copolyester Melts. II Comparison of capillary and rotary rheometer results, J. Rheol. 29 (1985) 539.

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org

[7] Jerman RE and Baird DG: Rheological properties of copolyester liquid crystalline melts. I. Capillary rheometry, J. Rheol. 25 (1981) 275.
[8] La Mantia FP and Valenza A: Shear and non-isothermal elogational characterization of a liquid crystalline polymer, Polym. Eng. Sci. 29 (1989) 625.
[9] Wissbrun KF: Flow behavior of a thermotropic liquid crystal aromatic copolyester, Chem. Eng. Comm. 53 (1987) 149.
[10] Lefeuvre P, De'Nève T and Navard P: Bagley plot of the Vectra B 950 thermotropic polymer, J. Rheol. 38 (1994) 169.
[11] Turek DE and Simon GP: The effect of die aspect ratio on the rheological properties of a thermotropic copolyester, J. Rheol. 36 (1992) 1057.
[12] Onogi S and Asada T: Rheology, Volume 1: Principles, G. Astaria, G. Marrucci and L. Nicolais (Eds.), Plenum press, New York (1980).
[13] Baleo Jean-Noël and Navard P: Rheo-optics of liquid-crystalline polymers in complex geometries, J. Rheol. 38 (1994) 1641.
[14] Larson RG and Mead DW: Development of orientation and texture during shearing of liquid-crystalline polymers, Liquid Crystal 12 (1992) 751.
[15] Graziano DJ and Mackley MR: Shear induced optical textures and their relaxation behaviour in thermotropic liquid Crystalline Polymers, Mol. Cryst. Liq. Cryst. 106 (1984) 73.
[16] Nguyen TN and Geiger K: Flow Behaviour and Shear induced Texture Development of a LCP Melt, Proceeding of XIIIth International Congress on Rheology, Cambridge, UK. (2000).
[17] Frank FC: On the Theory of Liquid Crystal, Disc. Farad. Soc. 25 (1958).
[18] Freedericksz V and Zwetkoff V: Über die Orientierung der anisotropen Flüssigkeiten in dünnen Schichten und die Messung einiger ihre elastischen Eigenschaften charakteristischen Konstanten, Physikalische Zeitschrift der Sowietunion 6 (1934) 491.
[19] Sun Zheng-Min and Kleman M: Measurement of the three elastic constants and the shear viscosity in a main-chain nematic polymer, Mol. Cryst. Liq. Cryst. 111 (1984) 321.
[20] De' Neve Th, Kleman M and Navard P: Obsevation of textures of nematic polymers and estimation of the elastic constants, Liquid Crystals. 18 (1994) 67.
[21] Gleißle W: Measurement of Viscosity, Normal Stress and Elongational Properties Applying Capillary Rheometry, Proceeding of 2nd ESAFORM Conference on the Material Forming, Guimaraes, Portugal (1999).
[22] Kleman M: Points, Lines and Walls in Liquid Crystalls, Magnetic Systems and Various Ordered Media, John Wiley & Sons (1983).
[23] Mazelet G and Kleman M: Observation of defects in a polyester nematic phase, Polymer 27 (1986) 714.
[24] Geiger K: Disklinationen in flüssigkristallinen Polymerschmelzen, Appl. Rheol. 6 (1996) 172.

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org