Evaluation of Melt Flow Instabilities of High-density Polyethylenes via an Optimised Method for Detection and Analysis of the Pressure Fluctuations in Capillary Rheometry

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Abstract:
An optimised method for the detection and analysis of the time dependent pressure associated with the development of melt flow instabilities during extrusion through a capillary die was developed and validated. The magnitude and frequency of the developed quasi-periodic distortions, as well as the pressure profiles along the die length, were found to depend on the *MWD*, topology, melt elasticity and uniaxial extensional flow properties. Both the onset and magnitude of strain hardening in uniaxial extension appear to be related to the onset for the development of melt flow instabilities under capillary flow. For a better understanding of the role of the extensional properties (namely that of a purely elastic instability) the Hencky strain to failure was also determined and correlated to the observed flow instabilities. Time resolution of the capillary rheometer was improved by a factor of 1000, pressure resolution by a factor of 100 compared to the original set-up.

Zusammenfassung:
Eine neuartige optimierte Methode zur Erfassung und Analyse des zeitabhängigen Drucks wurde entwickelt, um die entstehenden Fließinstabilitäten durch Extrusion mit eine Kapillardüse bezüglich der Zeit und Intensität zu quantifizieren. Sowohl die Größenordnung und die Frequenz der enstehenden quasi-periodischen Formänderungen, als auch die Druckprofile entlang der Düsenlänge, sind von der Molmassenverteilung (MWD), der Topologie, der Elastizität der Schmelze und den Dehnfließeigenschaften abhängig. Die Entstehung wie auch die Größenordnung der Dehnverfestigung beeinflußen die Fließinstabilitäten der Schmelze während der Kapillarextrusion. Die Hencky-Dehnung, bei der die Probe versagt wurde bestimmt, und mit den beobachteten Fließinstabilitäten korreliert, um den Einfluß der Dehneigenschaften (vor allem der rein elastischen Instabilität) zu verstehen. Die Zeitauflösung wurde dabei um den Faktor 1000, die Druckauflösung um den Faktor 100 verbessert.

Résumé:
Une méthode optimisée pour la détection et l'analyse de la dépendance temporelle de la pression associée avec le développement des instabilités d'écoulement d'un fondu lors de l'extrusion dans une filière capillaire a été développée et validée. L'amplitude et la fréquence des distorsions quasi-périodiques développées, ainsi que les profils de pression le long de la filière, se sont avérés dépendre de la distribution de masse moléculaire MWD, de la topologie, de l'élasticité du fondu et des propriétés d'écoulement en extension uni axiale. L'émergence et l'amplitude du durcissement à la déformation semblent être reliées à l'émergence du développement des instabilités d'écoulement du fondu dans un écoulement capillaire. Afin de mieux comprendre le rôle des propriétés extensionnelles (c'est-à-dire celui d'une instabilité purement élastique), la déformation de Henky à la rupture a été également déterminée et corrélée avec les instabilités d'écoulement observées.

Key words: Polyethylenes, stick-slip, sharkskin, Fourier transformation, molecular topology, capillary rheology, uniaxial extensional flow

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The results from this work point towards the conclusion that the onset shear rate at which melt flow instabilities occur correlates with the extensional flow properties, particularly the viscosity (or stress) growth. The critical condition for the onset of melt flow instabilities shifts to higher shear rates for materials showing failure at higher Hencky strain (such as LCB3) or materials with a lower *Mw* (such as LCB1). The development of melt flow instabilities such as stick-slip and helicoidal defect are highly influenced by the extensional properties of the material. The use of this non-conventional set-up should be extended in the future to the characterisation of melt flow instabilities on materials with a linear structure and a narrow molecular weight distribution. Such analysis will certainly help to get further insights on defects arising at the die, e.g. sharkskin.

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