A Study of Entrance Pressure Loss in Filled Polymer Melts

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Abstract:
The influence of the molecular structure of the polymer matrix and filler loading on the entrance pressure loss of polyethylene/wood flour composites has been investigated in this research by means of a capillary rheometer equipped with an orifice die. The entry flow of talc- and glass-filled polyethylene composites has been investigated as well. It was found that the entrance pressure loss of wood filled polyethylene composites greatly increased with increasing the wood flour loading. Talc and solid glass spheres also increase the entrance pressure loss, however not as much as wood flour. It was also observed that composites based on narrow molecular weight distribution (MWD) resins exhibited larger entrance pressure loss than the broad MWD and branched polyethylene based ones. It was concluded that measurements of the entrance pressure loss reveal some interesting features of the polymer-filler interactions and could provide significant insights in the processing of highly filled polymer melts.

Zusammenfassung:
Der Einfluss der molekularen Struktur des Matrixpolymers und des Füllstoffanteils auf den Eingangsdruckverlust von Polyethylen/Holzmehl-Kompositen wurde mittels eines Kapillarrheometers untersucht, das mit einer Austrittsdüse ausgestattet war. Die Eingangsströmung von mit Talk und mit Glas gefüllten Polyethylen-Kompositen wurde ebenfalls untersucht. Der Eingangsdruckverlust der mit Holz gefüllten Polyethylen-Komposite stieg stark mit steigendem Holzmehlanteil an. Talk und feste Glaskugeln erhöhten ebenfalls den Eingangsdruckverlust, jedoch nicht so stark wie Holzmehl. Die Komposite, die auf einer engverteilten Molekulargewichtsverteilung (MWD) des LDPE basierten, wiesen einen höheren Eingangsdruckverlust auf als die Komposite mit einer breiten MWD und die mit verzweigtem LDPE. Es wurde die Schlussfolgerung gezogen, dass die Messungen des Eingangsdruckverlustes einige interessante Aspekte der Polymer-Füllstoff-Wechselwirkungen aufdecken und wesentliche Einblicke in die Verarbeitungseigenschaften von hochgefüllten Polymerschmelzen ermöglichen könnten.

Résumé:
L'influence de la structure moléculaire de la matrice polymère et du taux de charge sur la perte de pression d'entrée pour des composites polyéthylène/bois a été étudiée dans cette recherche, au moyen d'un rhéomètre capillaire équipé d'une filière trouée. L'écoulement en entrée de composites de polyéthylène chargés avec du verre et du talc a également été étudié. On a trouvé que la perte de charge des composites de polyéthylène renforcés avec du bois augmente grandement avec l'augmentation de la charge en farine de bois. Les sphères de verre solide et de talc augmentent également la perte de charge à l'entrée du capillaire, mais dans une moindre mesure que la farine de bois. On a également observé que les composites formulés avec des résines de polyéthylène possédant une distribution de poids moléculaires (MWD) étroite, présentent une plus grande perte de charge que ceux formulés avec des MWD larges et du polyéthylène branché. On a conclu que les mesures de perte de charge révèlent certaines caractéristiques intéressantes des interactions polymère-charge, et pourraient fournir des indications importantes pour la mise en œuvre des fondus de polymères hautement chargés.

Key words: entrance pressure loss, wood fiber composites, viscosity, entry flow

1 INTRODUCTION

Scientific interest in polymer entry flows has existed since 1957 when Bagley published his famous paper on entrance correction for capillary viscometers [1]. Entrance pressure loss is observed with all fluids in regions of conduit cross-sectional changes. This is because the conduit shape and the rheological response of the fluid create extra velocity gradients, which gives rise to extra pressure drops. By using dies with different length to radius ratio, Bagley [1] was the first to provide a method for calculation of the entrance pressure loss in capillary flow.

Entrance vortices are observed when a viscoelastic fluid flows into a smaller capillary from

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of 45 wt%, which corresponds to 30, 17, and 18% volume fractions respectively. Glass spheres provide the least resistance to elongational deformation at the die entry, which is probably a consequence of the spherical shape and incompatibility with the matrix. The talc platy particles need to be oriented at the die entry, which is why, the talc-composites exhibit larger entrance pressure than the glass-filled ones. The much larger increase of the entrance pressure loss in case of the wood filler supports the conjecture that the filler-matrix interaction is the dominant factor in entry flow of natural fiber filled composites, in addition to fiber orientation.

4 CONCLUDING REMARKS

The effect of the polymer matrix molecular structure and filler loading on the entrance pressure loss in capillary flow of polyethylene composites has been investigated in this study. It was found that the entrance pressure loss increased with addition of fillers, most notably at filler concentration above 30 wt%. This increase is strongly dependent on the filler type and polymer matrix molecular structure. Wood flour added in the low molecular weight and narrow MWD polyethylene provides the largest increase of the entrance pressure loss. Talc and glass spheres also increased the entrance pressure, however this increase is not as pronounced as in the case of wood flour.

It was observed that narrow MWD polyethylenes provide larger increase of the entrance pressure loss than the broad MWD and branched polyethylene. The pressure drop increase in the long capillary is not as large as the increase of the entrance pressure loss with filler loading. Based on the results obtained, it could be inferred that measurement of the entrance pressure loss could provide useful information about the filler-matrix interactions in composite materials.

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