Thermal balance between viscous heating and inlet thermal condition in non stationary polymer flow through a cylindrical die

Yanneck Wielhorski a,*, Pierre Mousseau b, Yvon Jarny a, Didier Delaunay a, Nicolas Lefevre a

a Laboratoire de Thermocinétique de Nantes, LTN, UMR 6607, Ecole Polytechnique de l'Université de Nantes, site de la Chantrerie, rue Christian Pauc BP 50609, F-44306 Nantes, Cedex 3, France
b ERT OPERP 1086, GEPEA, IUT de Nantes, 2, avenue Professeur Jean Rouxel, F-44475 Carquefou, France

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During the forming of polymer materials under extrusion or injection moulding process conditions, the heat source resulting from the high viscous dissipation within the flow in the die channel plays an important role on the thermal field within the polymer and the experimental device. One difficulty to simulate numerically this kind of flow, besides the accurate knowledge of the actual rheological parameters of the materials, consists in fixing the boundary conditions of the spatial domain of integration. Indeed, for non stationary conditions, they are varying both in space and time. In this paper, experimental data (temperature and flow rate) measured in a specific instrumented die are compared to the solutions predicted by a set of coupled equations which models the heat source release, the heat conduction process and the polymer flow, under non stationary conditions. This analysis leads to evaluate the thermal balance between the viscous heating and the inlet thermal condition.

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1. Introduction

The forming of polymer is a physical complex problem with important economic stakes when the industrials want to improve their yield and the quality of the product. To obtain maximum throughput, the melt flow polymer temperature in processes must be determined with precision [1]. In practice, in-line determination of polymer melt temperature and its distribution is not simple due to a number of errors affecting the results by using intrusive or non-intrusive measurement methods. Indeed, the thermo-mechanical properties of polymers, like the viscosity, make their modelling more difficult than for a newtonian fluid. Furthermore, for industrial processes, we have to know the polymer temperature at the die exit just before the forming tool in order to fix the cooling temperature. That is why the knowledge of the spatial and time temperature evolution before the solidification of the polymer is a key point for the optimization of the forming process.

In previous studies, the goals were respectively to estimate the inlet thermal profile in the polymer [14–17] and its viscosity [23,24], from temperature measurements in the die wall. These former studies have been made on a stationary flow and on a channel with a rectangular cross section. In this study, the cross section of the channel is cylindrical. This new geometry was chosen because it allows much higher mechanical loads. However to install a pressure sensor, a flat part followed by a convergent part are required. Besides, our study is focused on non stationary flow due to the evolution of the inlet pressure and temperature of the polymer. The boundary conditions vary as a function of space and time. However, as in references [17] and [24], we use a well characterized thermoplastic polymer, a commercial low density polyethylene extrusion grade (commercial reference is Dowlex® 2042E).

With the final objective to know precisely the spatial and time evolution of the polymer temperature in the die in realistic flow conditions, experiments must be made to validate the numerical model. Actually, the difficulties of the numerical simulation are to set correct boundary conditions for the experimental device both in the steel and in the polymer. For this reason, experimental boundary conditions are used except for the inlet polymer temperature profile which remains unknown. However, the thermal balance between the heat source due to viscous dissipation and the inlet polymer temperature variations remains to be