69e Modeling of Non-Isothermal Jets in Polymer Melt Electrospinning

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The electrospinning process utilizes electrical field to produce high elongational forces that result in nearly one-dimensional fiber structures with fiber diameters as small as 50 nm. The nanofiber mats produced in this process have extremely attractive characteristics such as high surface area to mass ratio. Early electrospinning processes were based on polymer solutions, which involved coupling of momentum, energy, and mass transfer, as well as phase transition, thus making the process extremely complex and virtually impossible to model predictively. Recently we have developed an electrospinning scheme directly from polymer melts that can be used to spin a variety of polymers with different crystallization behaviors including nylon, polypropylene, polyethylene teraphthalate, and polylactic acid. Along with other experimental advances, this technique has renewed the interest in modeling of electrospinning. The new experiments eliminate the complications of mass transfer in modeling including the development of constitutive models, and thus allowing for tractable numerical simulation.

In the present study we formulate the governing equations for non-isothermal free surface flows of electrically charged viscoelastic fluids prior to the onset of whipping motion instabilities (stable jet region). We have fully coupled momentum, continuity, and energy equations, with Gauss' law and non-isothermal Giesekus constitutive model. Moreover, for polymers that exhibit significant crystallinity we have added a detailed crystallization model that incorporates microstructural elements, such as the number of crystals, and crystal size distributions in addition to the overall degree of crystallinity. We have derived those equations based on thin filament approximation and the system of differential equations governing electrically charged, non-isothermal polymeric jets have been numerically solved. Our results reveal that the shape of liquid cone and the resulting jets from melts are significantly different from those from solutions. We will compare predicted results with flow visualization experiments for the above-mentioned polymeric systems. The present model forms the basis for a full-scale, finite element analysis which will follow.