MISTING IN FORWARD ROLL COATING: STRUCTURE-PROPERTY-PROCESSING RELATIONSHIPS

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Abstract

Misting is the generation of drops (< 50 μm in diameter) upon splitting a liquid film between two counter-rotating rolls. In this thesis Newtonian liquids and polymer solutions were examined to connect misting mechanisms, solution rheology, molecular structure, process conditions, and drop count, drop size, and mist concentration.

As capillary number was raised Newtonian liquids were found to evolve from a smooth coating film to one with ribs, then septa (a sheet of liquid extended from the film-split connecting both roll surfaces). As capillary number was raised further break-up of a downstream septum free surface led to mist. High-speed video indicates that surface tension stabilizes septa while viscous drag destabilizes septa toward mist formation. This hypothesis is supported by experimental data of drop count, size, and mist concentration. Further analysis led to a non-dimensional number (misting number) describing mist concentration as a function of process and material variables.

As capillary number was raised polymer solutions also evolved from a smooth film to one with ribs, then septa. Perforation of the septum wall led to formation of filaments. The failure of filaments and their subsequent drop count, size, and mist concentration was examined by controlling solution rheology. A coating window, where misting was reduced by weak-viscoelasticity and increased by moderate-viscoelasticity, was found.

Viscoelasticity in uniaxial extensional flow was characterized by a constitutive equation applied to the approximate flow within a thinning filament. Analysis of the governing equations for elastocapillary thinning suggest that that neglecting viscous forces leads to an inaccurate prediction of the longest relaxation time. However, capillary thinning was shown to be useful for indexing the relative relaxation times of linear and branched polymer solutions, whose qualitative differences were supported by Brownian Dynamics simulations of dilute polymer solutions.

The results here demonstrate the ability to control misting of Newtonian and polymer solutions through material understanding and process control. The under-

standing gained of how the mechanisms that lead to misting are controlled by solution rheology, their molecular structure, and processing conditions allow formulators and coating engineers to optimize both materials and processing to minimize mist.