Frequency Response Analysis and Active Control of Slot Coating

Takeaki Tsuda *, L. E. Scriven ** and Juan M. de Santos **
*Dai Nippon Printing Co., Ltd.
Tsukuba, Ibaraki, 300-2646, Japan
** Department of Chemical Engineering & Materials Science
University of Minnesota
Minneapolis, MN 55455

The uniformity of fixed-gap slot coating is disturbed by run-out of backing roll, pulsations of liquid feed rate and web speed, and fluctuations of vacuum (reduced upstream air pressure). An attractive but apparently undeveloped way to improve uniformity in the face of these practicalities is active feed-back control with optimal selection of the control parameters. This can give as much as an order-of-magnitude improvement. A prerequisite control system design is detailed frequency response behavior ("Open loop response"). This can be drawn from a dynamic model of slot floating flow in a visco-capillary approximation with inertia-augmented lubrication flow in the gap, arc-of-circle upstream meniscus, and, inertia-augmented film flow beneath the downstream meniscus. The response to small sinusoidal disturbance in the gap and downstream meniscus regions can then be represented by transfer functions approximated by empirical modal functions. The results reveal two kinds of modes. One is a gap-squeeze mode important at lower frequencies and viscous in character; the other is higher frequency sinuous modes that are capillary waves on the downstream meniscus. Control parameters can be chosen accordingly and tuned to counter the disturbances that would otherwise detract from creating uniformity.