Coating Flow Analysis: How fundamental understanding helps process development and design

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The deposition of a thin and uniform liquid layer onto a moving substrate is an important step in the manufacturing of many different products, such as different optical films used in electronic displays, solar panels and flexible electronics. Market pressure pushes for more complex film functionality and structure, shorter time for process and product development and smaller manufacturing cost. This scenario poses many technological challenges for the coating industry, such as thinner and more uniform coating layers, use of complex coating liquids, complex film structure and increase in line speed and production yields. Fundamental understanding of the different physical phenomena involved in the different steps of coating and drying a liquid film has greatly helped the coating industry in the past on optimizing steady-state coating operation and drying conditions. Currently, experimental and theoretical models of coating and drying are being extended even further to be able to study coating in much more detail in order to help overcoming the present technological challenges.

This presentation discusses recent advances in coating flow analysis with three examples of slot coating flow that led to important fundamental understanding of the physical phenomena and consequent process improvement.

(a) Process optimization to improve uniformity: Because of the strict uniformity specifications of new products coming to the marked, the control of the effect of the different perturbations inherent to the process in the final film thickness becomes crucial. Two-dimensional transient flow model coupled with optimization algorithm have been used to study the sensitivity of coating flows to small episodic upsets and to ongoing periodic perturbations that cannot be avoided in manufacturing plants. Examples for single and two-layer slot coating are presented, as illustrated in Fig.1, which shows the amplification factor of the film thickness oscillation in a two-layer slot coating process as a function of the gap perturbation frequency.

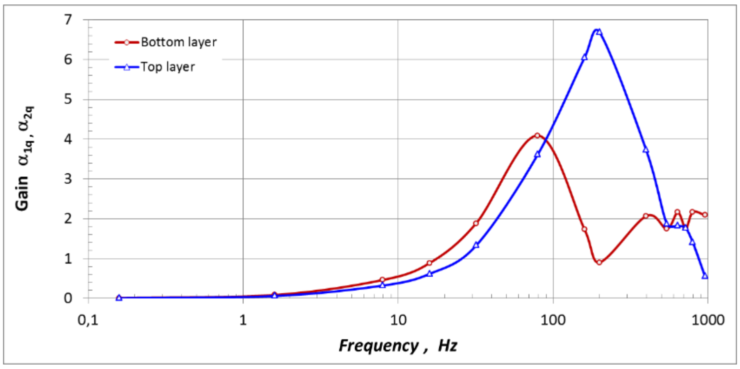

Figure 1: Amplification factor for two-layer slot coating related to gap oscillation.

(b) Discrete and patch coating: Coating technology can be used to create non-uniform structures on substrates. Common examples are the coating of electrodes on flexible films and flexible circuits. The resolution and control over the edges of the coated features are essential for product performance. Experiments and flow model are used to study how the edge quality is controlled by contact line motion.

(c) Flow of particle suspensions: Many functional films are made by coating particle suspensions. The performance may be optimized by controlling the final particle structure in the coated layer. Coating and drying process may have a strong effect and be used to achieve the desired structure. Continuous and discrete models are used to better understand the evolution of particle configuration during coating. Examples of how process conditions affect the particle distribution in the coated layer are presented. Figure 2 illustrates how the particle concentration field in the coating bead changes as the wet thickness is reduced.

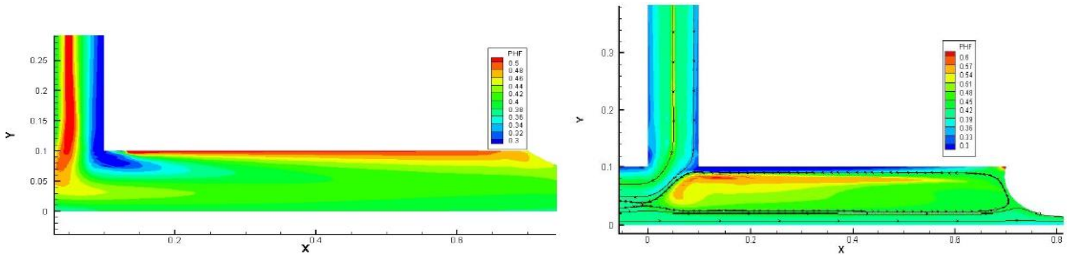

Figure 2: Particle concentration field in a slot coating bead for h = H/3 and h = H/5.