Simulations and Experiments for Flow Behavior and Operability Window in Slot Coating

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Abstract

Multi-dimensional calculations and experiments in slot coating, which is necessarily implemented in IT industries producing flat panel displays, Li-ion secondary batteries, and so on, have been conducted for analyzing flow dynamics and operability coating windows. Based on the previous theoretical considerations and experimental observations reporting the optimization of the slot coating flows (Lee et al., 2011), we would like to further investigate the effect of die lip configuration with different angles of upstream or downstream die lip on the operability windows for Newtonian coating liquid via two-dimensional finite element method. Also, coating flow fields predicted by three-dimensional calculations (using CFD software, Fluent) from internal die to external coating bead regimes have been successfully compared with those by experiments and simple 1-D viscocapillary model.

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Effect of die lip configuration on the operability coating window

Pre-metered slot coating has been extensively applied in a variety of functional films in displays, slurry coating in Li-ion secondary batteries, and so on. As in other coating cases, it is important to optimally control the flow behavior in coating flow regime for uniform coating operation. Many valuable aspects in this process have been explored via theoretical considerations using noble numerical simulations and flow visualization techniques. There remain unsolved issues for enhancing productivity and processability of slot coating systems.

As an indicator to determine uniform region free from leaking and bead break-up defects, 1-D viscocapillary model developed in Lee et al. (2011) was further revamped for constructing the various operability windows with the change of upstream or downstream die lip configuration (Fig.1). Windows determined from this model were quantitatively compared with those by 2-D Navier-Stokes model implemented with finite element technique, exhibiting good agreement between 1-D and 2-D models (Fig.2). It is noted that the vortex region occurred as the angle of upstream or downstream die lip changed under the uniform coating conditions, which may disturb the uniform coating under particulate suspension coating operations.

Comparison of flow behavior in slot coating using 3-D simulations and experiments

3-D calculations were conducted using CFD solver Fluent to predict flow dynamics of a Newtonian liquid flowing inside die to substrate surface and compared with experimental results obtained from small-scale lab coater (Fig.3). Considerable agreement between 1-D model and experiment can be shown in operability coating window. Dynamic results from 3-D calculations at some (leaking, uniform, bead breakup) points also qualitatively coincided with experimental observations (Fig.4).

References

KL Bhamidipati, S. Didari, P. Bedell, TAL Harris, *J. Non-Newtonian Fluid Mech.*, 166, 723 (2011).

CP Chin, HS Wu, SS Wang, *Ind. Res. Chem. Res.*, 49, 3802 (2010).

IA Gates, *Slot Coating Flows: Feasibility, Quality.* PhD Thesis, University of Minnesota (1999).

SH Lee, HJ Koh, BK Ryu, SJ Kim, HW Jung, JC Hyun, *Chem. Eng. Sci.*, 66, 4953 (2011).

CF Lin, DH Won, TJ Liu, PY Wu, *Adv. Polym. Tech.*, 29, 31 (2010).

JW Nam, LE Scriven, MS Carvalho, *J. Comput. Phys.*, 228, 4549 (2009).

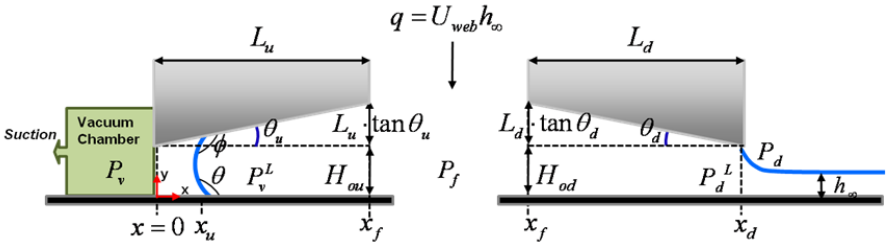

Fig.1. Geometry of slot coating bead region with slanting lip geometry.

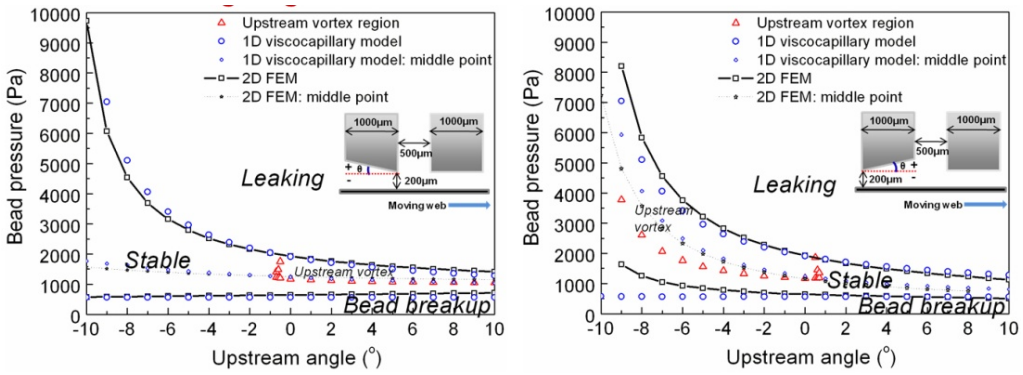

Fig.2. Effect of upstream die lip angle on the operability window.

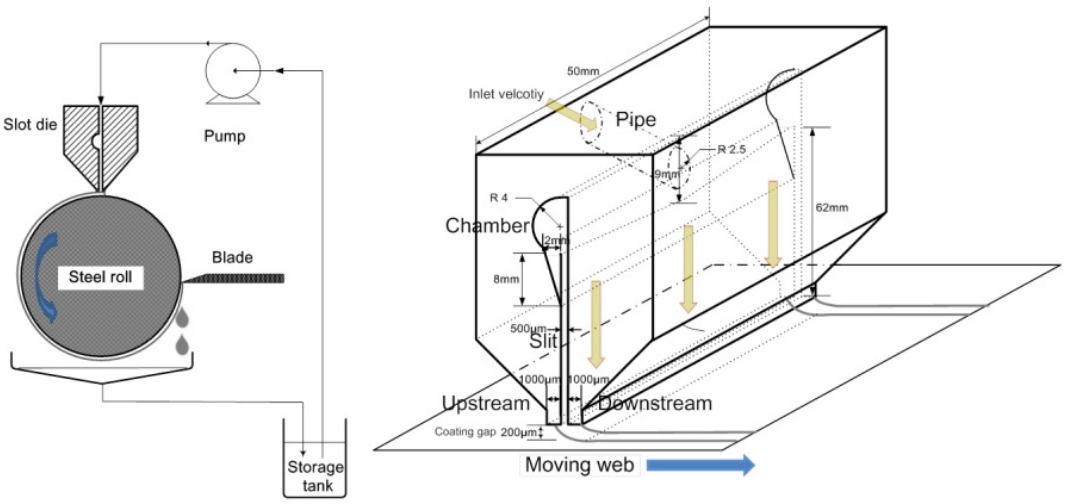

Fig.3. Schematic diagram of slot coater for experiments.

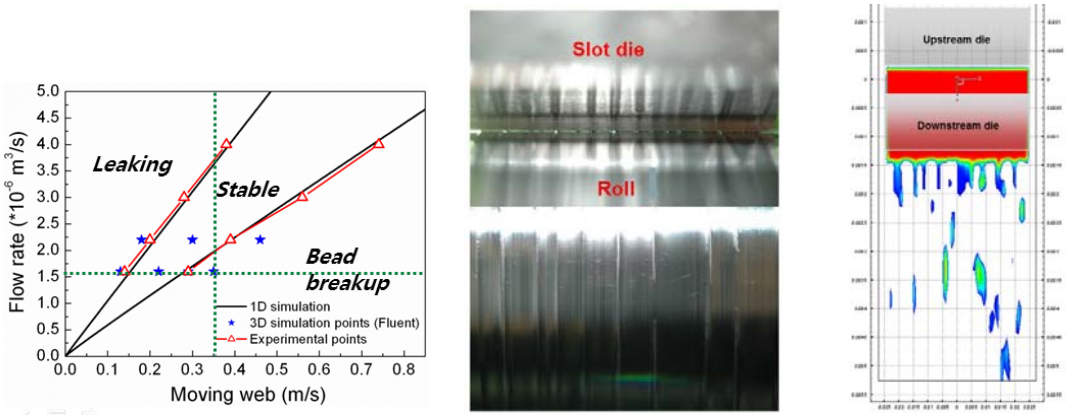

Fig.4. Comparison of window and flow behavior under bead breakup condition by 3-D model and experiments.