Improving Die Designs - Newtonian Flow Results

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Introduction: Coating dies distribute flow along a line by commonly using a cavity and slot. Unfortunately, a superior die design is often very expensive to build and maintain. Also, dies collect particulates at the slot destroying coating uniformity. We have sought designs for low cost, for particle tolerance and designs that perform a final filtration. While Secor (1) reviews designs and models, new improvements to dies and filtration are suggested by our modeling. Engineered metering sheets are described which offer design improvements and new coating methods. All of our disclosures have a patent pending status.

Drilled Hole Die Improvements: Drilled holes and orifice plates (3) have been used to replace slots. Modeling shows T-manifolds using drilled holes have a uniformity index, *UI*, that is a function of a viscous number, *Nv*, and a weak function of the number of holes. When the number of bores is large, we show the *UI* approaches the 1D model results for slots previously reported for Newtonian and powerlaw fluids (4). While drilled hole dies are often inexpensive, they are prone to clogging which causes streak defects in a coating. Adding cross web bores provides clogging tolerance and improves the *UI*. Here *UI* depends upon *Nv*, the number of added auxiliary cross bores, and the parameter $Ns=Kw/Kd*(Rw/Rd)^{1/2}$ where *Kd* is the number of through bores minus one, and *Kw* is the number of cross web bores plus one. The ratio *Rw/Rd* is the ratio of cross to through bore element flow resistance. Results approach the equivalent 2D slot model predictions when many cross bores are used. Large performance improvements are possible with a few cross bores when *Ns* is low. Also investigated are die designs without feed cavities.

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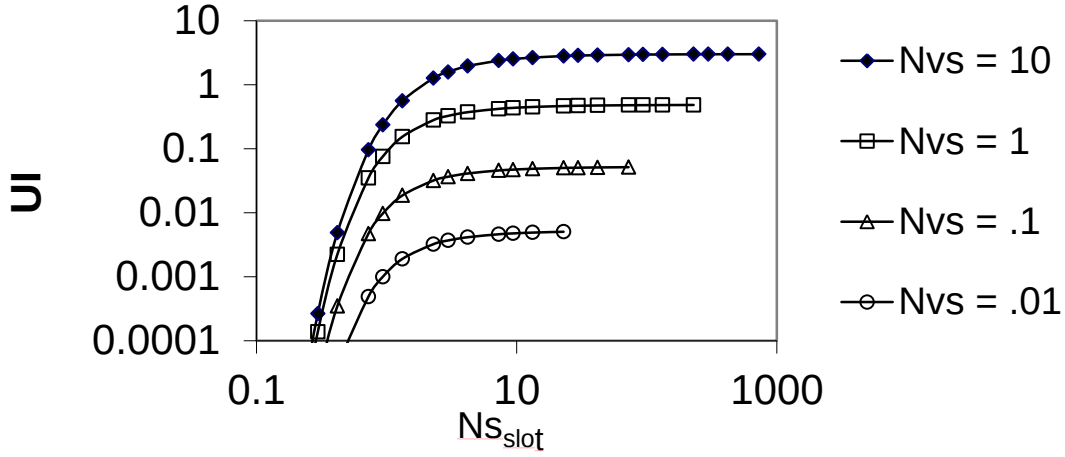
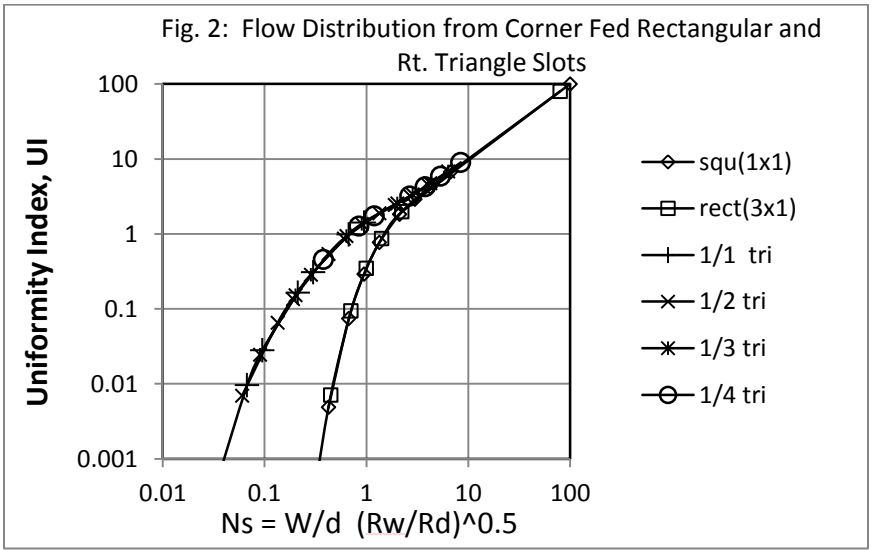
Rectangular or triangular area grid layouts are shown to give good coating distribution when fed at a corner point if the parameter *Ns* is small. Since *UI* strongly depends upon *Ns,* good coatings may be easily obtained for wide dies using multiple feed points. However, the fabrication of drilled hole grids is a problem.

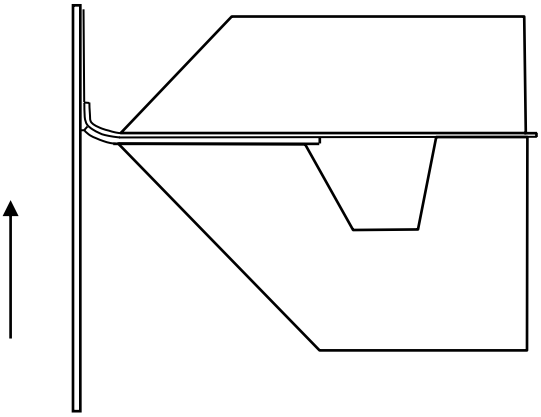
Improved Slots: It is shown that coating slots may be improved by designing them to be bi-directional. Neglecting gravity, inertia and entrance effects in T-dies, and using a 2D lubrication model for the slot, it is found that *UI* depends on Nv_{slot} and Ns_{slot} for Newtonians where $Ns_{slot} = W/d*(Rw/Rd)^{1/2}$. Dies without feed cavities are possible.

Figure 1: Performance of T-dies with Bi-directional Slots, W= coating width , d= slot length

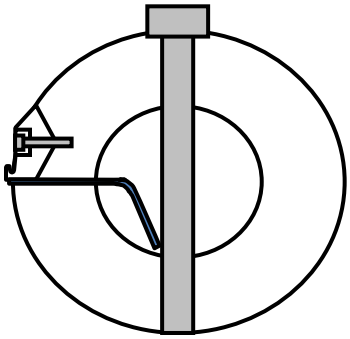




Fluid Metering Sheets for Filtration and Flow Uniformity: Micro-channels may be produced on substrates which may be mass produced using replication technology(2). The technology allows design of fluid metering sheets with variable flow distribution and filtering properties. Flow is conducted within the sheet and discharged at an edge. They are designed to distribute and filter fluid. Their utility arises from the large number of flow paths and interconnections. We have built a computer model based on an arbitrary three dimensional cube grid of repeating flow paths. The model uses up to 10^9 passageways where flows are calculated. Also, a stochastic straining filtration model was used to study particle capture and interaction with flow the distribution. In experiments, dies were challenged by a large number of particles. Improvements in filtration and *UI* were found with special choices of the flow resistance and particle capture probability distributions in the sheet. Our work suggests metering sheets enable new die designs, improved tolerance to clogging, and improved filter media designs. Illustrated are new designs.



Blade Coater with Metering Sheet



Contact Die with meter sheet and extruded polymeric lip

Improved Filter Elements: Our models have also been used to study in-depth filter elements. For 3-dimensional media, filtration is followed until a maximum pressure drop or a reduced total flow end point is reach. Important parameters for a given geometry are the capture probability and flow resistance distributions. Results indicate the volume of fluid processed may be greatly increased relative to commercially available media. For this, one of the important elements is the use of helper pores that have a low capture probability.

Important Note: All the findings, articles, apparatus, and methods disclosed in this presentation are covered in whole or in part by a pending patent application.

References

(1) R.B. Secor: "Analysis and Design of Internal Coating Die Cavities", Liquid Film Coating, Kistler and Schweizer editors, Chapman and Hall, London (1997).

(2) T.I. Insley et al, US Patent 6,290,685; "Microchanneled Active Fluid Transport Devices" (9/18/2001).

(3) G.W. Maier et al, US Patent 7,846,504; "Die Having Multiple Orifice Slot" (12/7/2010).

(4) W.K. Leonard, "Inertia and Gravitational Effects in Extrusion Dies for Non-Newtonian Fluids" Polymer Engrg Sci, 25(9), 570-576 (1985).