DIE FLOW CHANNEL
DESIGN FOR OPTIMIZED DISTRIBUTION
Applications of this Technology

• Web Coatings
  – Emulsions
  – Polymers
  – Hot Melts

• Polymer Film & Sheet Manufacture
Typical Flow Channel Designs
Conventional Technology

“T” Manifold
Typical Flow Channel Designs
Conventional Technology

Coat Hanger Manifold

Decreasing cross section manifold
Decreasing preland length
In order to achieve uniform thickness exit flow across the entire width:

The channel design must be determined using knowledge of the flow characteristics of the fluid or polymer to be processed.
Flow Characteristics

- VISCOSITY
- FLOW RATE
Definition of Viscosity

• The measure of a fluids internal resistance to flow or also a measure of fluid friction

• Scientific definition:
  – The ratio of Shear Stress to Shear Rate

• Typically measured in Poise, Centipoise, or Pascal-Seconds
Other Important Terms

• Shear Stress
  – The relative force applied to a quantity of fluid
  – Typical Units: Dynes / Square Centimeter

• Shear Rate
  – Rate of Relative Motion between adjacent layers of a moving liquid
  – Relative Velocity divided by Length
  – Typical Units: Sec$^{-1}$
Newtonian versus Non-Newtonian

- Newtonian fluid is one in which the viscosity does not depend on the shear rate.

- Polymers and many fluids are Non-Newtonian with the viscosity decreasing as the shear rate increases.
A variety of materials at their normal operating temps

VISCOSITY VERSUS SHEAR RATE

10000 10000 100 10 1 0.1

VISCOSITY (PA-SEC)

10000 1000 100 10 1

SHEAR RATE (SEC^{-1})

Radel Udel Nylon 6 ASA PVC HDPE PC PP Teflon AF
Flow Variables

- Rheology properties of the particular fluid or solution
- Temperature
- Flow Rate
- Shear Rate
- Geometry of the flow channel
Conventional Flow Channel Designs

- Sensitive to changes in polymer flow characteristics
- Require die adjustments if polymer is changed
- Material flowing from the ends of the die is in the die much longer than the material coming from the center of the die
Constant Shear
Flow Channel Design

Mathematically Derived Design for Manifold & Preland

Constant shear rate at all points yields a die that is:

• Insensitive to changes in polymer viscosity and rate

and:

• Any fluid particle path has the same residence time
Initial Development

• Design concept was originally developed by H. H. Winter; University of Massachusetts & H.G. Fritz; University of Stuttgart in the early 1980’s

• Revealed details in Antec paper – 1984 and subsequent articles
Key Concepts

• Manifold Design
  – Changed from a general round shape to a slit cross-section (flow through parallel plates)

• Constant Shear Rate
  – Developed formulas for the design of the entire flow channel in order to maintain a constant shear rate
Winter & Fritz Flow Channel Design

\[ H = h \left( \frac{B-X}{W} - 1 \right)^{1/2} \]

\[ H(X) = \text{Manifold Depth, } F(X) \]

\[ Y = 2W \left( \frac{B-X}{W} - 1 \right)^{1/2} \]

\[ W = \text{Manifold Width} \]

\[ h = \text{Slot Depth} \]

\[ Y/B > 0.6 \]

\[ B = 1/2 \text{ Die Slot Width} \]
10.0” Wide Die – Winter & Fritz
Results Achieved

• Benefits
  – A single die design achieves uniform flow independent of the material processed
  – The residence time for material inside the die is constant across the exit slot from center to ends

• Disadvantages
  – Front to back depth increases as width increases
  – Limited to narrow and very low pressure applications due to generally large wetted area
Premier Dies Corp. Sponsored Development
New Reduced Depth
Constant Shear Flow Channel

- *Patent Applied For* development has enhanced the design and allows the same results to be achieved at wider widths without the penalty of the large front to back depth
- Increases the applications to wider widths
- Developed by Professor Mohamed Elgindi at the University of Wisconsin – Eau Claire
New Reduced Depth Design

Manifold increases in width from center to ends

19” Wide Manifold in 3D
# Preland Length Comparison

<table>
<thead>
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<th>DESIGN INPUTS</th>
<th>CASE #1</th>
<th>CASE #2</th>
<th>CASE #3</th>
<th>CASE #4</th>
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<tbody>
<tr>
<td></td>
<td>OLD</td>
<td>NEW</td>
<td>OLD</td>
<td>NEW</td>
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<tr>
<td>DIE SLOT WIDTH</td>
<td>12</td>
<td>12</td>
<td>18</td>
<td>18</td>
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<tr>
<td>PRELAND GAP</td>
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<tr>
<td>MANIFOLD WIDTH - CENTER</td>
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<tr>
<td>MANIFOLD WIDTH - ENDS</td>
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<td>3</td>
<td>1.75</td>
<td>3.5</td>
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<tr>
<th>DESIGN OUTPUTS</th>
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<tr>
<td>PRELAND LENGTH</td>
<td>4.62</td>
<td>2.87</td>
<td>7.12</td>
<td>4.39</td>
<td>9.17</td>
<td>5.85</td>
<td>11.18</td>
<td>7.27</td>
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<td>REDUCTION IN LENGTH - INCHES</td>
<td>1.75</td>
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<tr>
<td>REDUCTION IN LENGTH - %</td>
<td>38%</td>
<td>38%</td>
<td>36%</td>
<td>35%</td>
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</table>
PRELAND LENGTH AT VARIOUS DIE WIDTHS

- 12" Width:
  - Old: 4.62
  - New: 2.87

- 18" Width:
  - Old: 7.12
  - New: 4.39

- 24" Width:
  - Old: 9.17
  - New: 5.85

- 30" Width:
  - Old: 11.18
  - New: 7.27
17” Wide Die Comparison

Coat Hanger

Constant Shear
19” Wide Die
4x10” Side by Side Manifold Die with Flow Splitting Feed
8" Wide Triple Manifold Die
Constant Shear Manifold Benefits

- Uniform Spreading Insensitive to Actual Viscosity
  - Processes virtually any polymer or fluid
- Constant Residence Time – Center of Die versus ends
  - Reduces product changeover time
- More Streamlined at Edges
  - Much reduced likelihood of burning and degradation at ends of die
POLYMER FLOW COMPARISON
Relative time for color or polymer changeover

Constant Shear Manifold

Coat Hanger Manifold

START

A sec

B sec

C sec

D sec
Constant Shear Manifold Issues

• Die must get deeper as width is increased
  – Starts to become a problem around 36” width

• Manifold has greater depth than other designs
  – Die needs to be slightly larger in size

• Slightly more Expensive to Manufacture
  – 10 to 20% cost premium

• Not Recommended for use with Co-Extrusion Feedblocks