A Practical Guide to Blown Film Troubleshooting

Paul Waller
# Table of Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Polymer Properties and Terminology</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Feeding Systems to Gearboxes</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>Extruder Screws and Set-up</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>Temperature Controllers to Screen Changers</td>
<td>51</td>
</tr>
<tr>
<td>5</td>
<td>Blown Film Dies</td>
<td>65</td>
</tr>
<tr>
<td>6</td>
<td>Bubble Cooling</td>
<td>93</td>
</tr>
<tr>
<td>7</td>
<td>Bubble Collapsing</td>
<td>119</td>
</tr>
<tr>
<td>8</td>
<td>Post Extrusion Operations</td>
<td>131</td>
</tr>
<tr>
<td>9</td>
<td>Troubleshooting Techniques</td>
<td>165</td>
</tr>
<tr>
<td></td>
<td>Film Defects Troubleshooting Guide</td>
<td>171</td>
</tr>
<tr>
<td></td>
<td>Roll Defects Troubleshooting Guide</td>
<td>188</td>
</tr>
<tr>
<td></td>
<td>Subject Index</td>
<td>195</td>
</tr>
</tbody>
</table>
Chapter 1 – Polymer Properties and Terminology

**Melt Strength Affects Bubble Shape**
The bubble shape affects the process of chain orientation. It depends on the melt strength of the polymer. High (strong) melt strength resins such as HDPE form a high stalk bubble as shown on the right. Low (weak) melt strength resins form low stalk bubbles as shown on the left.

**Process Time**
The long molecular chains become oriented in the machine direction as they travel through the die opening. The onset of solidification begins at the *Crystallization Line*, and is completed at the *Freeze Line*. The *Frost Line* is often visible in transparent films and is located somewhere between these two lines. The primary processing condition factors that control film properties can be summarized by the *Process Time*. 
Chapter 3 – Extruder Screws and Set-up

Barrier Screw Designs
There are two successful concepts for improving screw output capacity: The first is to delay the solid bed breakup until most of the pellets are melted. The screw for this is commonly referred to as a barrier flighted screw. The second uses repetitive solids and melt redistribution. Mixing pins in the metering zone are a common way of doing this. The limitation of both these concepts is that they narrow the processing window (range of operating conditions) under which acceptable quality product can be extruded. Higher output rates increase torque, requiring larger motors and gear reducers. It is often not practical to retrofit older extruders with modern barrier screw designs. Higher output rates reduce residence time inside the extruder, required faster melting rates. Melt overheating is a common problem with these high performance screws unless barrel temperature profiles are adjusted correctly. A generalized concept drawing for a smooth bore barrier screw is illustrated below.

Comparison of Conventional versus Barrier Screws
Barrier screws separate melted from unmelted polymer. Friction between the pellets and barrel wall does not diminish because of premature solid bed breakup. An average barrier screw will increase melting efficiency by 30% when compared to conventional single flighted screws. A 3D comparison of the unwrapped screw channel is illustrated below.
3. **Humped Temperature Profile**

This strategy is common when compensating for unstable output, known as surging. See page 57 for details. Extra energy to melt the pellets is added to the transition zone. Melting too quickly may result in gels or unstable solid bed breakup. See page 60 for details.
Assuming the extruder motor and drive are stable, surging can be analyzed by monitoring the following operating parameters.

Three parameters increase and decrease, just like in a chorus line of dancers:

- Extruder motor amperage
- Extruder back pressure
- Frost line height
- All 3 parameters increase and decrease in cycles
- Cycles are not always synchronized

**Symptoms of Solids Conveying Variations in Feed Zone**

- Frost line height lags back pressure and changes with back pressure
- Extruder back pressure lags behind motor amps and changes with output
- Extruder motor amperage declines when feeding rate declines
- Constant extruder screw speed

**Strategies to Avoid Solids Conveying Variations in Feed Zone**

**Processing Conditions**
- Keep feed throat cool
- Use water cooling, if available, to cool screw in feed zone

**Equipment**
- Remove blockages from feed throat
- Ensure that vacuum loaders can supply sufficient resin to feed hopper
- Maintain at least 60 cm (2 ft) of resin in the hopper to avoid starving the screw
Chapter 5 – Blown Film Dies

Melt fracture becomes transparent

Interfacial instability remains hazy

Water

Gels
Gels are classified first by size and distribution pattern, and then by shape and color. They include pinpoint (very small), arrowhead, chevron, V or J, fisheye, platelet or disc, lens (hollow) and discolored gels. Gels that are evenly dispersed throughout the film are likely to come from the raw material or extruder. Gels that form lanes of gel and gel-free regions in the machine direction are likely to be created inside the die.

The size of the gel compared to the film gauge defines the severity of the problem. Gels that are smaller than 5 microns will affect appearance but are not likely to result in mechanical failure of the film. As gels become larger, they become more unappealing and may result in mechanical failure of the film. The standard test methods for reporting gels only report the quantity larger than specific sizes. These include ASTM D-3351 for gels greater than 400 microns and the TAPPI Dirt Chart T-437 for black specs. Automatic gel counters are available, but are very expensive.

Unmelted Gels
Very small gels evenly dispersed throughout the film are often referred to as applesauce. Larger unmelts can deform enough to flow through screen packs and reform on the downstream side. The primary cause for unmelts is insufficient mixing in the extruder to complete the melting process.
3. **Disassembly and Cleaning**

If options 1 and 2 are not effective, it will be necessary to disassemble the die and pull the screw. This is the least preferred strategy because it takes many hours to complete the task. Purge the line with a low viscosity (high MI) stable polymer before beginning the procedure. This will make it easier to disassemble the die and pull the screw. Use only brass or copper tools that are not sharp enough to damage plating when cleaning the hot metal surfaces. Use polishing compound recommended by the equipment manufacturer to avoid stripping the plating off the metal. Remove as much polymer as possible while the steel is still hot. Polish the screw and die after the steel has cooled down to room temperature.
Chapter 6 – Bubble Cooling

**Slow Bubble Breathing**

- **Raw Material**
  - Melt strength is too weak
  - Not enough LDPE in formulation
  - Melt index too high

- **Processing Conditions**
  - Not enough air volume from air ring (frost line is too high)
  - Melt temperature too hot
  - Too much output for cooling system to control

- **Equipment**
  - IBC sensor(s) are too high
  - IBC blowers or valves are not balanced
  - Leaks in IBC ducts
  - Leaking IBC plenum (oscillating dies only)

**Air Ring and IBC Adjustments to Eliminate Slow Bubble Breathing**

Increase the air velocity and adjust air volume (if required) from the air ring. Adjust the movable parts of the air ring, the air ring blower and IBC (if available) in the following sequence, depending on the type of air ring installed on the line.

1. Single lip
   - Reduce Air Ring blower speed to increase venturi affect and lower frost line height

2. Dual lip with perforated ring
   - Close holes (if available)

3. Dual lip with iris
   - Reduce IBC cooling rate (if available) to increase melt strength
**Wrinkles**

Edge guides, misaligned rollers and improper tension can result in many types of wrinkles. Roller misalignment patterns can be eliminated using the following strategies. The objective is to keep to the left of the solid curved line shown below by adjusting tension or shifting the boundary between the wrinkle and no wrinkle zones.

Wrinkles appear to walk uphill. Wrinkles reach downstream roller and point toward narrow side. Slack edge (low tension) with no wrinkles. Wrinkles are an indication of gauge variation or unstable tension control. The patterns can be summarized as *machine direction* and *diagonal* wrinkles.

- **Symmetrical MD Wrinkles**
- **Symmetrical Diagonal Wrinkles**
- **Asymmetrical MD Wrinkles**
- **Asymmetrical Diagonal Wrinkles**
- **Asymmetrical MD Wrinkle**
- **Asymmetrical Diagonal Wrinkles**

![Diagram of Wrinkles](image-url)
Chapter 8 – Post Extrusion Operations

Tapered Rolls

These rolls are smaller in diameter at one end and gradually increase in diameter along the face of the roll. A gauge difference of 0.5 microns (0.02 mils) will result in large diameter differences as the roll builds up. The illustration below shows the affect of this difference across the roll face.

<table>
<thead>
<tr>
<th>Processing Conditions</th>
<th>Solutions for Tapered Rolls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce melt temperature variation (melt channeling)</td>
<td></td>
</tr>
<tr>
<td>Eliminate air drafts across the bubble</td>
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</tr>
</tbody>
</table>

**Equipment**
- Realign or level
  - Die
  - Air ring
  - Cage
  - Collapsing frame
  - Haul-off nip
  - Lay-on roller

Camber will cause film to track off center in converting equipment.
Some common equipment problems are illustrated in the following examples.

**Effect of a Misaligned Air Ring**

<table>
<thead>
<tr>
<th>Die Position</th>
<th>Gauge Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>41.9 μ / 1.65 mils</td>
</tr>
<tr>
<td></td>
<td>41.4 μ / 1.63 mils</td>
</tr>
<tr>
<td></td>
<td>40.4 μ / 1.59 mils</td>
</tr>
<tr>
<td>B</td>
<td>38.9 μ / 1.53 mils</td>
</tr>
<tr>
<td></td>
<td>38.9 μ / 1.50 mils</td>
</tr>
<tr>
<td></td>
<td>34.3 μ / 1.35 mils</td>
</tr>
<tr>
<td>C</td>
<td>33.0 μ / 1.30 mils</td>
</tr>
<tr>
<td></td>
<td>34.8 μ / 1.37 mils</td>
</tr>
<tr>
<td></td>
<td>37.3 μ / 1.47 mils</td>
</tr>
<tr>
<td>D</td>
<td>38.4 μ / 1.51 mils</td>
</tr>
<tr>
<td></td>
<td>39.9 μ / 1.57 mils</td>
</tr>
<tr>
<td></td>
<td>41.1 μ / 1.62 mils</td>
</tr>
<tr>
<td>A</td>
<td>41.9 μ / 1.65 mils</td>
</tr>
</tbody>
</table>
The following guide summarizes the troubleshooting tips described in the manual. The blown film line is split into several zones to remind operators which area of the line should be examined when problems occur. Each problem includes causes split into raw material, processing conditions and equipment. Recommendations for each cause are included.

**Blown Film Troubleshooting Guide**

Blown Film Properties 169
Blown Film Troubleshooting Guide Diagram 170

**Film Defects Troubleshooting Guide**

- Blocking 171
- Die lines, weld lines (MD) 172
- Gels – Applesauce (very small gels) 172
- Gels – Arrowheads, chevrons, (“V” or “J’ shaped) 173
- Gels – Discolored 174
- Gels – Fisheye, platelet, disc 174
- Gels – Hollow or void 175
- Low gloss, high haze, low clarity 176
- Low heat seal strength 176
- Machine direction gauge variation 177
- Melt fracture and shark skin 179
- Interfacial instability – short wave pattern 179
- Interfacial instability – short and long wave patterns 180
- Port lines 180
- Poor surface treatment 180
- Scratches in machine direction 181
- Splitty film (low machine direction tear strength) 181
- Streaks in machine direction 182
- Streaks in transverse direction 182
- Transverse direction gauge variation 183
- Uneven film or sheet width 185
- Uneven gussets 186
- Weak edge folds 186
- Wrong color 187
Roll Defects Troubleshooting Guide

Baggy edges 188
Buckled rolls 188
Bumpy rolls (Tin Canning) 188
Folds, creases 189
Non uniform surface hardness 189
Ringed rolls (fuzzy edges) 189
Roll too hard 190
Roll too soft 190
Sag in film (soft in middle of roll) 190
Starred rolls or crushed cores 191
Tapered, convex or concave rolls 191
Telescoped rolls 192
Uneven roll width 192
Wrinkles in roll 193
This book is designed to help readers understand how the complex interaction of raw materials, equipment and processing conditions affects productivity and film characteristics.

Contents include:
- Polymer characteristics
- Equipment options and comparisons
- Troubleshooting guides for:
  - Extruder temperature profiles
  - Screw wear
  - Surging
  - Melt fracture
  - Interfacial instability
  - Gels
  - Bubble instability
  - Surface treatment
  - Wrinkles
  - Roll geometry
  - Heat sealing
  - Gauge variation

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