7-9-11 Layers
Which are the Most Suitable Applications

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Agenda

• Introduction
• Background/technology revisited
• Benefits of coextrusion
• Advantages of multilayer lines with example structures
• The next generation
• Alternative technologies
Introduction (Equipment)

• Mono-layer blown film extrusion is very well established
• Film manufacturing evolved from mono-layer to coextrusion for many reasons
  • Equipment developments
  • Resin developments
  • Process development
  • Education
  • Market needs
  • Economic forces
• Coextrusion development began about 60 years ago
Alpine 5-Layer Plate Die

(Adapted from the UMASS-Lowell Plastics Engineering Department Process Engineering curriculum – UML)
Stacked Conical Mandrel Coextrusion Blown Film Die

7-Layer Taper Pack Macro Engineering Coextrusion Die for Heat Shrinkable Biax Film, Courtesy Macro Engineering
9-Layer Concentric (Nested) Spiral Die (UML)

Courtesy Battenfeld Gloucester
Blown Film Die Variation

Plate, or Pancake Die

Concentric Spiral Mandrel

Stacked Conical Spiral Mandrel

All images courtesy Gloucester Engineering
Benefits of Coextrusion

• So, how did we go from one to three and five layer films to 7, 9, and 11-layer films?
• What is driving the market to films with more and more layers? It seems all the major manufacturers are offering 7, 9, and 11 layers machines.
• The big question is why?
• Is there a real benefit to be gained from the additional capital expenditure, or is it marketing hype?
Benefits of Packaging & Coextrusion

Packaging
- Product protection
- Puncture and abuse resistance
- Vapor barrier
- Moisture barrier
- Grease barrier
- Chemical barrier
- Light barrier
- Printability
- Heat seal strength
- Heat seal initiation temperature
- Hot tack
- Machinability

Coextrusion
- Combining incompatible polymers in one step (lamination not needed)
- Optimization of film structures for specific applications
- Improved barrier properties
- Reduced layer thickness of expensive resins
- Controlled respiration (O₂ & CO₂ transmission)
- Improved physical properties
  - Improved Gelbo flex resistance (reduced flexural failures)
  - Thinner, stronger films
  - Improved gloss
- Additional attributes, such as anti-fog, anti-block, COF, two-sided color
- Expanded markets, i.e., competes with rigid packaging
- Reduced cost
- Use of new polymers
## Benefits of Coextrusion – Barrier Properties

<table>
<thead>
<tr>
<th>POLYMER</th>
<th>OTR @ 20°C, 65%RH (cm³ 20µ / m² day atm)</th>
<th>GAS BARRIER</th>
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<tbody>
<tr>
<td>27 Mol% Ethylene EVOH</td>
<td>0.2</td>
<td>Excellent</td>
</tr>
<tr>
<td>44 Mol% Ethylene EVOH</td>
<td>1.5</td>
<td>High</td>
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<tr>
<td>PVDC</td>
<td>2.6</td>
<td>Fair</td>
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<tr>
<td>LDPE</td>
<td>10000</td>
<td>50,000 x</td>
</tr>
<tr>
<td>EVA</td>
<td>18000</td>
<td></td>
</tr>
</tbody>
</table>
Benefits of Coextrusion – Toughness

• Using LDPE instead of EVOH as an example would require a 1 meter thick (50000 x 20µ) of LDPE to achieve the same O₂ barrier as EVOH

• Thinner layers are obviously less stiff than thicker layers, so improved Gelbo flex resistance is anticipated with thinner layers of stiff materials

• For example, polyamides can be substituted for polyester in a coex structure, allowing for a strong, tough structure with good permeability properties in a one-step blown film process

• For example, frozen food packaging
Benefits of Coextrusion – Heat Seal

Heat seal strength, heat seal initiation temperatures, and hot tack strength can be adjusted based on the performance required in the end product.

1-, and 3-Layer Films

• These are the backbone of the blown film industry, and certainly will not disappear any time soon
• Monolayer lines are perfectly suited for commodity, non-barrier films
• Existing lines require no capital outlay
• 1- and 3-layer films feed into the adhesive laminating market
• The limitations of 1- and 3-layer films are barrier, stiffness and heat seal properties
5-Layer Films

• Offer more options and flexibility than 3-layer films
  • Most typically as a barrier film with an EVOH core layer or a PA/EHOH/PA outer skin

Cereal liner, lidding & tube stock, meat packaging, medical devices (fin or lap seal)

Frozen food packaging (fin seal)
5-Layer Film Line

- 5-layer films eliminate the need for the secondary step of adhesive lamination (of simple structures)
- The modulii of laminated oriented PA, PP or PET films are similar to unoriented polyamide coex blown films [6]
- 5 extruders in (more or less) a semi-circle
- Big improvement over 3-layer films, but limited in performance compared to 7, 9, 11-layers

Photo courtesy Hosakawa Alpine
7-Layer Films – Cost reduction

- 7-layer structures can utilize a lower-cost LLDPE in the second layer and an expensive, high-performance metallocene LLDPE as the skin layer, which has superior hot tack and heat seal properties.
- [mLL / LL / Tie / EVOH / Tie / LL / mLL] optimizes performance and cost, and is used for milk packaging [4]
- Basically a cost reduction analog to the 5-layer structure previously shown.
7-Layer Films – Improved Barrier/Strength Properties

• If improved barrier properties and toughness are required in the finished product, the following structure is applicable and can be made with a 7-layer die

  [LL / Tie / Nylon / EVOH / Nylon / Tie / mLL]

• This structure is used as a lidding film with excellent barrier properties and gloss.

• Flexibility is controlled with thickness

• The metallocene PE layer can be any mPE, such as POP, etc.
7-Layer Films – Thermoform Fill Seal Trays

• Substituting the mLLDPE with EVA is used in a thermoformable cheese tray

• The point made here is that more layers offers the package designer more options

• Thought to be about 100 7-layer lines in use today
9-Layer Films – Semi-Rigid Barrier Structure

• 9-layer rigid, high barrier structure using cost/ performance optimized PE resins
• The thickness of the nylon layers control modulus
• Similar to the 7-layer structure except that the skin layers can be split into two to optimize cost and performance for a particular application
• Frozen foods, stand-up pouches, thermoform-fill-seal
• Approximately 50 9-layer lines are reported to be in use today
11-Layer Films

- 11-layer retortable, high-barrier structure using cost/performance optimized PP and copolymer PP resins
- Sous-vide cooking is all the rage today
- Sous-vide is slow cooking (up to 96 hours) at low temperatures (55-60°C) in a hermetically sealed bag
- 11-layers appears to give the converter & R&D specialist broad flexibility to optimize barrier, rigidity, heat seal properties, thermoformability, and cost.
11-Layer Hosakawa Alpine Coex Line (UML)
11-layer vs 5 layer vs monolayer

- Repairs become more challenging than on 11-layer lines vs 1/3/5-layer lines

- At some point there will be diminishing returns at which the cost, complexity, and maintenance of more extruders limits further development
The Next Generation

• While it is not possible to predict the future, at some point simply adding more extruders into bigger and bigger dies becomes unfeasible.

• Layer splitting technology is common now in flat film dies

• BBS Technologies has developed a nano-layer blown film die (US Patent # 8870561)

• True nanolayers in a 77-layer structure
Photomicrographs of nanoclay-filled mPE at 1µ, 500 nm, and 200 nm

• These are photos of a 77-layer polyolefin/polyamide coextrusion
• The benefits of this die are:
  • Greater strength and modulus due to increased BUR capability (5:1)
  • Improved barrier properties, which effectively halves the amount of polyamide required while retaining stiffness

Photomicrographs courtesy of Alpha Marathon Extrusion, Toronto
Thank you for your attention

Disclaimer: The author has no business affiliation and has received no compensation from any company or product shown in this presentation.

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