Particularities of Extrusion to design Peelable Structures for PP, PS, PET and PVC substrates

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Session 2, Paper 2-1
Aim of the presentation

• To discuss some of the issues related to the use of peelable resins converted by extrusion

• To show that peel/seal performance is dependant on the overall lid construction, and is finally more a system property than just a sealant property

• To introduce some new *ready-to-use* and *versatile* peelable resin, that should make life of processing people easier!
Scope of this work

This work focuses on the following field:

- Multipurpose lids for PP, PS, PET, PVC cups and trays
- Peelability by adhesive failure (interfacial peeling)
  - No cohesive fracture mechanism like in PE+PB or PE+talc systems
  - No « seal to itself » systems like in pouches and bags
- Structures involving a peelable layer made by extrusion, like
  - Extrusion coated structures
  - Laminated structures using a previously blown peelable film
What about extrusion for peelable structures?

Interest of extruded peelable layers

- Hygiene and safety in workshops
- Environment friendly: no solvent to dry and burn
- Sophisticated structures in one pass

Particularities

- Processing issues due to tackiness of top peelable layer
- Extruded layers generally thicker than lacquers, less viscous => more flowing under squeezing
- Curling effects sometimes tricky
Requirements for peelable structures

From downstream to upstream
- End use property: easy opening by peeling
- Reliable seal
- Compliance with regulations
- Good machineability at filling/sealing stages
- Easily processable at converters

For R&D people at converters and resin suppliers,

How to design
- Such peelable structures?
- Peelable resins fulfilling these requirements?
Heat sealing: so simple and so complex!

- **So simple**: heat transfer through the layers to melt the sealing resin and bond it to the cup material.
- **So complex**: how to analyze this non stationary process combining heat transfer and flow of polymers?

**Geometrical parameters**
- Cups geometries: flat or ringed rims, rigid or flexible design.
- Sealing bars geometries: flat, square or round profile, narrow or wide.

**Materials parameters**
- Heat conductivity, viscosity change with $T^\circ$ for each layer of lid and cup, elastic properties, thermal expansion coefficients.

**Process parameters**
- Temperature, pressure, cycle time.
Peelability Evaluation

1 - Using cups, tested manually, or recording forces

- **Initiation peak**
- **Propagation value**
- **Final peak**

- Method required to validate a specific application, but not so convenient for R&D purposes
Peelability Evaluation

2 - Using 15 mm wide strips, sealed on 15x15 mm²

- Easy to seal with common flat seal bars
- Easy to measure by peeling with a tensile machine
- But… **Results are not consistent with real cups ones**

- Reason: 2D sealing instead of 1D is different thermally and mechanically speaking
  - Heat transfer and dissipation
  - Squeeze flow during sealing
  - Internal stresses during and after cooling

\[
\text{Thickness} \ll \text{Length}
\]

\[1D \text{ usual sealing seam geometry} \neq 15\times15 \text{ mm}^2 \text{ 2D situation}\]
Peelability: Initiation Forces are misleading

- Initiation forces are very sensitive to the microscopic geometry of the outer part of the seal seam.
- This geometry results from the squeeze flow of cup material and peelable sealant.
- Very often a roll of squeezed cup material traps the sealant layer.
- Resulting initiation force is chaotic and difficult to interpret.
How to overcome these difficulties?

3 - Replacing the ring geometry by straight bars

- Keeping the same narrow profile, square or round shaped
- Keeping the same contact surface (=> same actual pressure)

Ring Sealing
- For real validation, needs cups
- Tricky initiation forces
- Not so convenient to record forces

Linear Sealing
- Possible with any piece of sheet
- Very convenient for measurements
- Distinction initiation / propagation
Separating Initiation and Propagation Forces

- Leads to consistent data and allows to deepen the investigations on sealing properties.
Peel forces: Influence of lid construction

- Aluminium based construction, sealed onto Polystyrene

![Graph showing the relationship between seal bar temperature and propagation force for a specific construction. The graph indicates an increasing trend in propagation force with increasing temperature. The construction details are noted in the graph as Alu / tie1 / Sealant 1 (37/10/15 µm).]
Comparison Alu / OPET based constructions

- Same sealant and tie resins, same thicknesses, but…

![Graph showing propagation force vs. seal bar temperature for Alu / tie1 / Sealant 1 and OPET / tie1 / Sealant 1 constructions.](image-url)

Alu / tie1 / Sealant 1
(37/10/15 µm)

OPET / tie1 / Sealant 1
(12/10/15 µm)
Initiation forces show the same trend

- Values are different, but comparison is consistent
Lid construction: third example

- Same tie and sealant in all three cases

**Graph:**
- **Y-axis:** Propagation Force (N/3mm)
- **X-axis:** Seal Bar Temperature (°C)

Lines and data points for:
- **Alu / tie1 / Sealant 1** (37/10/15 µm)
- **Paper / tie1 / OPET / tie1 / Sealant 1** (65/20/12/10/15 µm)
- **OPET / tie1 / Sealant 1** (12/10/15 µm)
Explaination: plasticity effects in multilayers

10 µm tie layer + increasing µm LDPE

37 µm alu foil

Peel strength increases with LDPE thickness because peel energy is mainly due to bulk plasticity in LDPE layer.

Peel Strength (N/15mm)

LDPE thickness (µm)
Yield stress is controlling plasticity

- Changing LDPE for a softer material decreases peel strength, as a result of yield strength decrease (11 MPa down to 3 MPa)
Effect of adding an intermediate MDPE layer

- **Construction**

<table>
<thead>
<tr>
<th>OPET / Lotader 4503</th>
<th>MDPE</th>
<th>Sealant</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 µm</td>
<td>6 µm</td>
<td>0 to 55 µm</td>
</tr>
</tbody>
</table>

- **Graph**

- **Examples of sealing onto**
  - CPET
  - PP
  - PVC
Effect of varying PE density

- Construction

OPET / Lotader 4503 / PE variab. density / Sealant

12 µm  6 µm  40 µm  15 µm

Examples of sealing onto PS

![Graph showing the effect of varying PE density on yield strength and propagation force](image)
What kind of resin as peelable layer?

- Sealing to PP, PS, PET, PVC relies on physico-chemical interactions
  - Strong enough for tightness
  - Weak enough for adhesive failure under peeling stresses
- Usually EVA or EMA based formulations including modifiers (tackifiers, rubberizers,...) : intrinsically amorphous and tacky
- As top layer in extrusion, this gives difficult issues
  - Chill roll release in extrusion coating
  - Film splitting after collapsing in blown extrusion
  - Blocking and friction, which is harmful to machineability at all stages
- Additivation for processing is not easy
  - Such amorphous and polar resins can trap additives and limit their migration
  - High temperature resistance and non volatility are required for extrusion coating
- A real challenge!
A new proposal as ready-to-use resin

Lotryl Bestpeel 2407
- Ethylene Methyl Acrylate copolymer based, MFI 7
- Ready-to-use for easy converting
- Processability of an autoclave high pressure radical copolymer - the preferred one in extrusion coating
  - Global melt stability, low neck-in, drawability
- Thermal stability up to 310°C
- Efficient additivation for the different extrusion processes
  - Chill roll release in extrusion coating
  - Film splitting in blown extrusion
  - Antiblock and slip specifically adapted
- Coextrudable with PE and all ethylene copolymers
- Composition compliant with EU and FDA regulations
Versatile sealing properties to PP, PS, PET, PVC

Initiation Force in N/15 mm
Propagation Force in N/3 mm

- Construction 1
  - Alu / EAA or E-BA-MAH / Bestpeel 2407
  - 37 µm 6 µm 15 µm

- Construction 2
  - Paper /4503/OPET/4503 / Bestpeel 2407
  - 15 12 5 15 µm

Sealing conditions:
0.6 to 1 s, 200°C, 2.2 MPa actual pressure
Versatile sealing properties to PP, PS, PET, PVC

**Construction 3**

- **Paper / 4403/ PA / 4403 / Bestpeel 2407**
- **Sealing conditions**: 0.6 to 1 s, 200°C, 2.2 MPa actual pressure

**Construction 4**

- **OPET/ 4503 / MDPE / Bestpeel 2407**
- **Sealing conditions**: 0.6 to 1 s, 200°C, 2.2 MPa actual pressure
Effect of Temp. on sealing to PS, PP and PET

- Construction: Alu 37 µm / Tie 6 µm / Bestpeel 2407 15 µm

- Sealing performances to PS, PP and PET are very close
- From 170°C, sealing performance reaches a safe and steady plateau
- Not recommended for low temperature sealing

Sealing time: 0.7 s, 2.2 MPa actual pressure
Conclusions

- Extrusion offers interesting possibilities to design peelable structures and to produce them in an environment friendly way.
- Excellent processability of peelable resins remains a strong prerequisite for converters.
- Although simple at first look, heat sealing is a complex process that may strongly affect extruded layers.
- A simple methodology has been presented to help in understanding peel/seal performances as properties of multilayers.
- A new resin is proposed to offer improved possibilities in both processing and end use properties.
Acknowledgements

- Grateful thanks to Sébastien Callouet and Damien Rauline for years of fruitful collaboration in R&D.

- Special thanks to Betty Laurent for her tireless commitment to make confusing matters become clear.