Formulating substrates for winding in vacuum metallization

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Introduction

• What does the word “film” represent

• Winding in air and vacuum

• Removing the importance or control of Air in winding
  “Formulate for Winding”
Substrates i.e. Films

- Substrates or “Films” are comprised of an interior portion, called the Core which has two adjacent surfaces.
- The skins may be composed of the core itself or of different materials and may contain intermediate layers.
Winding in Air or Vacuum

• Film winding is an important unit process for many plain, metallized and converted films.

• As in most processes the material and the winder combine to define the potential for success.

• For winding COF is not important in and of itself. 
  – Controlling film to film spacing not slipping.

• We are going to look at what it takes to Formulate for winding.
Film surfaces

• Regardless of the application, most films have “inexpensive” polymer cores used to carry special more expensive surfaces
  – Special surface properties or attributes
    • Printable, metallizable, enhanced adhesion,
    • Controlled surface chemistry
  – Defined surface quality
    • Uniform surface smoothness
    • Matte surface structure
• This is more difficult to do with single layer films and today coextrusion is widely used
• So what is the film surface you are using?
• And what is the best surface for winding
Winding smooth Film

• For a perfectly smooth film surface,
  – the layer to layer film wraps are only separated by air trapped during winding
• For a smooth film, the air layer is important to:
  – prevent blocking
  – Allow film to smooth out wrinkles as it winds
• Low film to film COF may allow smooth roll formation
• “Slip” addition will prevent blocking of film surfaces
• In general the air layer alone is insufficient to produce a good roll
  – Air escapes from the roll with time
Formulating for winding

• Improperly wound or formulated films results in many film and roll defects on unwinding
  – Baggy film
  – Blocking
  – Telescoping
  – TD corrugations
  – MD Tin canning

• Air is used to help minimize/overcome some problems on winding

• Formulating well can minimize the importance of air in winding
  – We want to use the film surface to replace the air when building a roll
Substrate Winding in Air

- Film winding, to form a roll, is a process of building a long spiral of film on itself around a circular core.
  - typically 40,000 meters or more in length
  - Roll contains both film and air
  - Roll density is an excellent measure of the outcome

Measuring local roll density changes
Winding in Air

- During winding in air, air is pumped into the roll by the film and roll surface motion and trapped between the winding layers.
- Thickness of the air layer is calculated from the air bearing equation.
- Defines the important process variables for film winding:
  - Tension, winding speed, size of the roll

\[ t = 0.65R \left[ 12\mu \frac{V}{T} \right]^{2/3} \]

where:
\( \mu \) = fluid (air) viscosity
\( R \) = radius of surface
\( V \) = velocity of the film
\( T = T_0 - BV_w^2 \) T is tension, B is basis weight
The problem with air

• The trapped air layer is unstable with time and as the roll builds
  – Roll structure dependent on winding speed, film tension roll diameter and air viscosity (temperature)

• Too much trapped air can cause
  – Egg shaped rolls
  – Telescoping
  – Internal roll collapse – corrugations

• Too little air can cause
  – Blocking and crushed cores
  – Baggy lanes and stretched film
  – Knife edge
The problem with vacuum chambers

• There is no air to aid in winding the roll
  – Leads to hard roll problems
• It deflates the rolls put into vacuum chamber
  – Corrugates rolls \(\Rightarrow\) leads to blushing
  – May telescope roll as air escapes
• Making film slippery does not help
• Winding loosely does not help
  – Roll collapse on pressurization
  – Telescoping
  – Film slipping and Scratching on rewinding
• Need to control the structure of the roll in vacuum
Winding in vacuum

- Need to replace the air for controlling the film to film spacing

- Want to control the film to film spacing so that air easily reenters the roll on pressurization
  - Or exits the roll on chamber evacuation

- What spacing should we use?
  - How rough should the surface be?

- How do we optimize film surface(s) for metallization and winding?
What Film spacing (Air Layer) Thickness?

- For winding in air, the film to film air layer separation varies as the air layer thickness varies during the roll formation
  - Vary “control” by changing of tension and layon roll pressure
- Need to find the optimum spacing for winding in vacuum
- Also need to optimize “COF” for metallization with chill roll

\[
t = 0.65 * R \left[ 12 \mu \frac{V}{T} \right]^{\frac{2}{3}}
\]

where:
- \( \mu \) = fluid (air) viscosity
- \( R \) = radius of surface
- \( V \) = velocity of the film
- \( T \) = web tension
Early Film Formulations

• Originally films were formulated to prevent blocking
  – Particulates added to reduce surface to surface contact
    • Called antiblock
  – Migratory additives “bloom” diffuse to surface to prevent film to film blocking
    • Also made film surface very slippery – called slip

• Winding and web handling improvements were noted for rougher films

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<th>Film surface: particulate additives</th>
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<td>Film Core: polymer + migratory additives</td>
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<td>Film surface: particulate additives</td>
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100X - reflection
Antiblock Controlled Web Separation

- Control by Particle diameter $D_p$, and skin thickness, $t$
  - Particles generally larger than final layer thickness
- $D_p$, Greater than wound air layer
- Film separation 0.5 to 2 $\mu$m
- $0.5 \ D_p < t < 3 \ D_p$
- Control of slit or mill roll density
Controlled film to film spacing

- Would like a minimum spacing of 2 microns
  - Need to optimize particle diameter for
    - Air escape and ingress in chamber
    - Easy film expansion on chill roll over the boats
    - Winding of the metallized film
- Coextruded film surface containing properly sized particles
  - Particle shape and size distribution important
Film for metallization

- Will have a surface to control film to film spacing and a smooth surface for deposition
- Antiblock particles will be about 4-5 microns in diameter in a 1 micron layer
  - Today spherical particles are favored (Tospearl® & Epostar®)
- May use a mixture of particle with some ranging up to 8 microns
- Small amount of Slip in skin for blocking
TOSPEARL Examples

• Toray
  – 4,966,933  metallized film

• Mitsubishi Petrochemical
  – 4,769,418  monolayer and coex OPP packaging
               and cigarette film

• Sumitomo Chemical
  – JP Kokai H07-179679  single layer LLDPE
     packaging film

• ExxonMobil Films
  – 5,725,962  multilayer oriented HDPE

• Teijin
  – 5,372,879  PET magnetic recording tape
Conclusions

• Need to understand the structure of the film
  – Smooth surface vs. rough surface
  – Differential surface to optimize metallization

• Look past COF to understand what controls films winding properties

• Films which wind well in vacuum also wind very well in air

• We should formulate for winding
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- Polymer Processing and Troubleshooting
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- Extrusion and Melt System Design, Specification and Start-Up
- Polymer Film Design and Manufacture
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- Confidentiality
- Complete confidentiality of client information with no disclosure of confidential information
- Ethical
- All patentable concepts developed while working for client, disclosed and assigned to client,
- Efficiency
- A knack for being able to “zero-in” on the problem at hand and to systematically identify solutions,
- Team Player/Excellent Communicator
- Able to work well with line-operators, engineering staff and management to cross-communicate technical information,
- LIFETIME EXPERIENCE/ TOP-NOTCH KNOWLEDGE
- Troubleshoot or focus your R & D having the advantage of a lifetime of learning and experience,
- Continuous Improvement
- Goal is to exceed the client’s expectations and to provide information about the most recent advancements in the field,
- References
- Professional references gladly provided.