Extrusion Coating & Laminating

2008 Extrusion Coating Short Course, May 1, 2008

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Discussion Topics

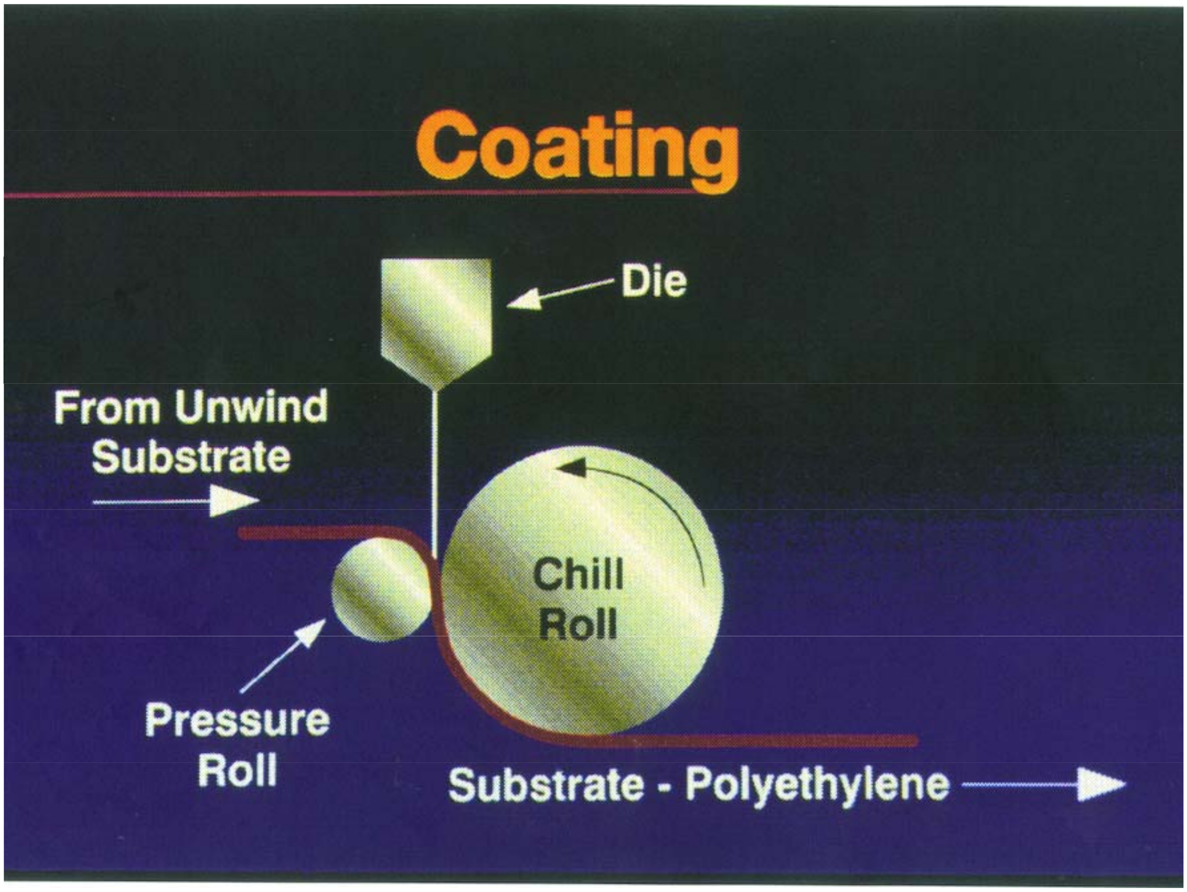
- Equipment and Purpose
- Chill Water System Design and Control
- Basics of Process
- Calculations
- Troubleshooting

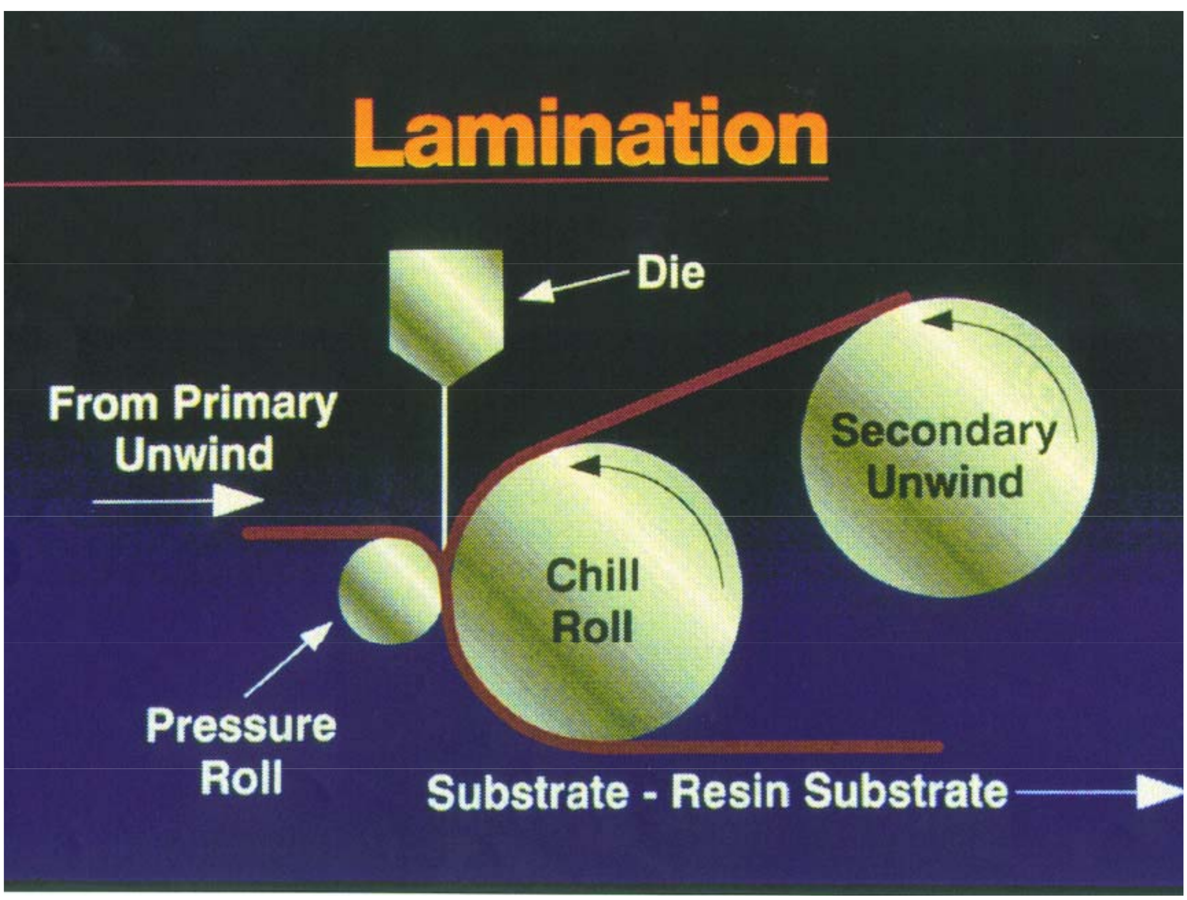
Extrusion Coating & Laminating

The goal in extrusion coating and/or laminating is to form a continuous, inclusion free polymer layer of uniform thickness, that adheres to the desired substrate(s).

Extrusion Coating Uses

- Milk Cartons
- Ream Wrap
- Juice Cartons
- Snack Food Packaging
- Photo Paper
- Bakery Trays
- Sugar Pouch
- Cheese Wrap
- Snacks
- Dry Mixes
- Lidding Stock
- Multiwall Bags
- Medical Packaging


Coating
Die
From Unwind
Substrate
Chill
Roll
Pressure
Roll
Substrate - Polyethylene

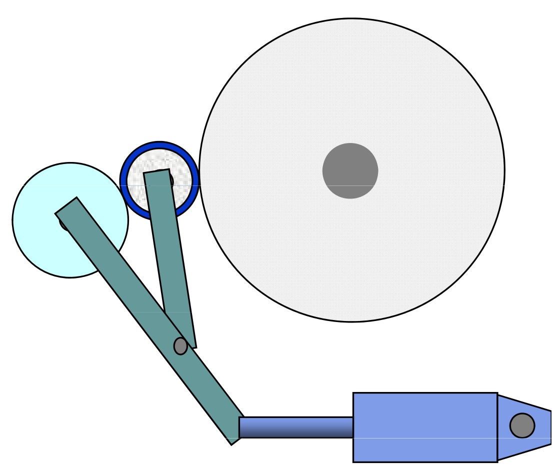

Lamination
Die
From Primary
Unwind
Secondary
Unwind
Chill
Roll
Pressure
Roll
Substrate - Resin Substrate

Nip Roll

- What: Water cooled (generally double shell) roll with a rubber covering
- Function:
  - To combine the substrate(s) and molten polymer together at the chill roll with even pressure
  - It removes air from the product
  - It facilitates cooling

Nip Roll

- Operation
  - Opens and closes with either pneumatic air cylinders or air bags.
  - Pressure is changed by adjusting air pressure to cylinders or bags.
  - Typical pressure is 150 pli but can be higher.
  - Both rolls open for threading and safety

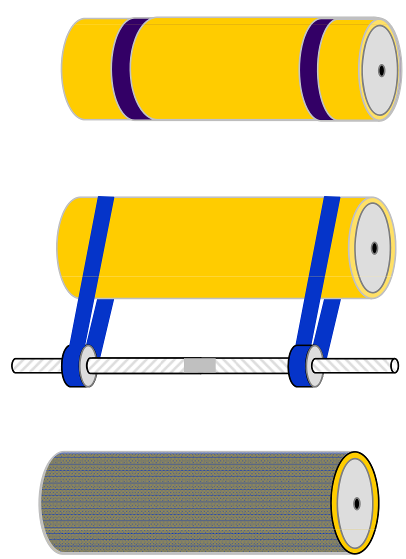


Nip Roll Coverings

- Hypalon (Chlorosulfonated Polyethylene)
  - Shore hardness range: 40-90
  - Good release, temp resistance, ozone resistance and easily reground
- Neoprene (Polychloroprene)
  - Shore hardness range: 15-80
  - Regrindable, not as durable, good release, inexpensive
- Silicone (Polymethylsiloxane)
  - Shore hardness range: 40-70
  - Soft, v good release, temp resistance, good for porous substances

Nip Roll Release Options

- Why do the edges need more release than center?
- Teflon® Tape
  - Change for different widths
- Teflon® Belts
  - Adjustable but difficult to use
- Teflon® Sleeves
  - Costly



Nip Roll Deflection

- Bending of the roll due to gravity, tension and pressure
  - Backing roll helps the deflection
  - Function of roll diameter and construction
  - Can be measured by nip impression tape OR…
- Corrected by crowning the roll
  - Caution: improper crowning will generate wrinkles in the nip

Backing Roll

- What: Water Cooled
  - Chrome plated double shell
  - Increases the life of the nip roll covering
- Function:
  - Cools surface of nip roll to reduce sticking
  - Reduces bowing/deflection of the nip roll

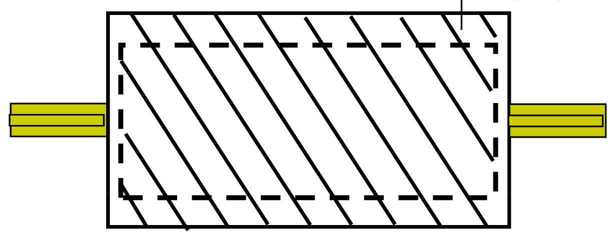
Stripping Roll

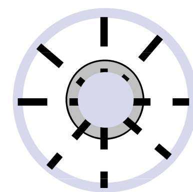
- What:
  - Steel, aluminum or rubber covered idler roll
  - Opened and closed with pneumatic cylinders
- Function:
  - Initiate even removal of product from chill roll
- Location:
  - Metal roll is 1” or less from chill roll
  - Rubber roll contacts chill roll
- Opens for threading and safety
  - Is adjustable if a wide variety of products is to be made

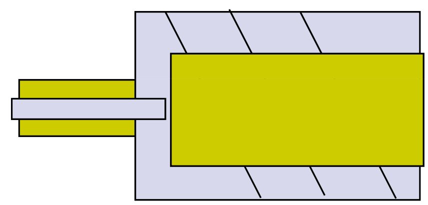
Chill Roll Function

- Quench molten polymer to strippable temperature
- Set extrusion line speed – Lead section
- Impart surface texture to final product (extrusion coating only)

Chill Roll Construction







- Diameter range: 18-50 inches
- Mono flow
  - In one end, out other
- Single shell desgn
  - Small Rolls only – not Recommended!!
- Double shell design
  - Small amount of water, next to outer shell
- Double shell spiral fluted
  - Most common design
  - Lowest delta T

Chill Roll Finish

- Surface roughness is a measure of the smoothness or texture of the roll surface
  - Ra – “Average Roughness”
  - RMS – “Root Mean Square”
  - 10 Ra = 11 RMS
- Surface roughness determines how easily the polymer can be removed from the roll and the surface finish of an extrusion coated product.

Chill Roll Finishes

- Matte – 30-125 Ra typical
  - Grit blasted, plated with dull finish and good release
- Gloss – 4-10 Ra typical
  - Precision ground and polished with good surface finish and release
- Mirror – 2-4 Ra typical
  - Belt or stone polish with high gloss and poor release
- Optical Mirror – 1 Ra or less

Material Considerations

- Heat Conductivity (k) – Steady state heat transfer rate within solid or liquid materials
- Thermal Expansion – Fractional change in length or volume of material for unit temperature change
- Durability – resistance to dents, scratches or deformation
- Weight
- Cost of raw materials and fabrication

Material Selection

Material	Coefficient of Thermal Expansion*	Heat Conductivity**
Aluminum	12.8	1460
Brass	11.4	833
Chromium	3.4	480
Copper	9.8	2670
Gold	7.9	2090
Iron(pure)	6.6	529
Nickel	7.2	421
Silver	10.5	2910
Steel(SAE 1020)	6.6	360
Steel(SAE 1095)	5.7	360
Steel 285 Grade B	6.5	-
Stainless Steel(I8-8)	9.5	-

*10e-6 in/in *°F
**BTU-in /(°F –ft2 –hr)

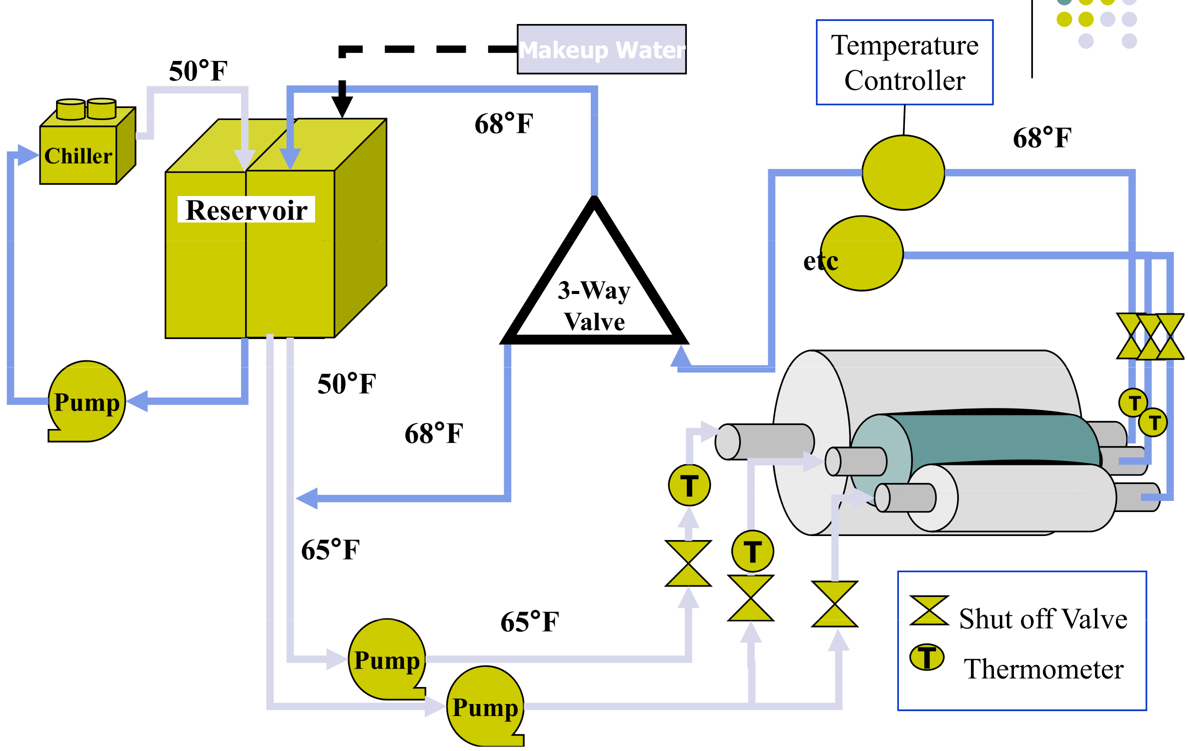
Chill Roll Temperature

- What do I need?
- The ideal chill roll temperature is cool enough to allow the coating to release cleanly, but warm enough so the polymer does not cool before having a chance to wet the substrate adequately.

Water Recirculation System

- Usually a closed loop system
  - Same water is chilled and re-circulated
- Cooling can be varied
  - Based on extruder output
  - By changing temperature of rolls
- Water temperature is controlled
  - Usually runs at 50-85°F

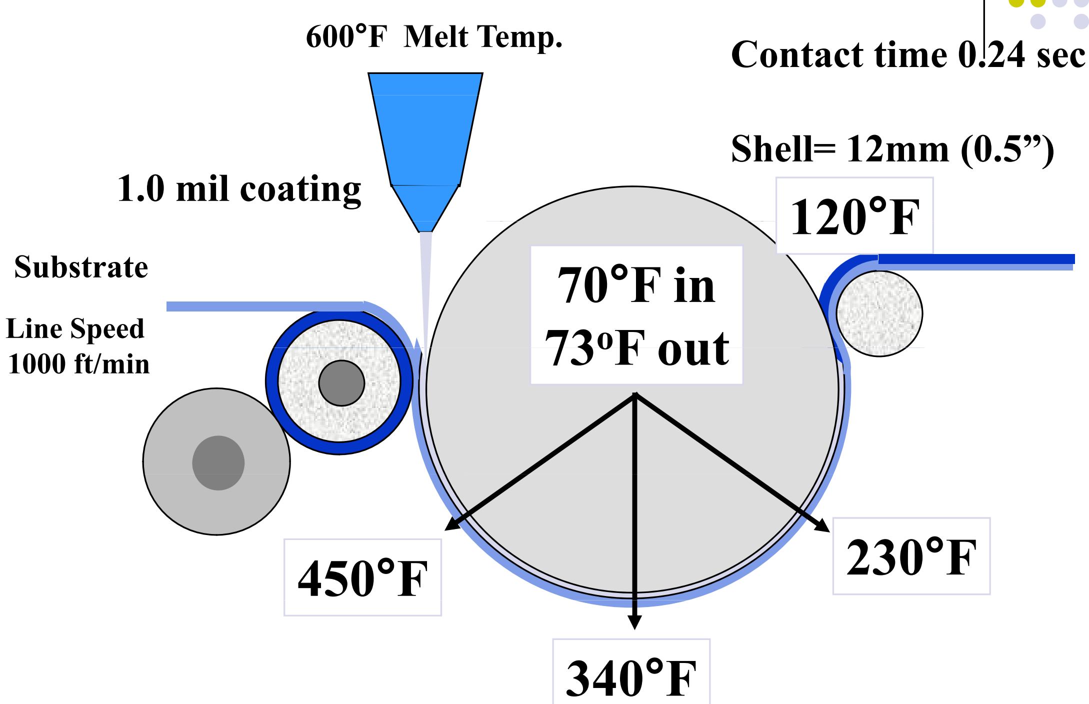
Closed loop chill roll system



Chill System Fouling

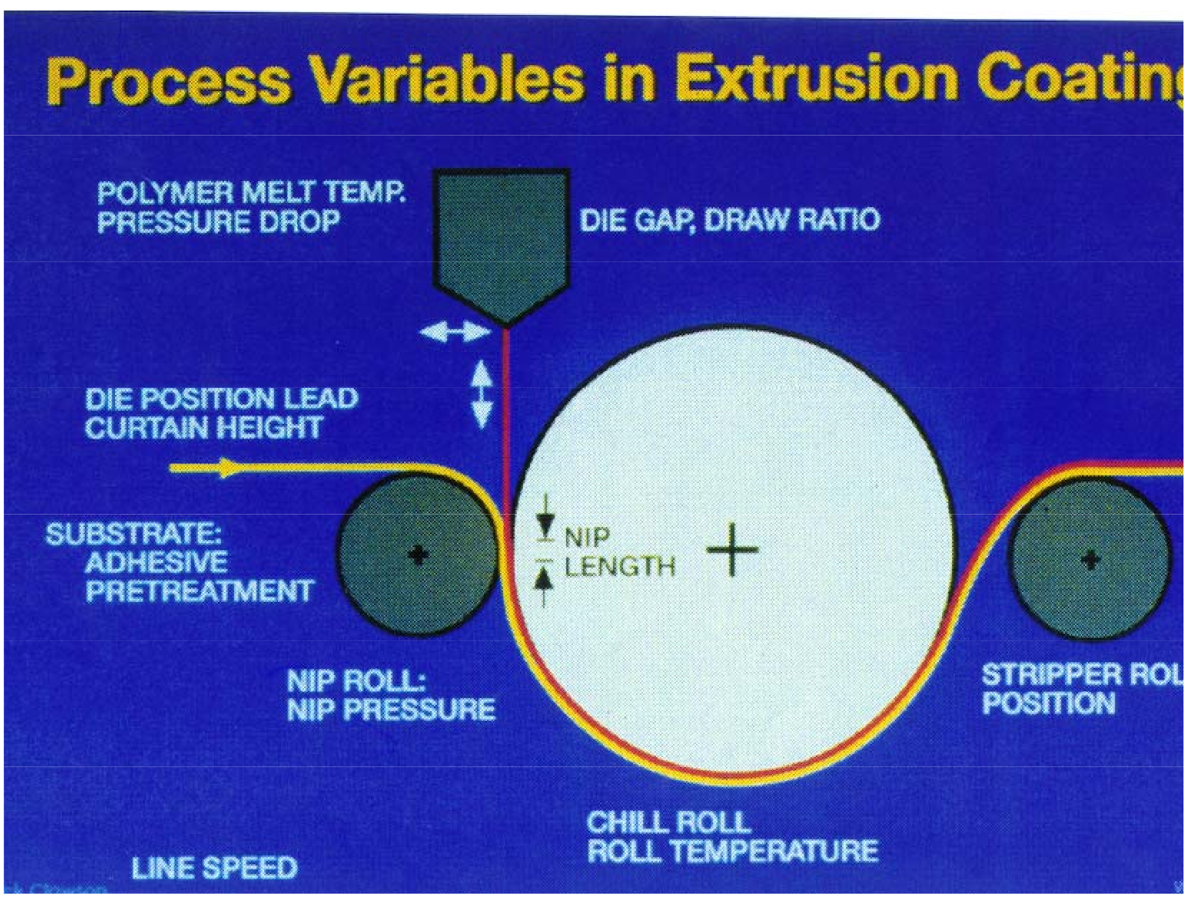
- What: Any layer or deposit of extraneous material on a heat-transfer surface. This reduces thermal conductivity of surface.
- Causes
  - Scale or mineral deposits
  - Algae
  - Rust
- Prevention
  - Initial system treatment
  - Maintenance program
- Removal of build-up is either chemical or mechanical

Chill Roll Temperature



Extrusion Process Variables

- Polymer Melt Temperature
- Linespeed
- Air Gap/Drawdown
- Die Position Lead
- Die Gap (not discussed)
- Chill Roll Temperature
- Nip Roll Pressure
- Nip Roll Hardness



Oxidation (melt temperature)

- All substances are either organic or inorganic
- Organic materials will burn
- High temperatures promote faster oxidation rates
  - At some temperature the ignition point will be reached.

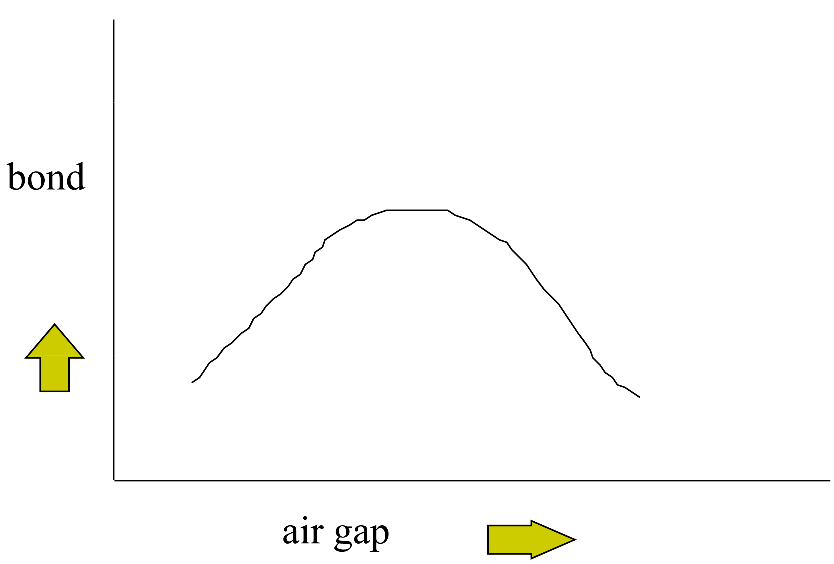
Bond / Adhesion

- All organic materials have a surface skin
  - This is an oxidized layer of itself (rust)
- Some materials resist oxidation such as stainless steel
- <u>*TO OBTAIN ADHESION BETWEEN TWO MATERIALS, ONE MUST BE LIQUID!!!*</u>
- Too much oxidation destroys adhesion as does too little.

Air Gap

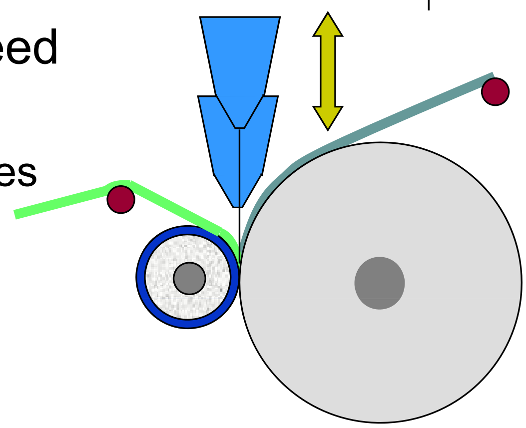
- The amount of time the molten polymer is in contact with air effects its adhesion to the substrate.
  - The longer the polymer is exposed to air, the cooler it becomes and tends to decrease adhesion
  - If the melt temperature is high enough, increased time will increase oxidation and will improve adhesion
  - Therefore, an optimum air gap permitting maximum adhesion exists for each set of circumstances

Bond versus Air gap



Melt Curtain Air Gap

- Determined by linespeed
- Raising Die
  - Time in air gap increases
  - 100ms for LDPE
  - TIAG=60 x gap(mm) / linespeed (m/min)
  - Neck-In increases
  - Melt temperature drops
  - 1” increase in gap = 10°F increase in melt temperature



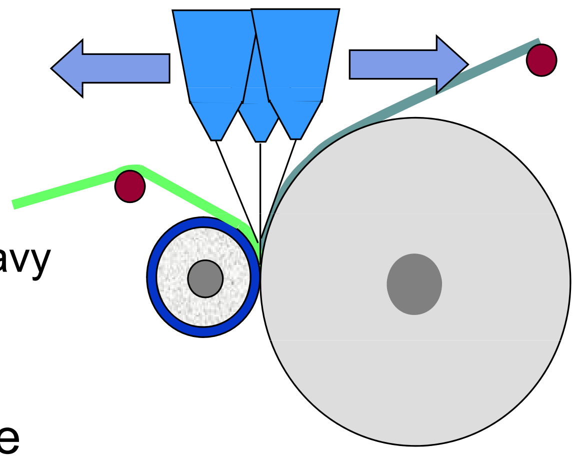
Air Gap (in)	Line Speed (fpm)
7.0	up to 700
8.5	700 – 1,200
10.0	1,200 – 1,800
12.0	1,800 and up

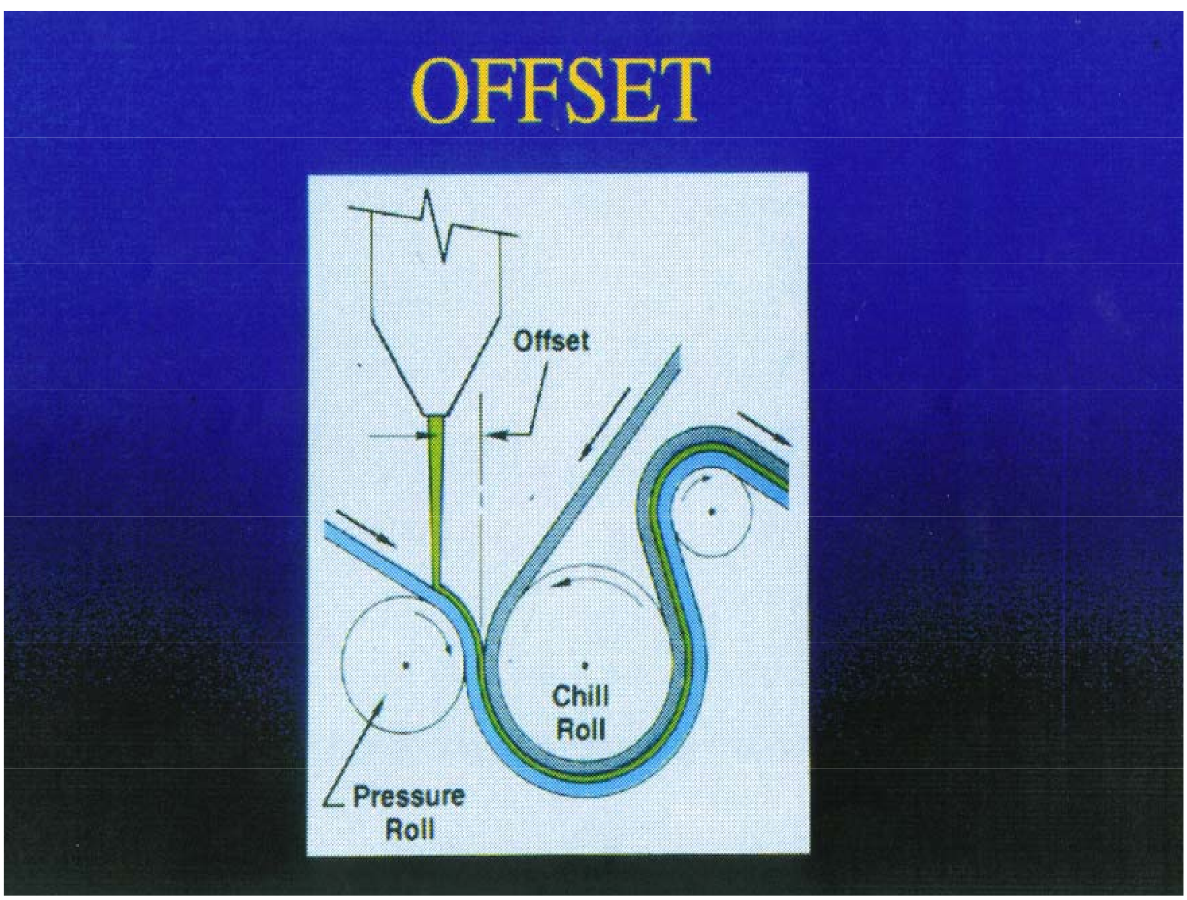
Neck-In

- Determined by:
  - Resin properties such as molecular weight and molecular weight distribution
  - Extrusion conditions such as melt temperature, line speed, output rate and die pressure
  - Equipment geometry such as screw design, air gap and die lip gap

Die Position Lead

- Lead onto either substrate for improved adhesion
- Issues
  - Substrate burn through
  - Web contraction on heavy coatweights
  - Linespeed will effect
- Work needs to be done to optimize location

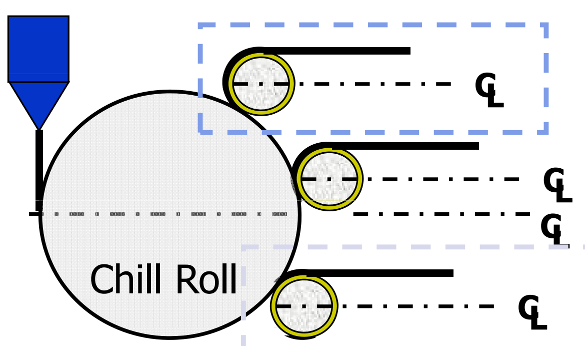




Chill Roll Temperature Setting

- Too Cold produces rapid quench rate
  - Reduced adhesion
  - Roll may sweat in high humidity
- Too Warm produces slower quench rate
  - Polymer may stick to roll
  - Bond issues or tearing with substrate
  - Can wrap chill roll
- Uneven Temperature
  - Poor or uneven strippability
  - Flow marks in product
  - Indication that chill roll may be fouling

Chill Roll Strip Position

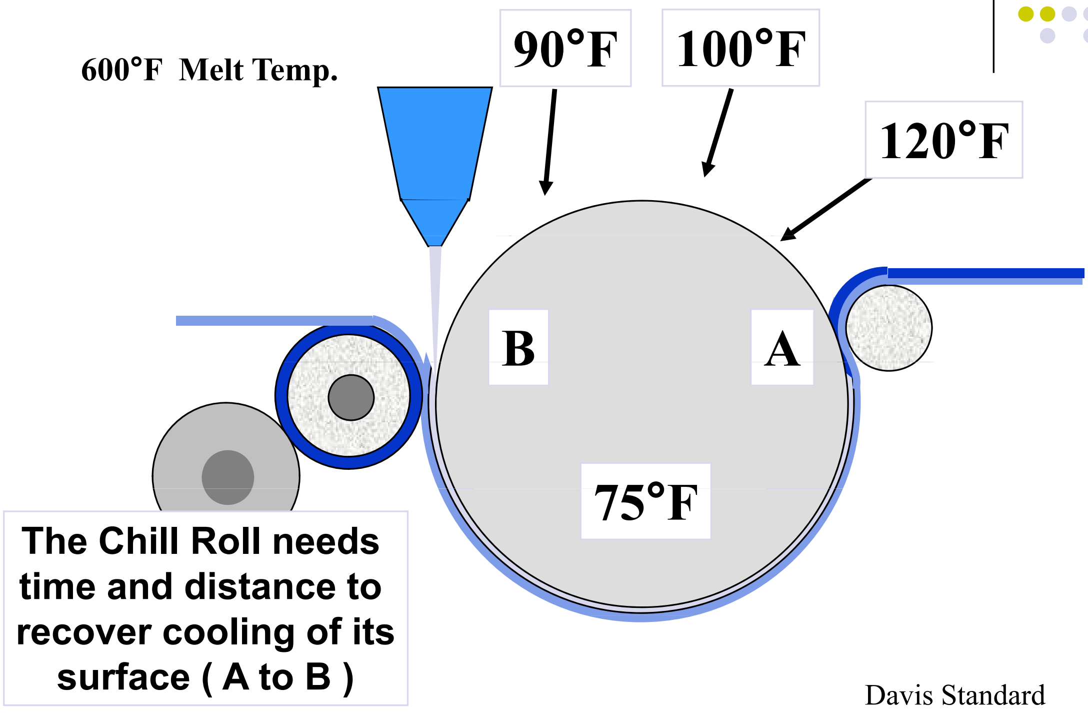


If Roll to High….
…Chill Roll Surface Cannot Recover

If Roll to Low….
...Poor Stripability Resulting in Quality Defects

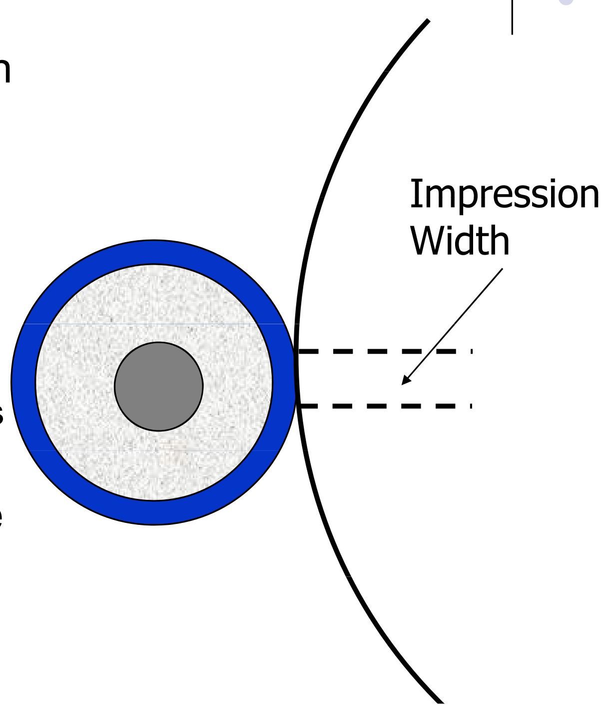
A misaligned or Worn Roll Can Result in Wrinkles in the Product

Chill Roll Recovery



Nip Impression

- Amount of impression determined by:
  - Roll Hardness
  - Roll Diameter
  - Nip Pressure
- Wider nip
  - Improved adhesion
  - For heavier substrates
  - Can create pinholes
- Even nip across the roll is important!!!



Quick Calculation for Chill Water GPM

$$m_w x C_{pw} x \Delta T_w = m_p(C_{pp} x \Delta T_p + hf_p) \text{ x Eff}$$

m_w = Mass Flow Water, lb/hr
C_{pw} = Specific Heat Water, BTU/lb-°F
ΔT_w= Temperature Rise Water, °F

m_p= Extruder Output, lb/hr
C_{pp}=Specific Heat Polymer, BTU/lb-°F
ΔT_p= Temperature Change Polymer, °F
hf_p = heat of Fusion Polymer, BTU/lb
Eff = Effeciency of System

$$\text{GPM} = [(m_p \text{ x } 0.75 \text{ x } \Delta T_p)/(\Delta T_w \text{ x } 500)] \text{ x } 1.2$$

How much water do we need to pump through our chill roll if we have a rate or 1000 lb/hr LDPE, Melt Temperature 600°F, a Strip Temperature of 100°F, and 3°F Water Temperature Rise?

$$\text{GPM} = 1000^{lb}/_{hr}\,(0.55^{BTU}/_{lb\text{-}°F} \text{ x } (600\text{-}100°F) + 0.48^{Btu}/_{lb}) / (1^{BTU}/_{lb} \text{ x } 3°F \text{ x } 480) * 0.7 = 275\text{gpm}$$

$$\text{GPM} = [(1000 \text{ x } 0.75 \text{ x } (600\text{-}100)/(3 \text{ x } 500)] \text{ x } 1.3 = 325\text{gpm}$$

***Assuming Chill roll is of adequate size**
****Increase GPM to allow for Nip and Backing Roll Flow**

Quick Calculation for Cooling Tonnage

$$\text{Ton} = [m_p x 0.75 x \Delta T_p/12{,}000] \text{ x } 1.2$$

M_p = Extruder Output, lb/hr
ΔT_p = Temperature Change Polymer, °F
Ton = Tonnage of Refrigeration required or available at 50°F
1.2 = Efficiency of 80%

How much cooling is required if we are extruding 1000lb/hr of 600°F LDPE with a stripping Temperature of 100°F.

$$\text{Ton} = [1000 \text{ lb/hr x } 0.75 \text{ x } (600\text{-}100)°F / 12{,}000] \text{ x } 1.2 = 37.5 \text{ Ton}$$

Chill Roll Contact Time

Calculate Contact and Recover Time and Length for a Extrusion Line Having a 24 inch Chill Roll with a 220° Wrap at a Line Speed if 500fpm.

$$\textbf{Contact Time, sec} = \frac{\textbf{CR Diameter x Wrap\%}}{\textbf{Line Speed x 22.93}}$$

$$= \frac{24 \times 220}{500 \times 22.93}$$

$$= 0.46 \text{ sec}$$

$$\textbf{Recovery Time,sec} = \frac{\textbf{CR Diameter x (1-Wrap\%)}}{\textbf{Line Speed x 22.93}}$$

$$= \frac{24 \times (360-220)}{500 \times 22.93}$$

$$= 0.29 \text{ sec}$$

Chill Roll Contact Length

Calculate Contact and Recover Time and Length for a Extrusion Line Having a 24 inch Chill Roll with a 220° Wrap at a Line Speed if 500fpm.

$$\textbf{Contact Length,ft} = \frac{\textbf{CR Dia. x Wrap\%}}{\textbf{1376}}$$

$$= \frac{24 \times 220}{1376}$$

$$= 3.84 \text{ ft}$$

Recovery Length,ft = CR Dia. x 3.14/12 – Contact Length

$$= 24\text{x}3.14/12-3.84$$

$$= 2.44 \text{ ft}$$

Troubleshooting – Problems Related to the Laminator

- A problem with it’s causes will be listed
- Solutions are based on what we have gone over in this presentation.
- Audience will give answers by filling out work book as each problem is given.
- Group discussion and review of solutions.

Solutions Workbook

Problem	#1	#2	#3	#4	#5	#6
Solutions						
Increase Air Gap						
Decrease Air Gap						
Chill Roll to Die (Left/Right)						
Increase Chill Roll Temperature						
Decrease Chill Roll Temperature						
Increase Nip Pressure						
Decrease Nip Pressure						
Change Stripper Position						
Chill Roll Fouled (Clean)						
Call Beth						

Problem #1

- Poor Adhesion of Extrudate to base or laminated substrate.
- Due to: Inadequate oxidation only
  - There are two solutions related to the laminator for this problem

Problem #2

- Poor adhesion of the polymer to the substrate.
- Due to: Premature Cooling
  - There are three possible solutions to this problem

Problem #3

- Poor Adhesion of the Polymer to the Substrate
- Due to: Sticking to the Chill Roll
  - There are two possible solutions to this problem

Problem #4

- Excessive Odor
- Due to Over-Oxidation
  - There is one solution relating to the laminator for this problem

Problem #5

- Poor Heat Sealability
- Due to: Over-Oxidation
  - There is one solution related to the laminator for this problem

Problem #6

- Poor Adhesion Across the Web
- Adhesion is good in some areas and poor in others
- Due to: Reduced Thermal Conductivity
  - There are two possible solutions related to this problem and one is tricky!!

Conclusion

- Equipment and Purpose
- Chill Water System Design and Control
- Basics of Process
- Calculations
- Troubleshooting
- Thanks to Optex Process Solutions, LLC