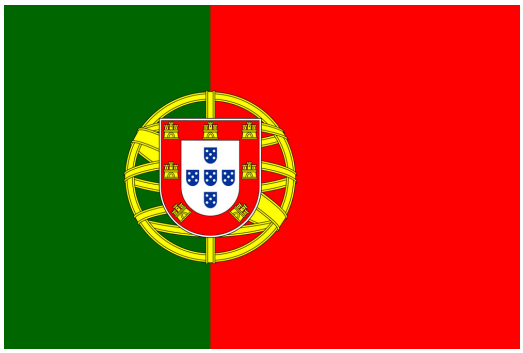

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Effect of Polyolefin Molecular Structure on Product Properties in Extrusion Coating

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OUTLINE

- Objectives
- Materials and Methods
- Results
  - Neck-in
  - Draw Down Ratio
  - Velocity profiles in Air Gap and at Die Exit
  - WVTR properties
- Conclusions

OBJECTIVES

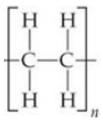
- Compare autoclave LDPE, cyclic olefin copolymer (COC) and their blends in extrusion coating (EC)
- Apply the same EC processing set-ups for all the materials
- Study effect of polyolefin molecular structure on melt flux in air gap region
- Evaluate coating properties

MATERIALS

Polyolefins

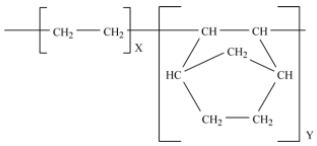
I **Autoclave LDPE**

- Density = 923 kg/m^3
- Melt density = 760 kg/m^3
- MFI at 190°C/2.16 kg = 4.5 g/10 min
- Degree of branching:
  - High long chain branching
- Chemical structure:



II Cyclic olefin copolymer (COC)

- Density = 1010 kg/m^3
- Melt density = 920 kg/m^3
- MVR at 190°C/2.16 kg = 2.0 cm^3/10 min
- Degree of branching:
  - Basically none
- Chemical structure:



MATERIALS

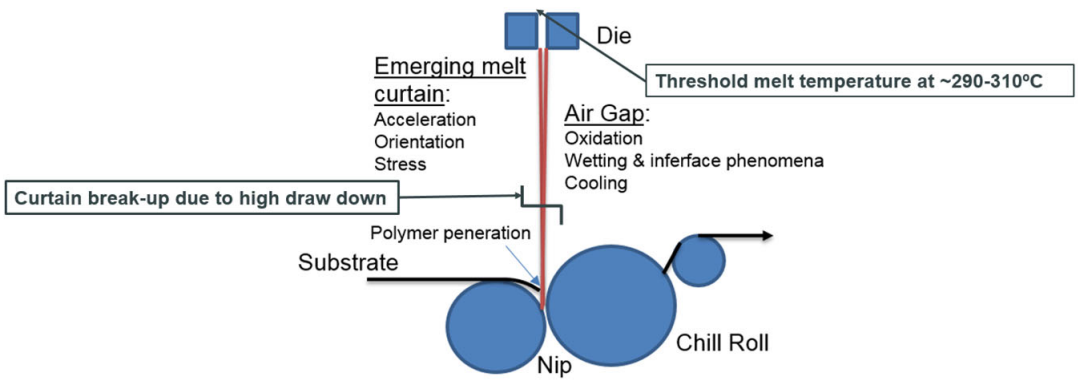
Material Recipes in EC

Material	Code	Composition	Density	Melt density	Specific throughput
		[wt-%]	[kg/cm³]	[kg/cm³]	[kg/(h·rpm)]
Autoclave LDPE	LDPE100	100	923	760	0.62
Blend 1 of LDPE and COC	LDPE80/COC20	80 + 20	941[A]	787[A]	0.65
Blend 2 of LDPE and COC	LDPE20/COC80	20 + 80	999[A]	883[A]	0.67
Cyclic olefin copolymer COC	COC100	100	1010	920	0.66

[A] Calculated value based on the rule of mixtures.

METHODS

Extrusion Coating Trial Principle



METHODS

Pilot Line and Laboratory Measurements

- Specific throughput (PT)
- Neck-in (NI)
- Draw down ratio (DDR)
- Optical microscopy with polarization
- Water vapor transmission rate (WVTR)

METHODS

Melt Velocity Equations

TIAG

$v = v_L$ (1)

Newtonian

$v = v_o DDR^{z/L}$ (2), where

v = Melt velocity [m/min]
$v_f = v_L$ = Line speed [m/min]
v_0 = Melt velocity at die exit [m/min]
L = Air gap [mm]
z = Distance from die exit [mm]
DDR = Draw down ratio

METHODS

Process Time Equations

$$t_f = TIAG = \frac{L}{v_f} \qquad (3)$$

$$t_f^{Newtonian} = \frac{L}{v_f}\left(\frac{DDR-1}{ln(DDR)}\right) \qquad (4), \text{ where}$$

L = Air gap [mm]
v_f = Line speed [m/min]
DDR = Draw down ratio

METHODS

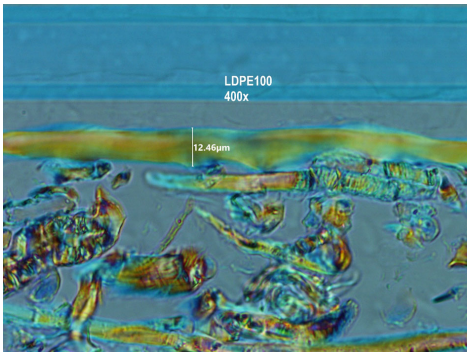
Water Vapor Transmission Rate Test

- **Coated cardboard samples tested according to the standard ASTM E96/E96M – 10**
- **Gravimetric test method (desiccant and water)**
- **Test conditions:**
  - **T = 23°C**
  - **RH = 50 %**
  - **N = 5 parallel samples**

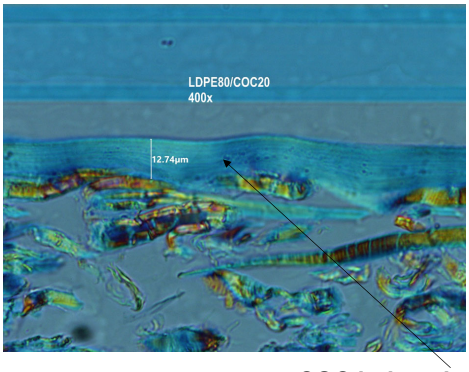
RESULTS

Optical Micrographs (400x)

LDPE100



LDPE80/COC20

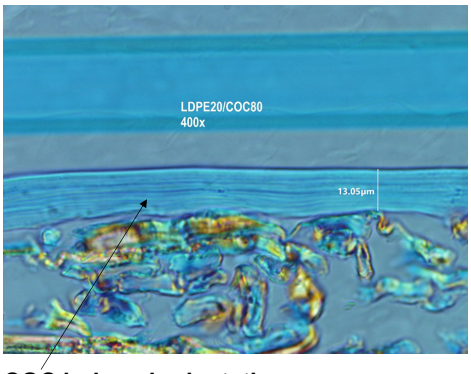


COC induced orientation

RESULTS

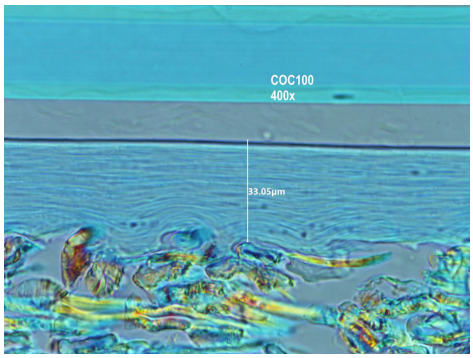
Optical Micrographs (400x)

LDPE20/COC8



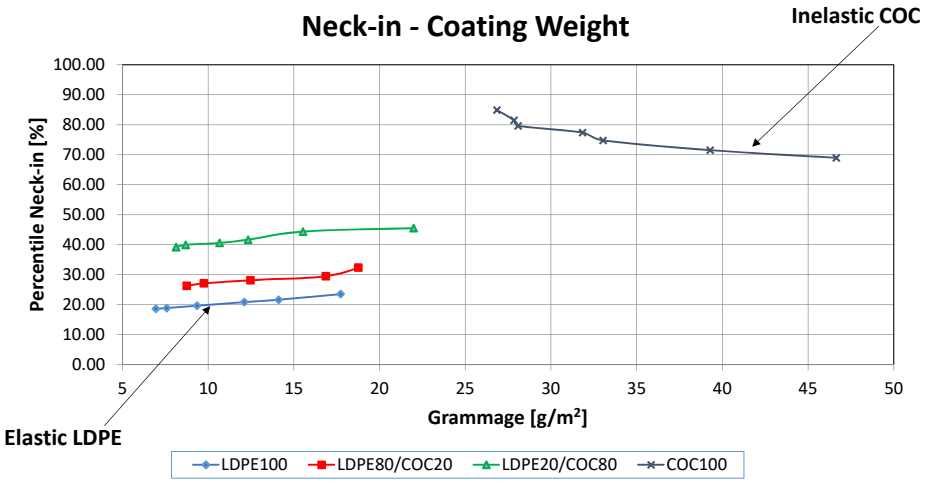
COC induced orientation

COC100



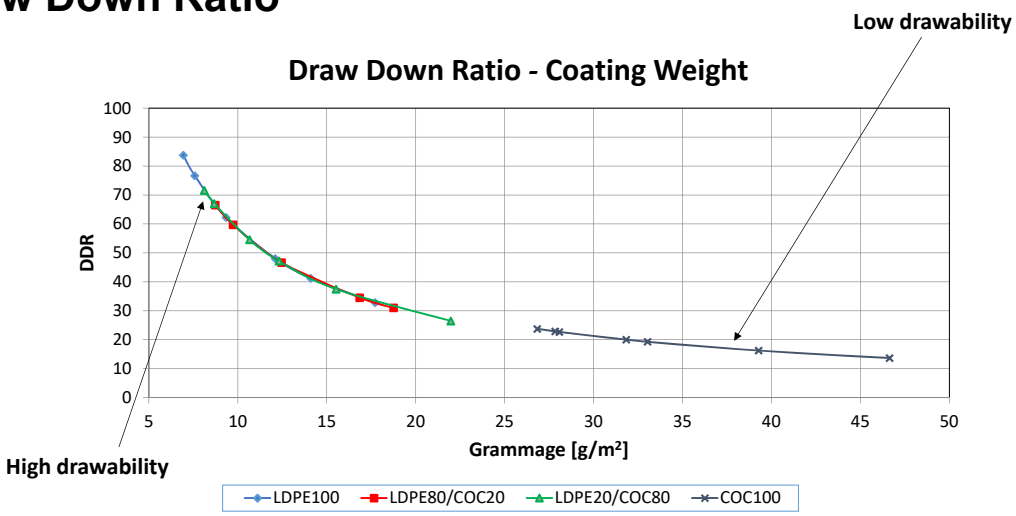
RESULTS

Neck-in



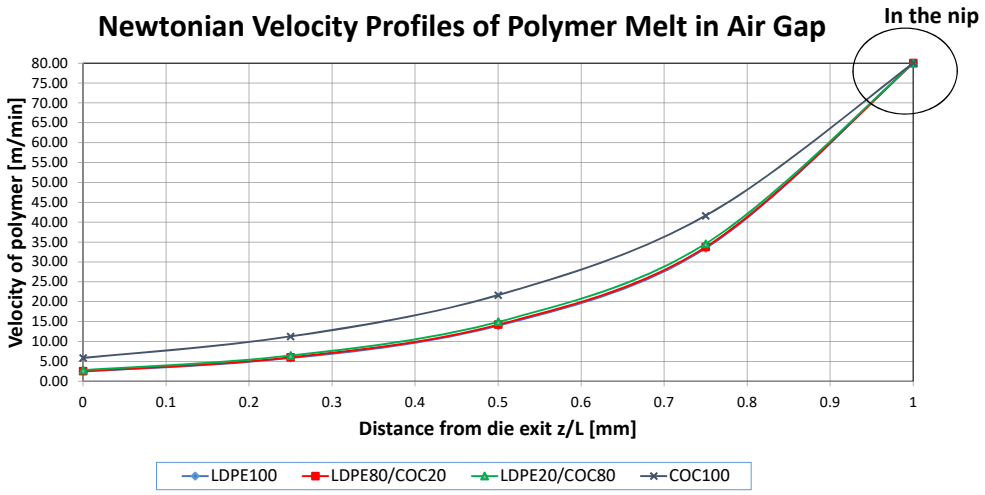
RESULTS

Draw Down Ratio



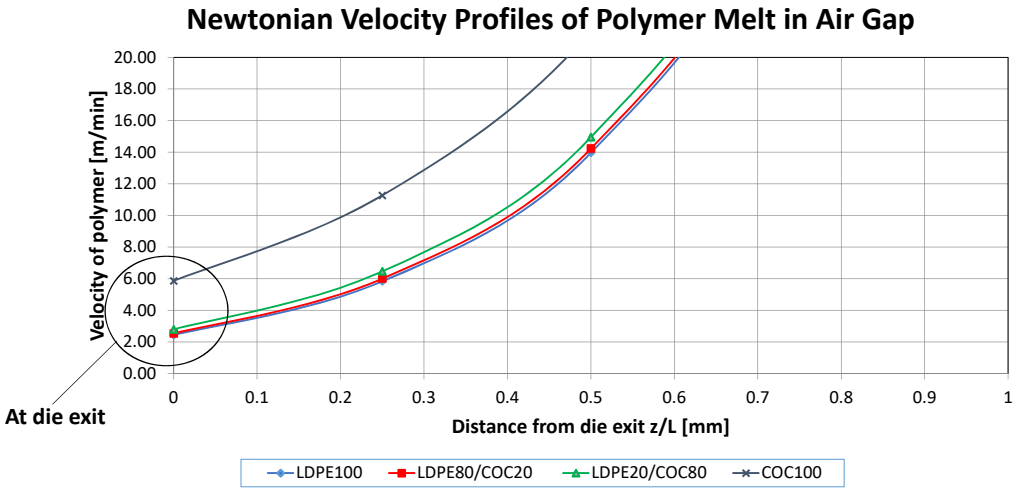
RESULTS

Velocity Profiles in Air Gap



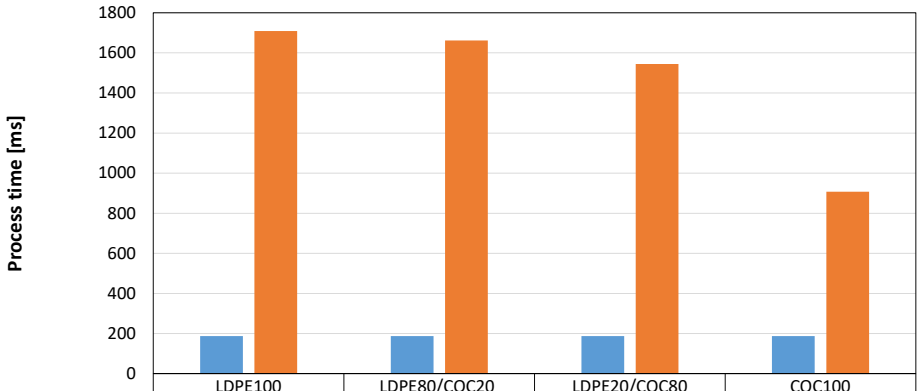
RESULTS

Velocity Profiles at Die Exit



RESULTS

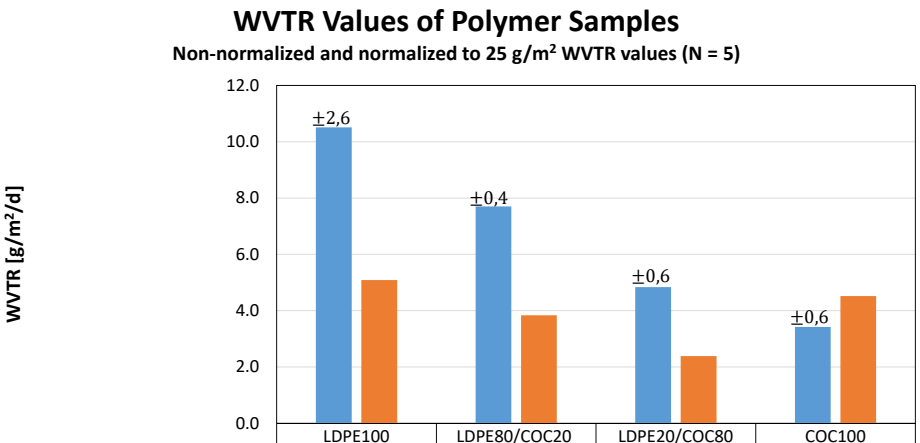
Process Times



	LDPE100	LDPE80/COC20	LDPE20/COC80	COC100
TIAG [ms]	188	188	188	188
Newtonian [ms]	1709	1662	1545	907

RESULTS

Water Vapor Transmission Rate



	LDPE100	LDPE80/COC20	LDPE20/COC80	COC100
Non-normalized WVTR [g/m2/d]	10.5	7.7	4.8	3.4
Normalized WVTR [g/m2/d]	5.1	3.8	2.4	4.5

CONCLUSIONS

- Highly branched LDPE is elastic in flowing conditions
- COC is practically inelastic in flowing conditions
- COC is enhancing flowability of molten LDPE
- COC is improving water vapour barrier properties of LDPE coatings
- Newtonian model enables to analyze the flow behaviour of accelerating polymer melts in the air gap region

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"Thank You"
for your patience

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