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Processing and Properties of Biaxially Oriented Polypropylene-Based Nanocomposites

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Context and Objectives

- Several applications for PP-based nanocomposites:
 - injection molded products
 - extruded cast sheets
 - thermoforming parts
 - bottles
 - blown films, etc.
- Assess the processability of PP-based nanocomposites using a laboratory biaxial stretcher:
 - effect of blend formulation on processability and performance
 - establish structure-process-property relationships

Materials

Matrices

- Polypropylene from Basell
 - Profax PDC1274 (injection grade)
 - Profax HL451H (extrusion grade, BOPP)

Coupling agents

- Polybond 3150 and S192 from Chemtura
- Epolene 3015 from Eastman

Clays

- Cloisite 15A from Southern Clay

PP matrix (PDC1274)

comp. uncomp.		% Clois
	PPNC1-2	2
	PPNC1-4	4
	PPNC2-2	2
	PPNC2-4	4

HPP matrix (HL451H)

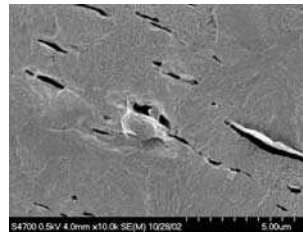
	% Clois
HPPNC1-2	2
HPPNC1-4	4
HPPNC2-2	2
HPPNC2-4	4

Blends (2 and 4 wt.% clay)

	% Clay
PPNC1-2	2
PPNC2-4	4
PPNC1-2	2
PPNC2-4	4

} Poor dispersion
d = 2.86 nm

} Good dispersion
d = 3.55 nm



Outline

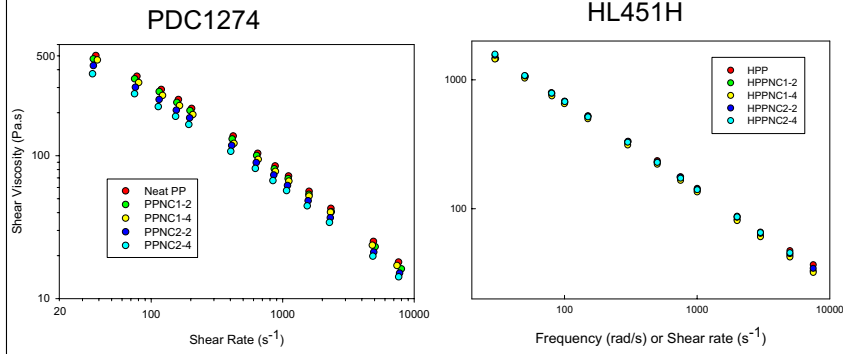
Processing

- cast extrusion
- thermoforming
- biaxial stretching
- injection molding

Characterization

- rheology
- thermal properties
- mechanical properties
- X-Ray, FTIR

Capillary Rheology at 200°C



- higher viscosity for HL451H matrix
- adding clay lowers viscosity
- no significant effect of clay on flow properties at high shear rates

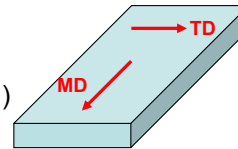
Cast Sheet Extrusion

RandCastle Cast film Line

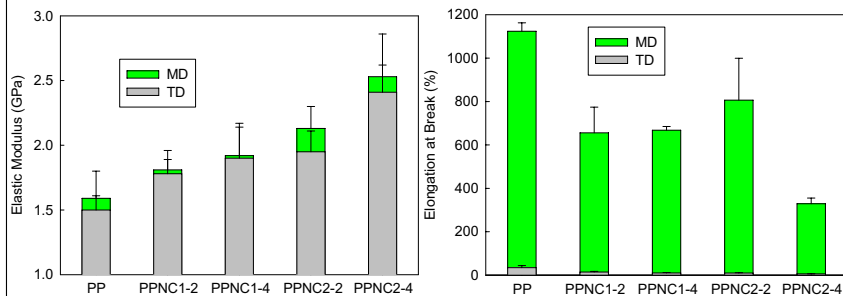
- equipped with flat die
 - width: 20 cm
 - film thickness ~ 1 mm
- operating conditions
 - melt temperature: 185°C for PP, 200°C for HPP
 - 100 rpm
 - rolls temperature: 30°C



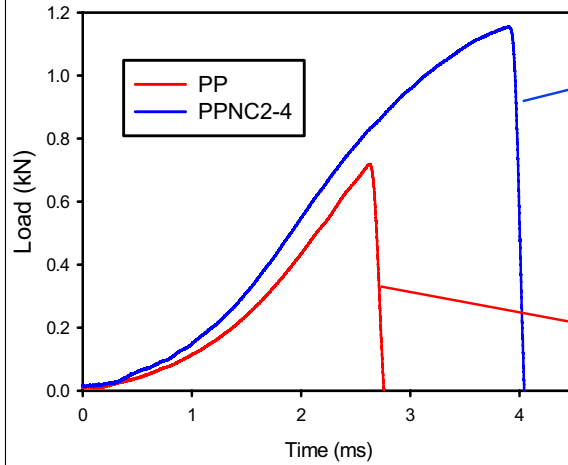
- tensile properties on rectangular strips (D-882)



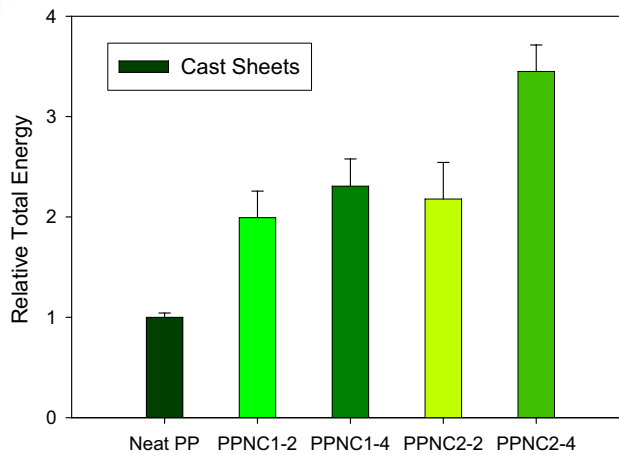
Mechanical Properties Cast sheets



Instrumented Impact Cast Sheets (Dynatup)



Instrumented Impact (Dynatup)



E_{total} for neat PP (1 mm) \approx 2 J

Brückner Laboratory Biaxial Stretcher

Initial film thickness:

20 to 2000 μ m

Min. sample dimension:

85 x 85 mm

Max. draw ratio:

10:1 both axis

Max. draw speed:

0.5 m/s

Drawing:

sequential or simultaneous

Max. force:

2000 N

Max. temperature:

250°C

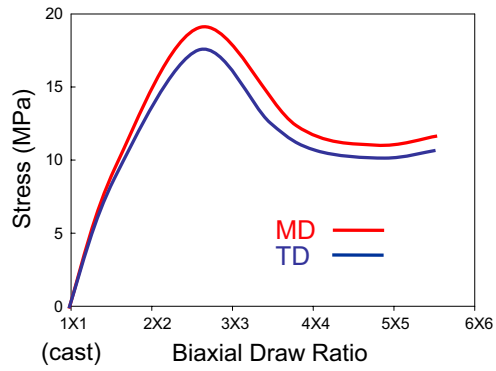


Brückner Laboratory Biaxial Stretcher

Drawability results

Maximum biaxial draw ratio

Maximum stress

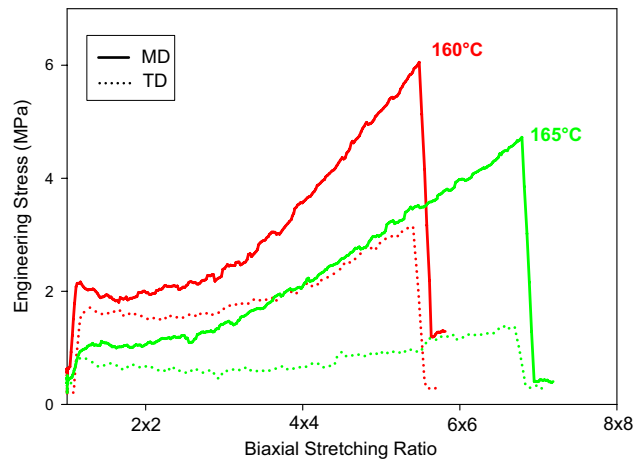


Used to simulate industrial processes

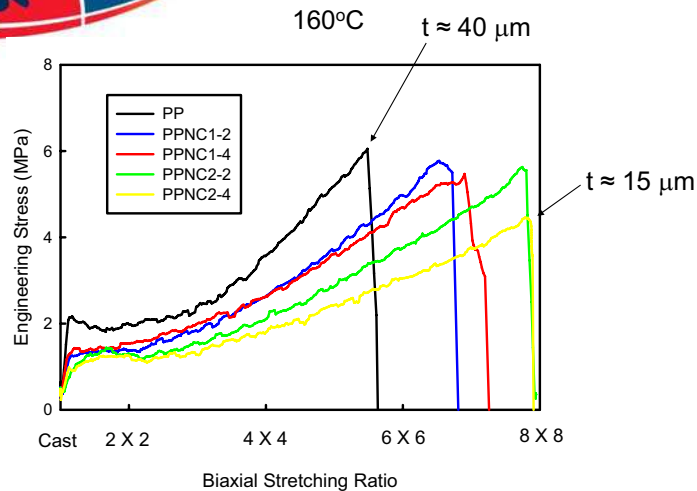
Double-bubble, tenter frame (biaxial orientation), thermoforming, machine direction orientation (MDO)

Biaxial Stress-Strain Curves: effect of temperature

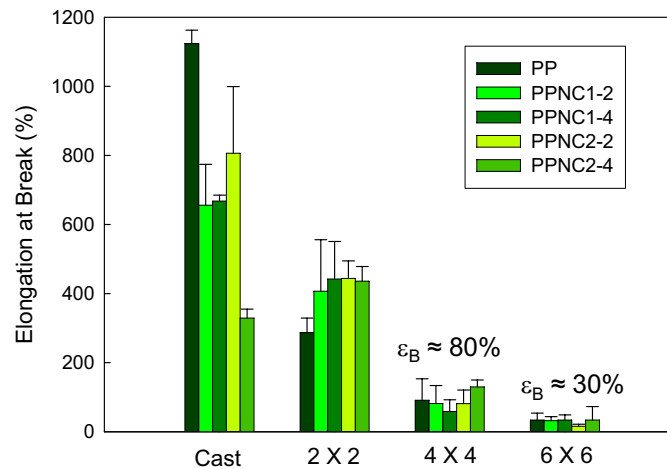
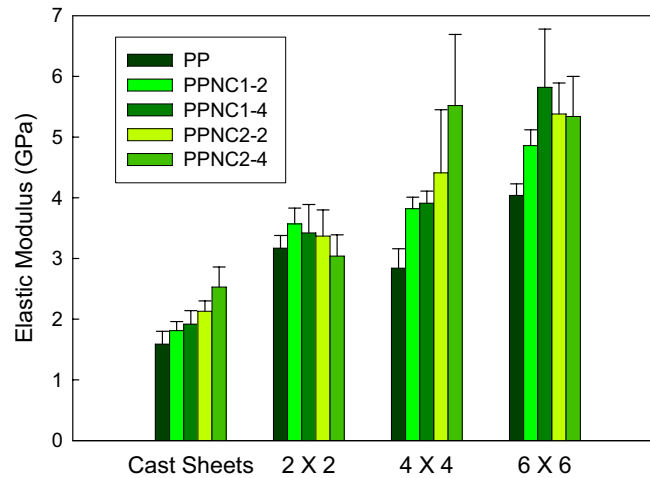
PP 1274 matrix, initial thickness of 1 mm



Biaxial Stress-Strain Curves: effect of clay and compatibilization



• effect of adding clay and compatibilization:
increased draw ratio & lower drawing stress



Cast sheets

- addition of clay reduces viscosity
- tensile modulus and strength of nanocomposites higher than or similar to neat PP (values similar in both MD and TD)
- elongation at break drops with clay content; significant differences between MD and TD
- impact resistance of nanocomposite cast sheets higher than neat PP

PP-based nanocomposite biaxial films

- Biaxial processability was addressed:
 - significant effect of temperature
 - high biaxial draw ratios can be obtained (increased by addition of clay)
- Tensile properties affected by increasing biaxial draw ratio:
 - properties are balanced in MD and TD compared to cast sheets
 - with addition of clay, modulus increases and strength decreases slightly
 - improved tensile modulus and strength with increasing draw ratio, but lower elongation at break