International Conference on Nanotechnology for Renewable Materials

Production of Translucent Films from Cellulose Filaments for Packaging Applications

Part 2: Manufacturing Process

François Drolet, Rafik Allem, Sylvie St-Amour, Tony Manfred

FPInnovations

TAPPI NANO DIVISION

12-16 JUNE 2023 • VANCOUVER, B.C. CANADA

Outline

- Background & Approach
- Production of CF films on pilot paper machines (PM)
    - Twin-wire PM at FPInnovations
    - Top-former PM at Innofibre
- Impact of calendering & surface treatment
- Converting trial
- Summary

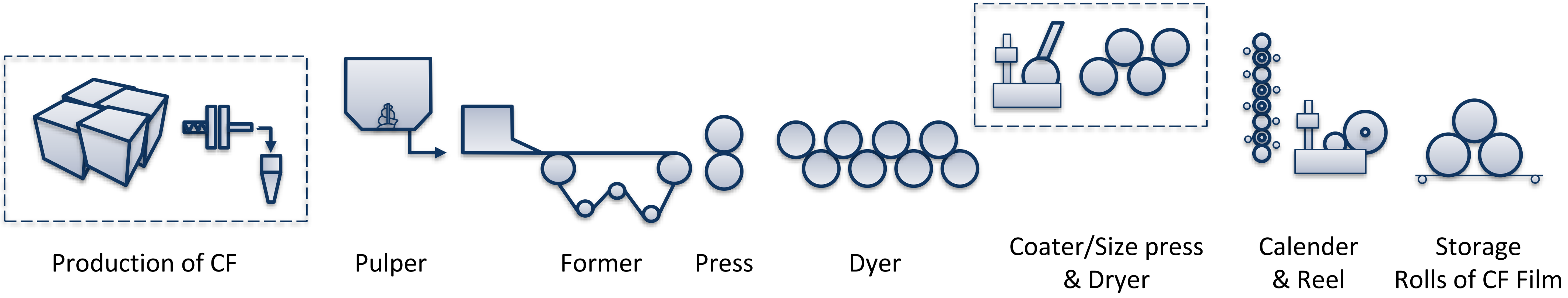
Background and Approach

- Objective
  - To develop a paper-based alternative to plastic films to make translucent packaging products that are repulpable, recyclable and compostable
- Rationale
  - Market pull from converters and brand owners
  - Patented Cellulose Filaments (CF) technology using papermaking approach
  - Promising barrier properties obtained in laboratory trials
- Stepwise approach
  - Start with applications having fewest requirements and focus on scale-up
  - Move to applications requiring barrier properties and/or heat-sealability

Process for Making Translucent CF Film on a Paper Machine

- Large-scale manufacturing process for making a repulpable thin film of grammage from 15 to 40 g/m²
- Dry films of 100% CF are redispersible in water
    - Rolls of CF film can be shipped in dry form to mill sites where they can be repulped and added to existing furnishes for reinforcement purposes

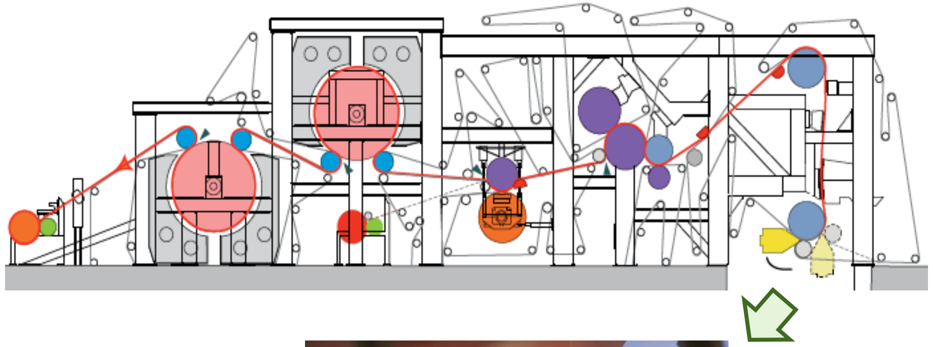
➢ For packaging applications, the optical, mechanical and barrier properties of the CF film need to be optimized. Film uniformity is also critical

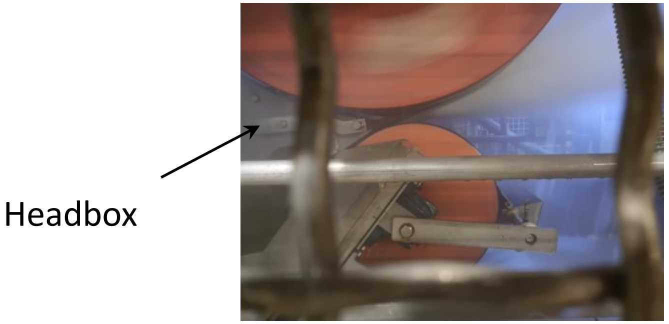


CF Film Production: Twin-Wire with Yankee Dryers

Operating conditions for CF film production:

- **Speed:** 400-450 m/min
- **Web width:** ~30 cm
- **Target grammage (O.D.) :** 15-22 g/m^2
- **Forming section:** Large forming roll, 90˚ wrap
- **Headbox consistency:** 0.4-0.6%
- **J/W ratio:** 1.2 to 1.4
- **Press section:** Tri-nip and shoe presses
- **Drying section:** Two 10-foot Yankee dryers and post-dryer





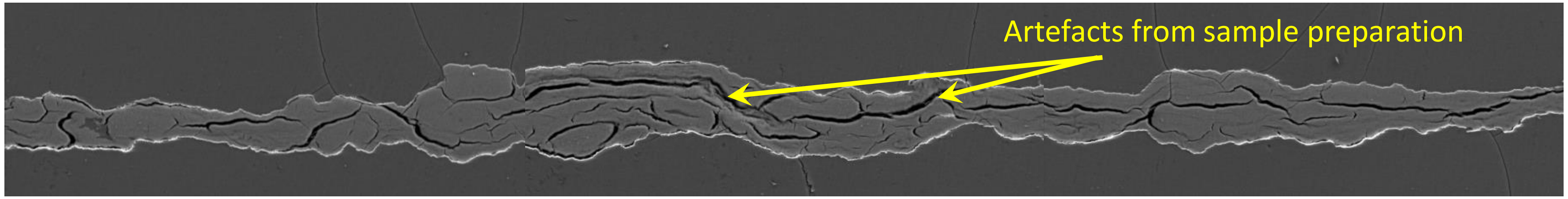
CF Film Production: Top-Former with Dryer Cans

Operating conditions for CF film production:

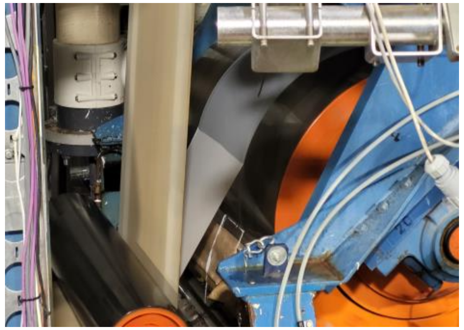
- **Speed:** 200 m/min
- **Web width:** ~35 cm
- **Target grammage (O.D.) :** 19-35 g/m^2
- **Forming section:** Fourdrinier table with top-former
- **Headbox consistency:** 0.4-0.6%
- **J/W ratio: ~1.0**
- **Press section:** bi-nip, jumbo and shoe presses
- **Drying:** three sections, 28 dryer cans in total

CF Film Production: Challenges & Solutions

Challenge	Mitigation measures
▪ CF drains very slowly	▪ Reduce machine speed ▪ Increase vacuums ▪ Optimize forming fabric ▪ Add kraft pulp to furnish
▪ Web sticks to rollers and felts	▪ Increase draws ▪ Apply lubricant on rollers
▪ Picking at top former	▪ Reduce grammage
▪ Presence of pinholes in sheet	▪ Improve formation, optimize drying & press sections
▪ Uneven sheet formation	▪ Optimize forming section and fabric

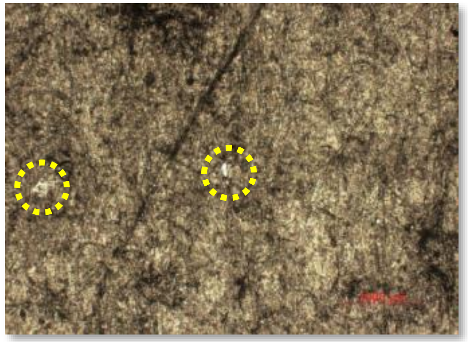


Cross-sectional view of a CF film produced on PM, exhibiting non-uniform mass distribution



CF film sticking to a granite roller

CF film sticking to a felt



Pinholes in CF film

Properties of Translucent Films Produced on Pilot PM

	Top-former		Twin-wire
	100% CF	**85% CF, 15% SWK**	**100% CF**
Grammage (g/m^2)	21.6	31.1	19.9
Tensile Strength (MD|CD, kN/m)	2.3 | 0.3	3.9 | 0.5	2.5 | 0.5
Elongation at break (MD|CD, %)	1.6 | 1.9	2.2 | 2.0	1.7 | 1.3
Tear Strength (MD|CD, mN)	68 | 111	124 | 220	65 | 121
Opacity* (%)	16.1	18.7	17.2
Transmittance (%)	82	81	-
Haze (%)	70	74	-

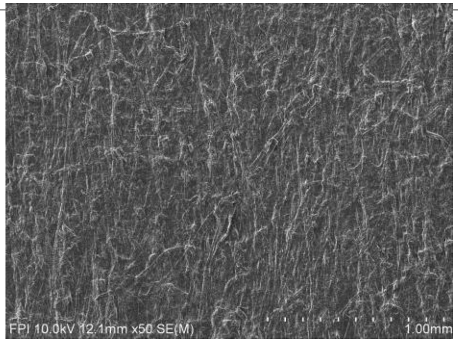
* R_∞ measured with single sheet over white backing; Calendering conditions: Temperature: 150˚C; Pressure: 250 kN/m; 2 passes

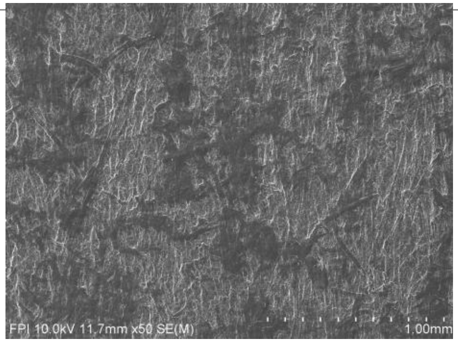
- CFs differing in terms of fibre source and refining energy were used on the twin-wire and top-former PMs
- Strength properties of films produced on PM are lower than those of corresponding handsheets
- MD/CD tensile ratio is generally high
  - Likely due to high draws on the paper machine and shrinkage during drying
  - On top-former PM, J/W ratio was found to have little impact on MD/CD ratio

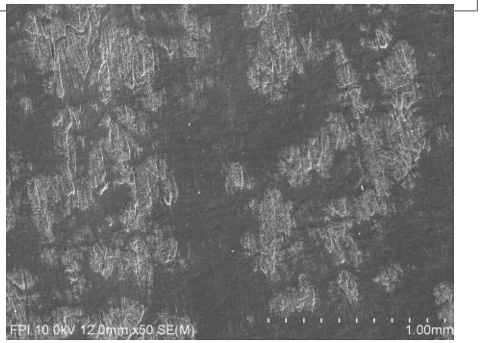
Effect of Calendering Conditions

- Calendering improves optical properties:
  - In particular, opacity drops by more than 5 percentage points
  - Higher gains in optical properties are achieved with hard-nip calendering
- Mechanical properties are negatively impacted by hard-nip calendering

100% CF Films	Uncalendered	Soft-nip Calendered	Hard-nip Calendered
Cal. Load (kN/m)	-	250	250
Cal. Temp (˚C)	-	150	90
Opacity (%)	22.2	16.1	15.0
Transmittance (%)	82	82	84
Haze (%)	71	70	58
Tensile Index (MD, N·m/g)	109	107	83
Tensile Index (CD, N·m/g)	16.0	15.4	9.5







Surface Application of Starch on Pilot Flexo Coater

- Grammage of CF film: 19.8 g/m², produced on twin-wire PM
- Conditions of surface application:
  - Coat weight ~ 1.4 g/m² on each side
  - Three coating units (conventional & slalom channel engraved geometry)
  - Hot air drying: 2 dryers at 60°C + 3 dryers at 80°C + chiller. Speed: 10 m/min
- No web breaks during trial

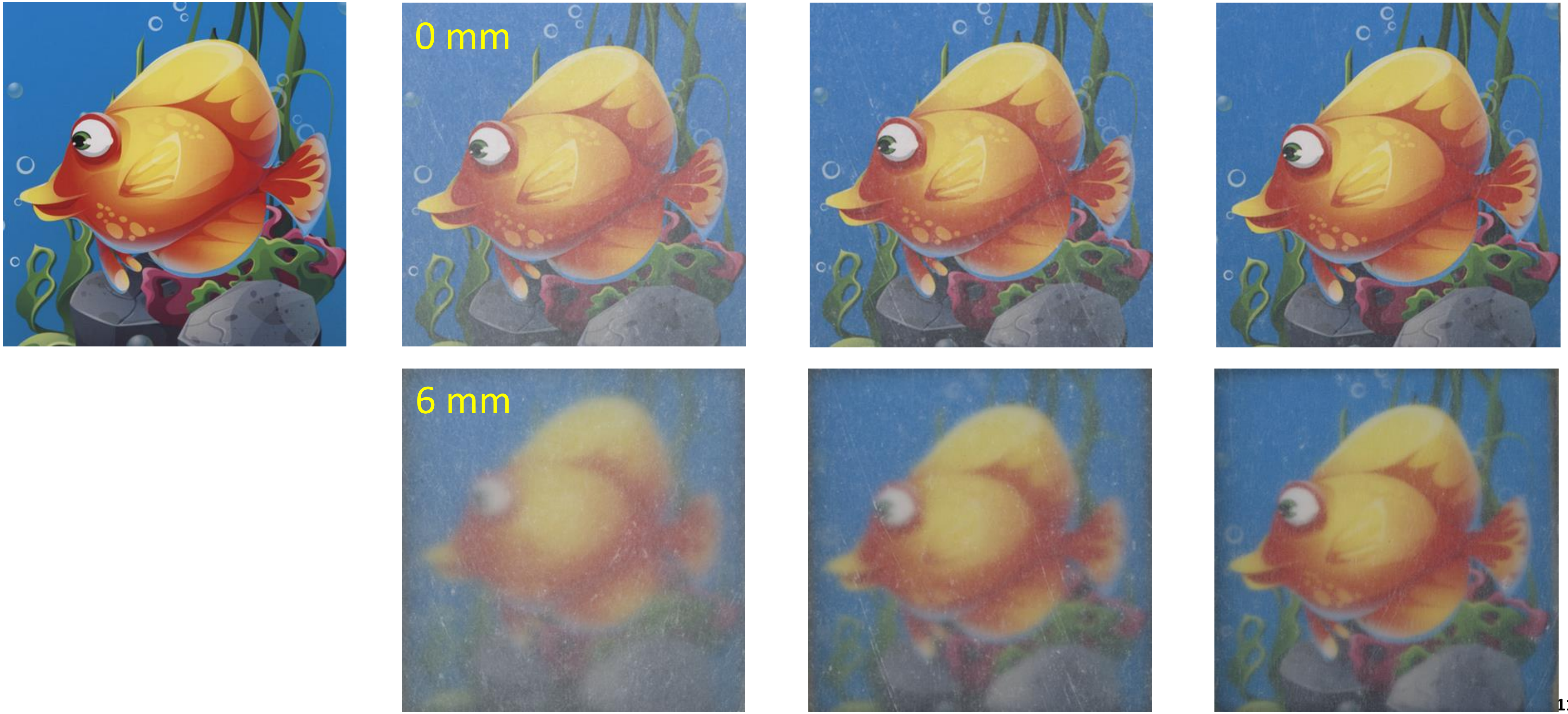
100% CF Films	Uncoated		Coated	
Calendering	**Before**	**After**	**Before**	**After**
Opacity (%)	20.0	16.7	13.9	10.5
Transmittance (%)	86	73	88	88
Haze (%)	82	85	74	47

Flexo printing/coating station

- Significant improvement in haze with starch application as compared to calendering alone

Visual Assessment of Transparency and Haze

Original image	Covered with film from PM	Covered with coated film	Covered with coated & calendered film

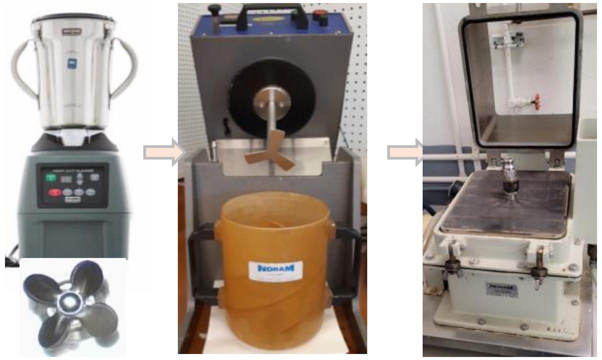


Barrier Properties & Sustainability Aspects

- Grease resistance of 100% CF films (~20 g/m²)
  - Kit test of 12
  - Cobb test with castor oil
    - ✓ 1.8 g/m² for calendered CF film
    - ✓ 0.8 g/m² for starch coated & calendered films

- Small improvement in water resistance was obtained by addition of AKD

- No resistance to oxygen
  - Likely due to uneven mass distribution in the sheet



- Uncoated and starch-coated CF films are repulpable
  - Test based on the Fiber Box Association (FBA) Voluntary Standard
  - Rejects << 1%

- CF film has 100% bio-based carbon content
  - USDA Certified Biobased Product

Window Bag Converting Trial

- Calendered CF film was successfully substituted for a PET window in a bread bag product

- Converting trial was conducted on commercial equipment
  - Minor adjustments were made at start-up on perforating unit
  - Machine speed: 140 bags/minute; no breaks

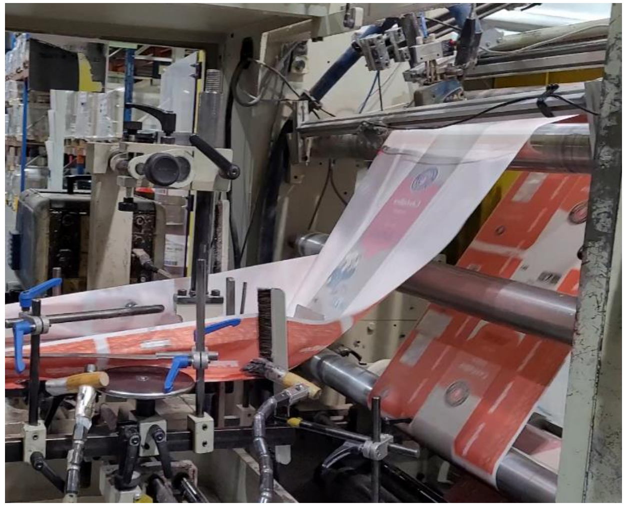
- Very good adhesion between paper and film; good flexo print quality

Unwinding

Gluing to paper

Printing

Folding



Finished product

Summary

- Translucent CF films of various grammages can be produced under stable conditions on high-speed paper machines
  - 8-hour CF film production run was recently completed without any web breaks on Fourdrinier PM
  - Key challenges: slow drainage, strong web adhesion to rollers and felts, uneven formation

- Surface treatment & calendering are effective at enhancing optical properties
  - Surface texture and roughness are key factors controlling optical properties
  - Hard-nip calendering provides high gains in optical properties but negatively impacts strength
  - Coating imparts significant improvement in transmittance and haze

- CF film was successfully converted into a window bag on commercial equipment
  - Potential of CF film for use in various flexible packaging applications

François Drolet
francois.drolet@fpinnovations.ca
514-782-4630

Rafik Allem
rafik.allem@fpinnovations.ca
514-782-4555

Shaune Hanley
shaune.hanley@resolutefp.com
514-953-8970

Gurminder Minhas
gminhas@performancebiofilaments.com
604-786-9586