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Injection-molded composites based on recycled carbon fibers and natural fibers

Mihai, Mihaela; Stoeffler, Karen; Lee, Ellen; Lobo, Harry; Houston, Dan

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Injection-Molded Composites Based on Recycled Carbon Fibers and Cellulosic Fibers

Mihaela Mihai & Karen Stoeffler
Automotive and Surface Transportation, National Research Council Canada

Ellen Lee, Harry Lobo & Dan Houston
Ford Motor Company

Plastic-in-Motion, 4-7 June, 2017

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Canada

Presentation content

- ✓ About NRC
- ✓ Objectives
- ✓ Composite Design & Performances
- ✓ Lightweighting by Injection-foaming at Laboratory Scale:
  - ➢ Use of Chemical Blowing Agents
  - ➢ Use of Physical Blowing Agent - MuCell Technology
- ✓ Lightweighting by Injection-foaming at Industrial Scale
  - ➢ Use of Chemical Blowing Agents
- ✓ Conclusions



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Fleet Forward 2020



Advanced Manufacturing



Polymer and Composite Products Manufacturing



Design Systems



Rail Vehicle Track Optimization

Technical areas:

1. High-volume high-performance composites
2. Advanced composites manufacturing efficiency
3. Bio-refineries and sustainable manufacturing
4. Value-added processing and polymer products

Main objective

- To develop thermoplastic composites based on polypropylene (PP) and polyamide 6 (PA6) reinforced with **recycled carbon fibers (rCF)** and **cellulosic fibers** for use in the fabrication of injection-molded automotive components.

PP-based part
Central Console





PA-based part
EcoLon Engine Covers





Image Courtesy of Ford Motor Company

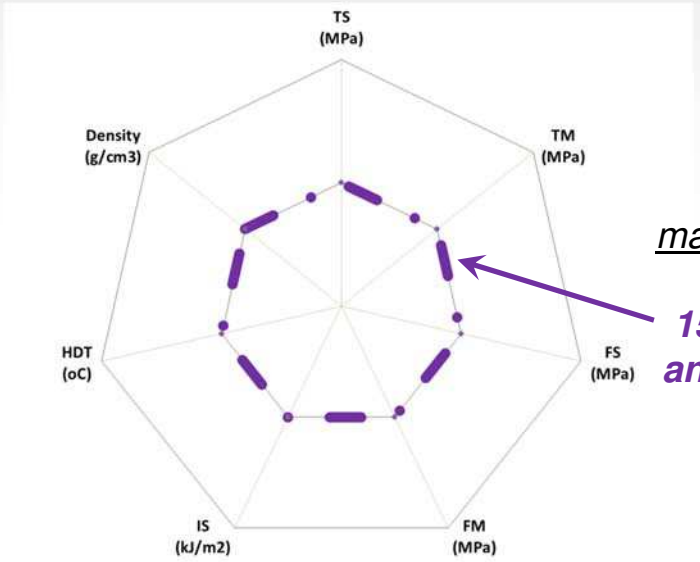
To develop sustainable biocomposites containing combinations of rCF / cellulosic fibers which compete with and would replace Ford composite grades such PP & PA6 minerals filled or glass fibers reinforced currently used in interior applications.

Specific objectives & Targeted properties

Specific objectives:

To develop new materials that:

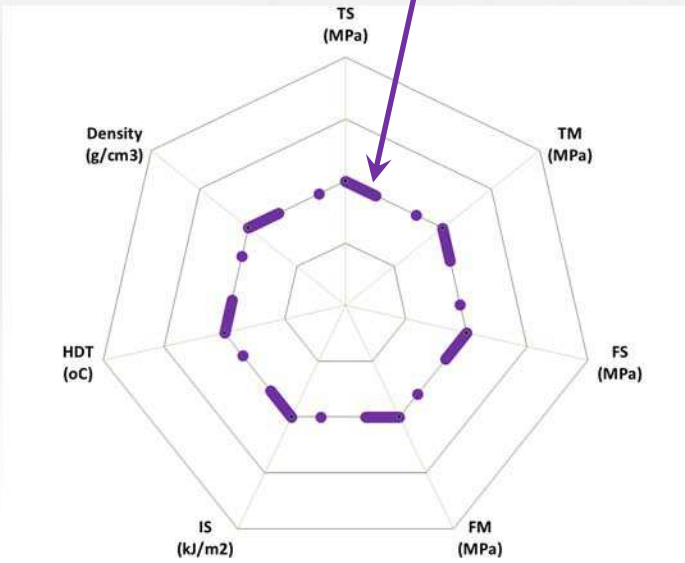
- ✓ Integrate up to 40 % recycled and/or renewable content;
- ✓ Have a good balance of properties (mechanical performance, thermal performance and dimensional stability);
- ✓ Are up to 10 % lighter than conventional reference materials;
- ✓ Have neutral cost than conventional reference materials;
- ✓ Durable and recyclable.



Ford current PA6 material to be replaced:
PA6 containing 15 wt.% glass fibers and 25 wt.% minerals

Targeted properties:

Ford current PP material to be replaced:
PP containing 20 to 30 wt.% glass fibers

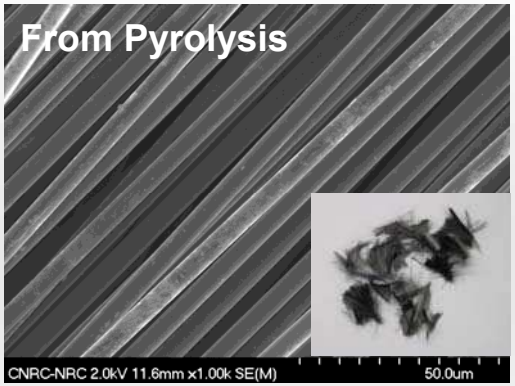


All following graphs contain as reference the purple line representing the properties of Ford material

Selection of Carbon Fibers and Cellulosic Fibers

Recycled Carbon Fibers (rCF)

Carbon Conversions



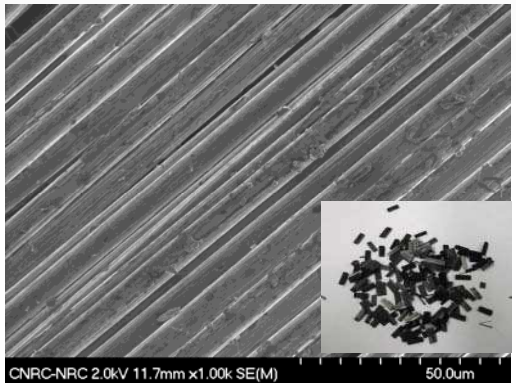
L = 13 mm, D = 5.1μm, No sizing



L = 6 mm, D = 4.9 μm, Mix of sizings

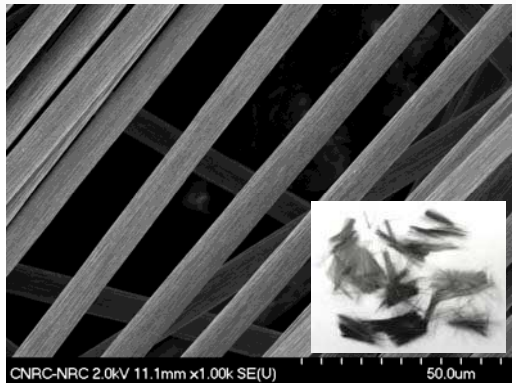
Virgin Carbon Fibers (vCF)

TohoTenax



L = 5.8 mm, D = 6.9 μm, Sized for PP & PA

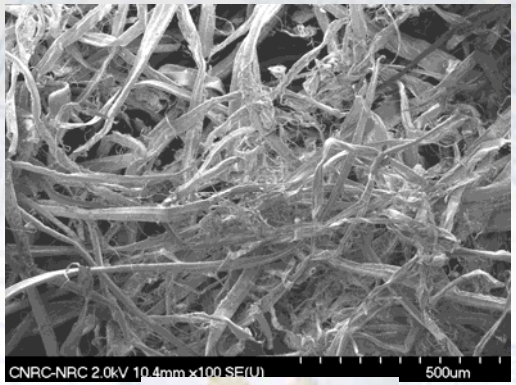
Zoltek



L = 13 mm, D = 8.1 μm, Sized for PP & PA6

Cellulosic Fibers

Thermomechanical Pulp (TMP), Papier Masson, White Birch





L = 1.8 mm, D = 23 μm

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Formulations of PP Composites

Development of PP / 30 wt.% (rCF+TMP) formulations

Variation of rCF & vCF grades and combinations with TMP

FIBER TYPE & CF/TMP combinations

COMPOUNDED FORMULATIONS



rCF, pyrolysis, Carbon Conversions

		PP	Fiber Pellets: Mixture		CA1
		wt.%	wt.% rCF	wt.% TMP	wt.%
Pellets rCF/TMP	25% rCF / 75% TMP	X	7.5	22.5	Y
	50% rCF / 50% TMP	X	15	15	Y
	75% rCF / 25% TMP	X	22.5	7.5	Y



rCF, post-industrial waste, Carbon Conversions

		PP	Fibers		CA1
		wt.%	wt.% rCF	wt.% TMP pellets	wt.%
Pellets of TMP	0% rCF / 100% TMP	X	0	30	Y
Unpelletized rCF	25% rCF / 75% TMP	X	7.5	22.5	Y
	50% rCF / 50% TMP	X	15	15	Y
	75% rCF / 25% TMP	X	22.5	7.5	Y
	100% rCF / 0% TMP	X	30	0	Y



vCF, virgin, PP sized, Zoltek

		PP	Fibers		CA1
		wt.%	wt.% vCF	wt.% TMP pellets	wt.%
Pellets of TMP					
Unpelletized vCF	50% vCF / 50% TMP	X	15	15	Y



vCF, virgin, PP sized, Toho Tenax

		PP	Fibers		CA1
		wt.%	wt.% vCF	wt.% TMP pellets	wt.%
Pellets of TMP					
Unpelletized CF	50% vCF / 50% TMP	X	15	15	Y

CA1 = coupling agent for PP / fibers adhesion

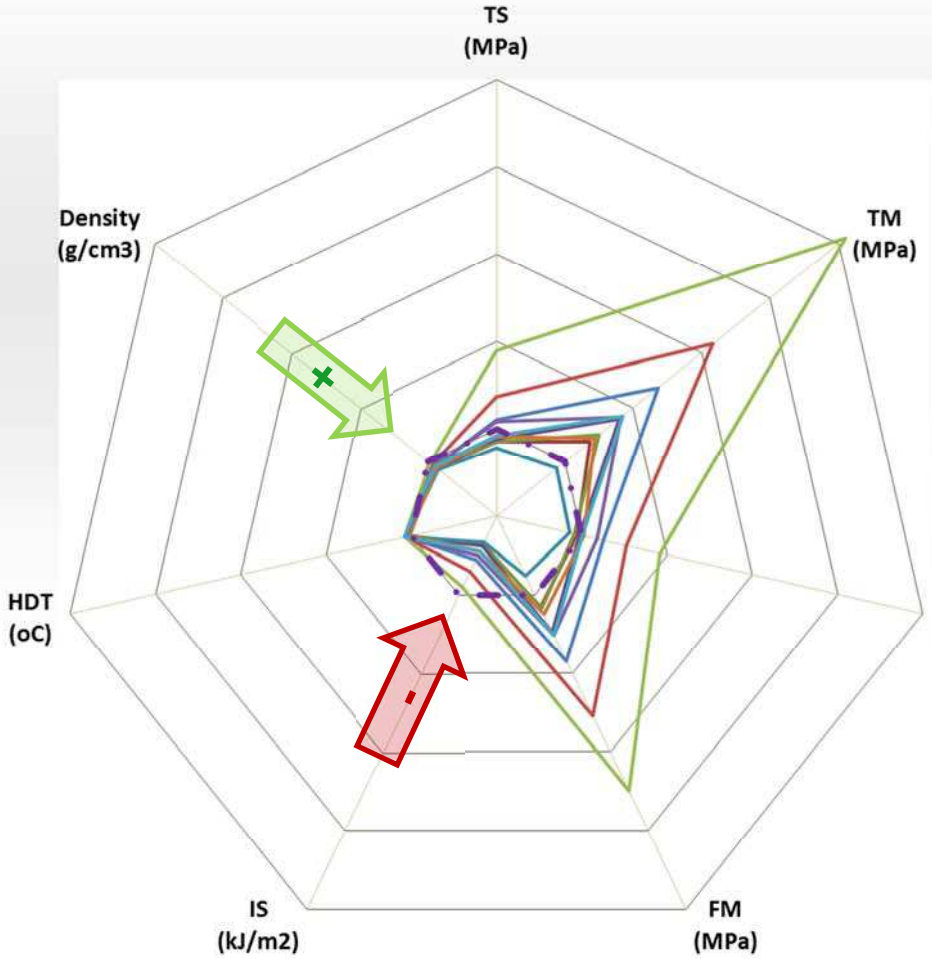
Compounding parameters:
190°C, 50 rpm

Injection parameters:
190°C barrel temperature
30°C mold temperature
50 Bar holding pressure

Properties of PP Composites

Results: Development of PP / 30 wt.% (rCF+TMP) formulations

Variation of CF grades and combinations with TMP



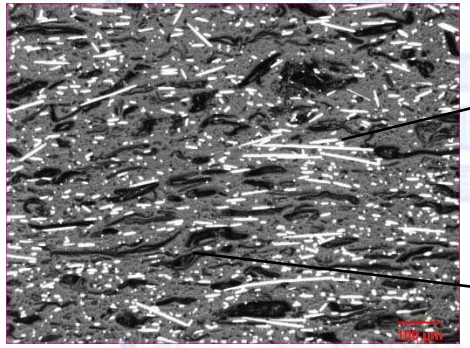
25% rCF / 75% TMP
50% rCF / 50% TMP
75% CF / 25% TMP
rCF, pyrolysis, Carbon Conversions

0% rCF / 100% TMP
25% rCF / 75% TMP
50% rCF / 50% TMP
75% rCF / 25% TMP
100% rCF / 0% TMP
rCF, post ind. waste Carbon Conversions

50% vCF / 50% TMP
vCF, Zoltek

50% vCF / 50% TMP
vCF, TohoTenax

Mat. Ref. Ford PP / 30%GF



rCF-MIT PY
In white

TMP
In black

Common morphology

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Properties of PP Composites

Results: Development of PP / 30 wt.% (rCF+TMP) formulations

Variation of CF grades and combinations with TMP

	TS (MPa)	TM (MPa)	FS (MPa)	FM (MPa)	IS (kJ/m²)	HDT (°C)	Density (g/cm³)	
Reference Ford PP / 20 & 30%GF	32-55.0	2500-4000	-	2500-4000	2.3-6	105 -145.0	1.08-1.21	
25% rCF / 75% TMP	47.1	5464	75.1	4596	2.2	152.3	1.07	rCF, pyrolysis, Carbon Conversions
50% rCF / 50% TMP	47.0	5985	72.9	4702	2.2	148.3	1.10	
75% CF / 25% TMP	48.7	7191	77.5	5893	2.3	153.5	1.14	
0% rCF / 100% TMP	42.9	3499	68.3	3030	2.0	153.4	1.03	rCF, post ind. waste Carbon Conversions
25% rCF / 75% TMP	50.4	5735	82.0	4972	2.7	149.3	1.07	
50% rCF / 50% TMP	61.0	9454	100.5	7360	3.3	152.9	1.10	
75% rCF / 25% TMP	75.1	12659	121.5	10145	4.2	154.9	1.14	
100% rCF / 0% TMP	104.1	20430	153.0	13956	5.4	156.3	1.18	
50% vCF / 50% TMP	59.6	7261	94.1	6053	3.0	155.1	1.10	vCF, Zoltek
50% vCF / 50% TMP	50.7	7365	80.5	6046	2.6	156.4	1.10	vCF, TohoTenax
MIN to MAX VARIATION	-22 to +90%	-13 to +411%	-15 to 91%	-24 to +249%	-67 to -10%	+ 6 to +8%	-3 to -15%	Benefits

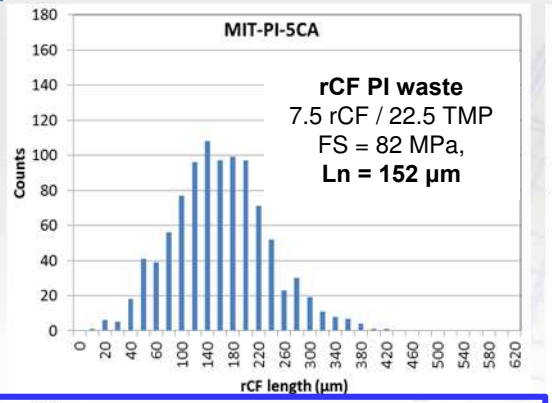
Properties of PP Composites

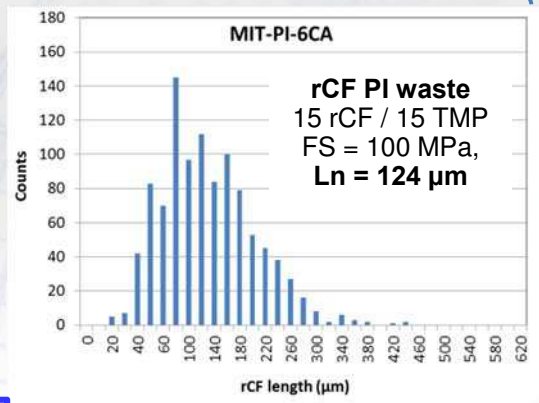
CF - Recovery Method: 2h in boiling xylene, filtered on 15 cm filter until plugged, returned liquid and filter to fresh boiling xylene for 30 min, filtered on 15 cm filter, washed with hot xylene, and dried.

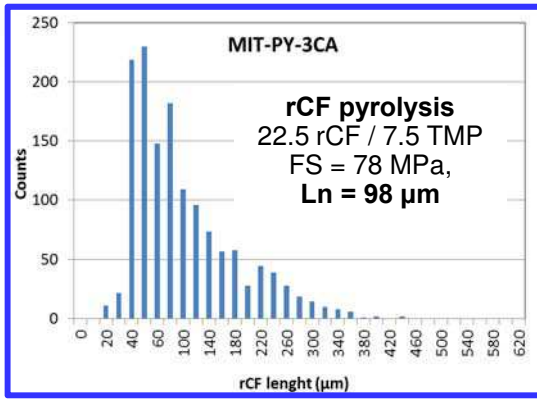


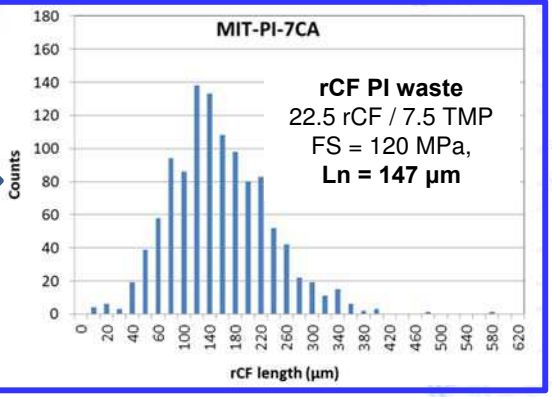
rCF from pyrolysis is shorter (98 µm) than rCF from waste (around 125 µm). This is linked to its additional processing step: it was obtained by pyrolysis and then granulated before compounding.

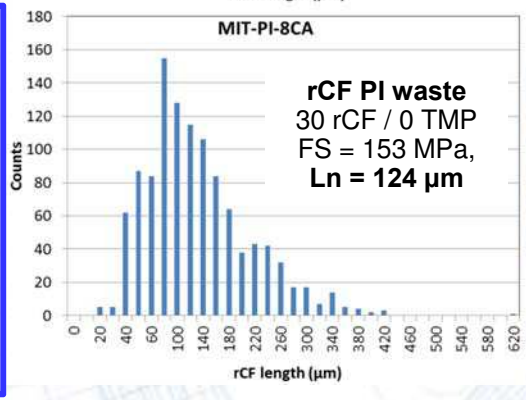












Formulations of PA6 Composites

Development of PA6 / 30 wt.% (rCF+TMP) formulations

Variation of CF grades and combinations with TMP

FIBER TYPE & CF/TMP combinations

COMPOUNDED FORMULATIONS



rCF, pyrolysis, Carbon Conversions

		PA6 wt.%	Fiber Pellet: Mixture wt.% rCF	wt.% TMP	CA wt.%
Pellets rCF/TMP	25% rCF / 75% TMP	X	7.5	22.5	Y
	50% rCF / 50% TMP	X	15	15	Y
	75% rCF / 25% TMP	X	22.5	7.5	Y



rCF, post-industrial waste, Carbon Conversions

		PA6 wt.%	Fibers wt.% rCF	wt.% TMP	CA wt.%
Pellets of TMP Unpelletized rCF	0% rCF / 100% TMP	X	0	30	Y
	25% rCF / 75% TMP	X	7.5	22.5	Y
	50% rCF / 50% TMP	X	15	15	Y
	75% rCF / 25% TMP	X	22.5	7.5	Y
	100% rCF / 0% TMP	X	30	0	Y



vCF, virgin, no sizing, Zoltek

		PA6 wt.%	Fibers wt.% vCF	wt.% TMP	CA wt.%
Pellets CF/TMP	50% rCF / 50% TMP	X	15	15	Y



vCF, Toho Tenax, PA6 sized

		PA6 wt.%	Fibers wt.% vCF	wt.% TMP	CA wt.%
Pellets of TMP Unpelletized CF	50% rCF / 50% TMP	X	15	15	Y

CA = coupling agent for PA6 / fibers adhesion

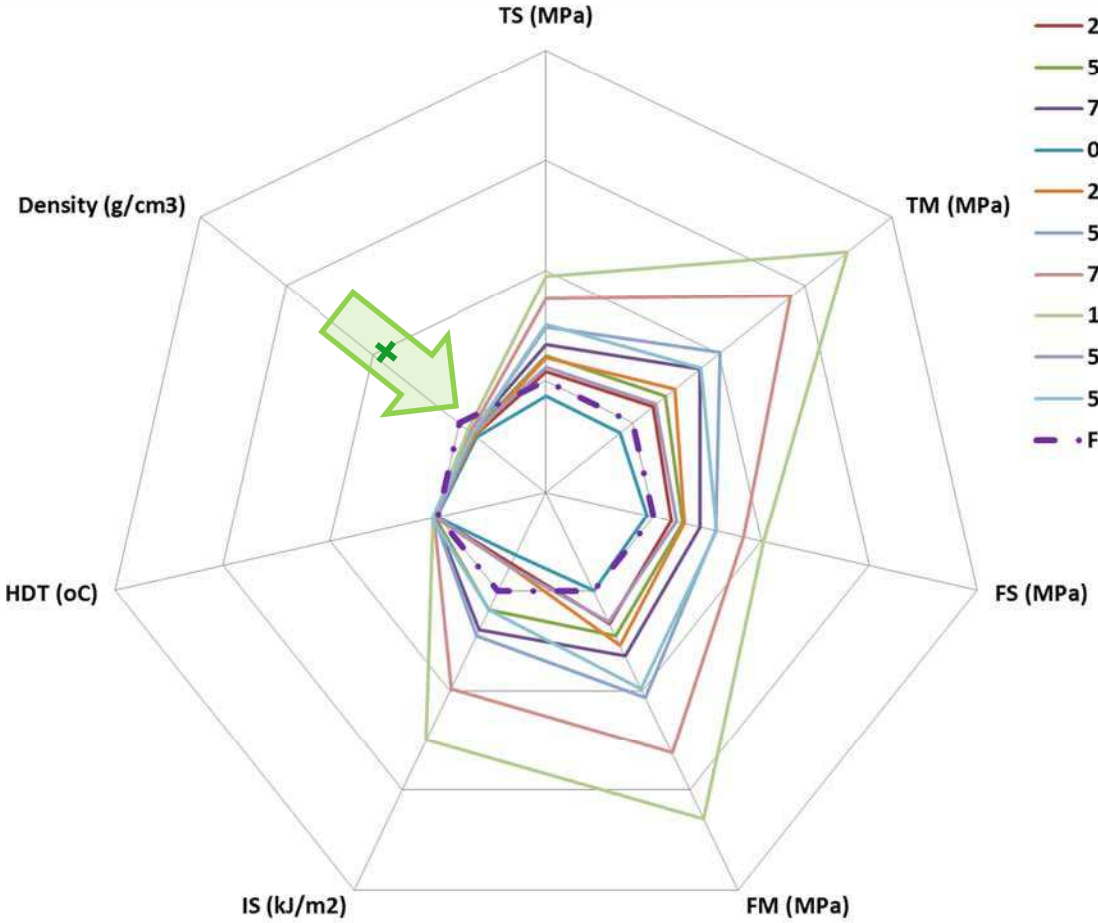
Compounding parameters:
240°C, 50 rpm

Injection parameters:
240°C barrel temperature
60°C mold temperature
50 Bar holding pressure

Properties of PA6 Composites

Results: Development of PA6 / 30 wt.% (rCF+TMP) formulations

Variation of CF grades and TMP combinations



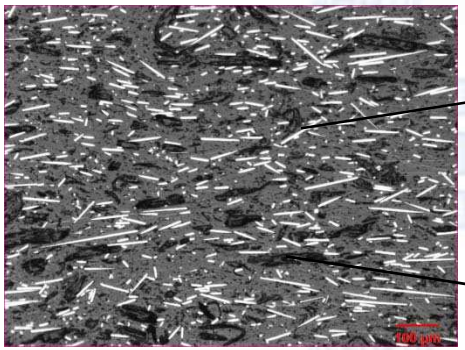
- 25% rCF / 75% TMP
- 50% rCF / 50% TMP
- 75% CF / 25% TMP

rCF, pyrolysis, Carbon Conversions

- 0% rCF / 100% TMP
- 25% rCF / 75% TMP
- 50% rCF / 50% TMP
- 75% rCF / 25% TMP
- 100% rCF / 0% TMP

rCF, post ind. waste Carbon Conversions

- 50% vCF / 50% TMP — vCF, Zoltek
- 50% vCF / 50% TMP — vCF, TohoTenax
- Ford PA6/15%GF/25%minerals



rCF-CC PY In white

TMP In black

Common morphologies

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Properties of PA6 Composites

Results: Development of PA6 / 30 wt.% (rCF+TMP) formulations

Variation of CF grades and combinations with TMP

	TS (MPa)	TM (MPa)	FS (MPa)	FM (MPa)	IS (kJ/m²)	HDT (°C)	Density (g/cm³)
Ford PA6/15%GF/25%minerals	100.0	7000	150.0	6000	3.0	205.0	1.50
25% rCF / 75% TMP	108.3	8651	174.7	7971	2.2	209.6	1.24
50% rCF / 50% TMP	122.7	9684	190.8	8707	3.6	211.5	1.27
75% CF / 25% TMP	133.0	12496	214.9	9900	4.2	211.8	1.31
0% rCF / 100% TMP	86.8	6003	140.6	5972	1.9	207.6	1.20
25% rCF / 75% TMP	120.9	10435	192.3	9292	2.3	210.9	1.24
50% rCF / 50% TMP	148.5	14101	236.3	12394	4.3	212.6	1.27
75% rCF / 25% TMP	174.4	19842	275.6	15785	5.9	213.4	1.31
100% rCF / 0% TMP	194.9	24420	303.3	19749	7.5	214.3	1.35
50% vCF / 50% TMP	112.6	8921	181.7	7853	2.3	207.8	1.27
50% vCF / 50% TMP	150.9	12520	238.0	11900	3.6	217.2	1.27
MIN to MAX VARIATION	-13 to +95%	-14 to 249%	-6 to +102%	0 to 229%	-36% to +150%	+1 to 6%	-10 to -20%

rCF, pyrolysis, Carbon Conversions

rCF, post ind. waste Carbon Conversions

vCF, Zoltek

vCF, TohoTenax

Benefits

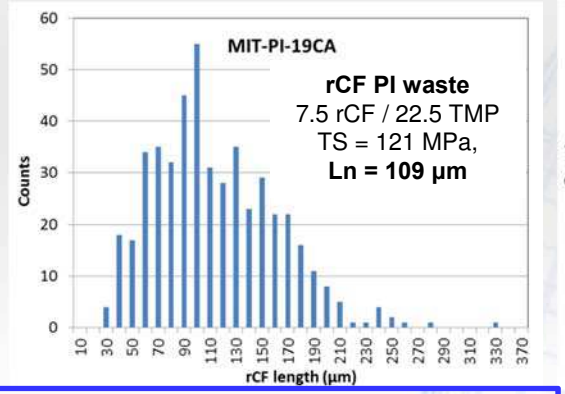
Properties of PA6 Composites

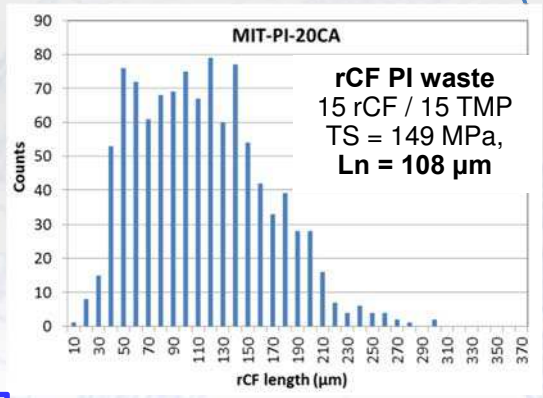
Recovery Method of rCF: 2h boiling in formic acid, filtered on 9 cm filter, washed with hot formic acid, and dried.

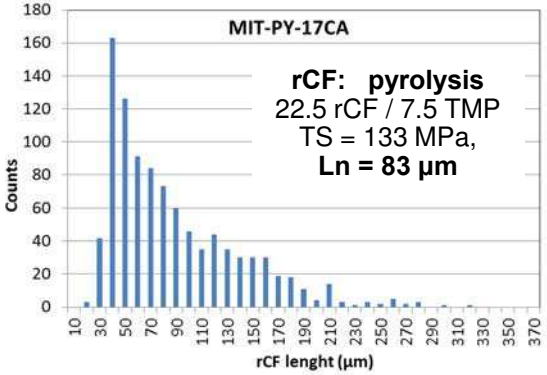
rCF from pyrolysis, 83 µm, proved to be shorter than the rCF from industrial waste, around 110 µm. The reason is its additional history: it was obtained by pyrolysis and went through granulation step before compounding.

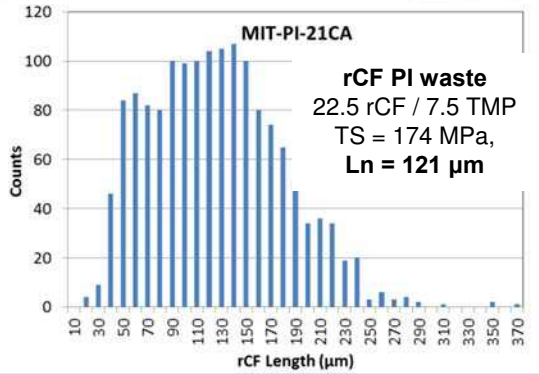


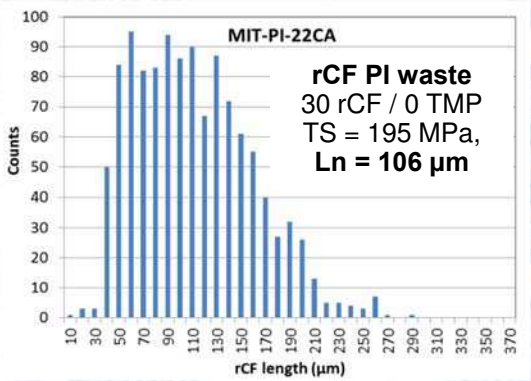




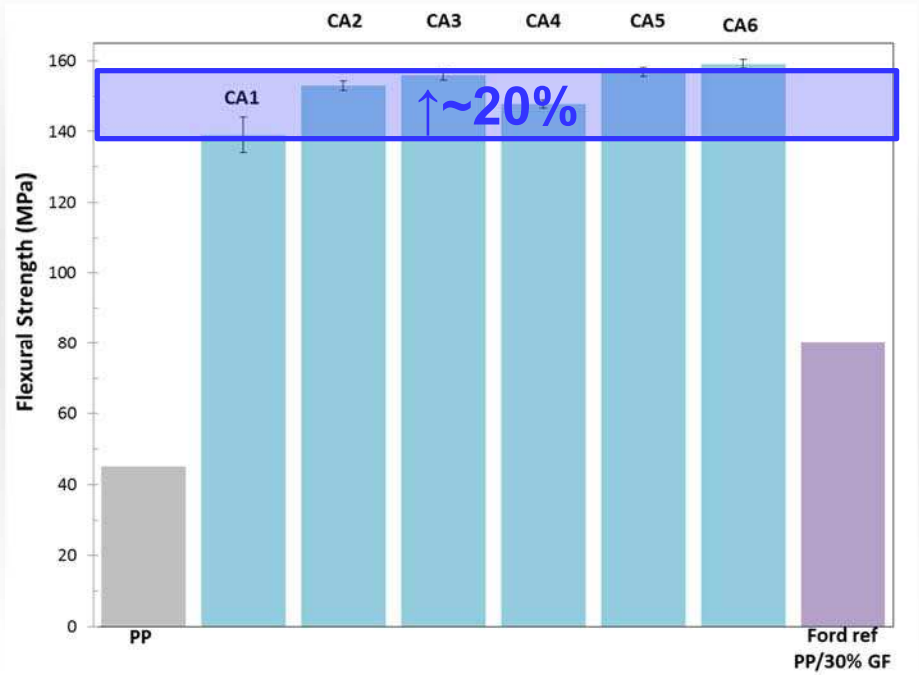


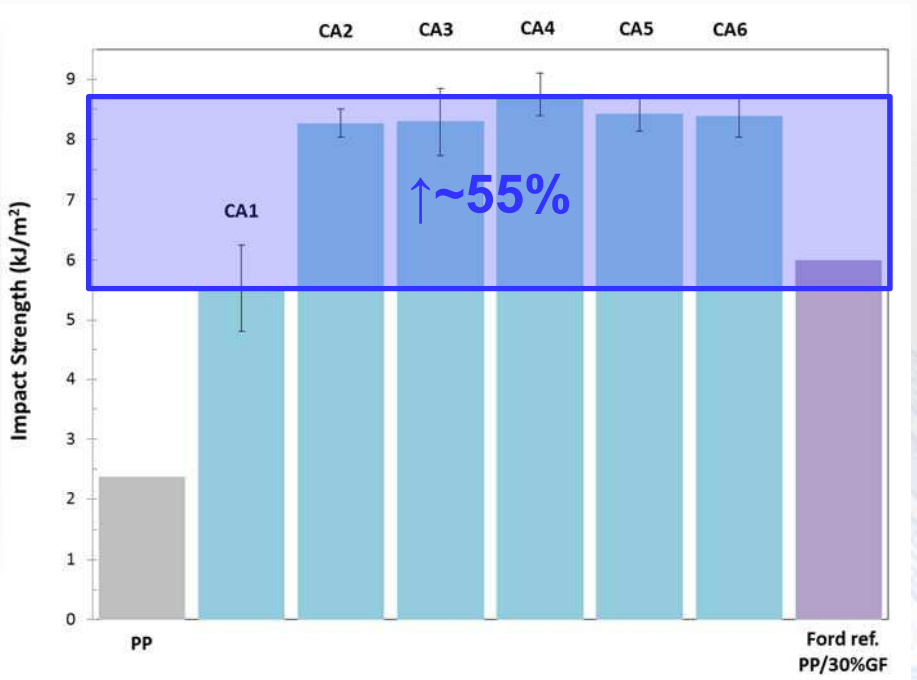






Optimization of PP composites: formulation and compounding process





PP / 30wt.% rCF composites:

CA Optimization trials allowed to boost the:

- **TS by 25%**
- **IS by 55%**

Compared at the preceding formulations

Other optimizations were done:

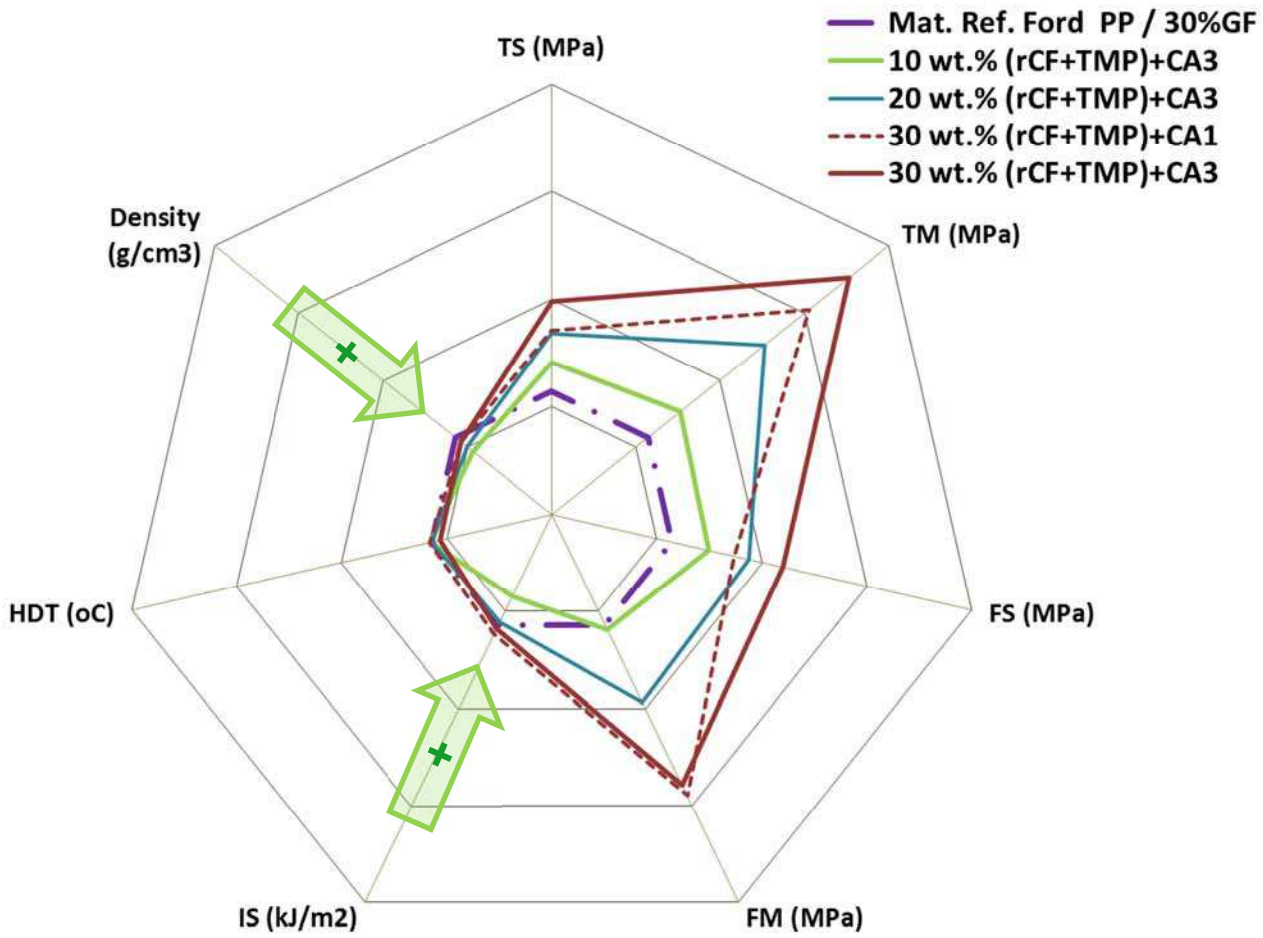
New coupling agents

Fibers feeding

Screw configuration

Optimization of PP composites: formulation and compounding process

Formulation optimization of PP composites





rCF industrial waste CC



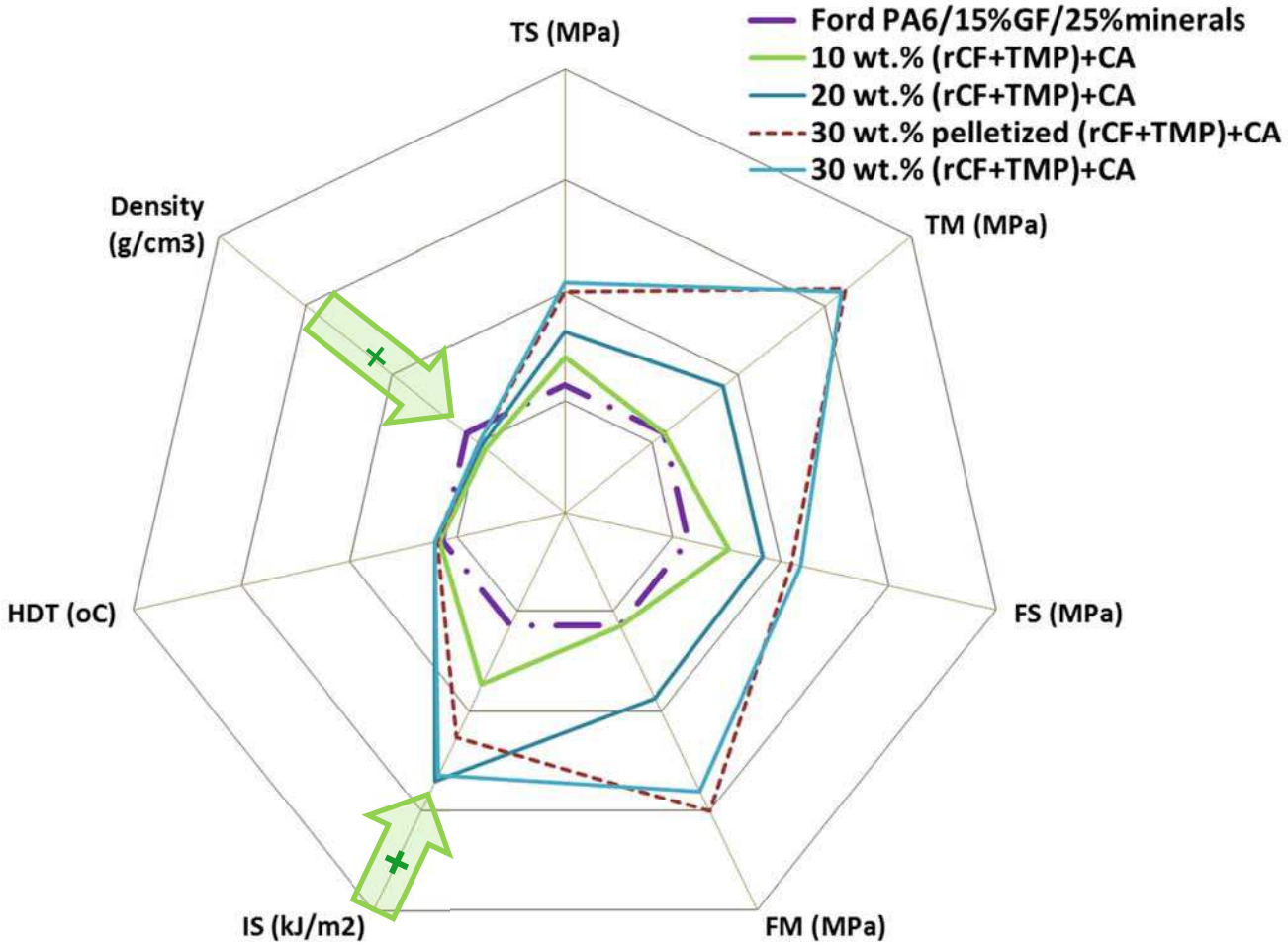
TMP

Optimizations:

Variation of fiber content
New coupling agents
Fibers feeding
Screw configuration

Optimization of PA6 composites: formulation and compounding process

Formulation optimization of PA6 composites





rCF industrial waste CC



TMP

Optimizations:

Variation of fiber content
New coupling agents
Fibers feeding
Screw configuration

Lightweighting of composites by injection foaming at the laboratory scale

Foaming using Chemical Blowing Agents (CBAs) & MuCell technology – PP composites

PP wt.%	rCF wt.%	TMP wt.%	Coupling Agent wt.%
X	15	15	Y
X	22.5	7.5	Y

2 formulations selected

Foaming using Chemical Blowing Agents (CBAs) and MuCell Technology – PA6 composites

PA6 wt.%	rCF wt.%	TMP wt.%	Coupling Agent wt.%
X	15	15	Y
X	22.5	7.5	Y

2 formulations selected

Varied parameters :

Blowing agent type & concentration

Injection rate

Shot size

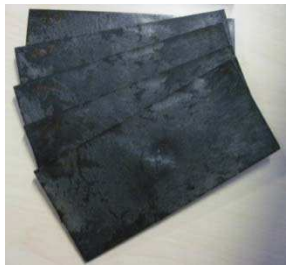
Mold temperature

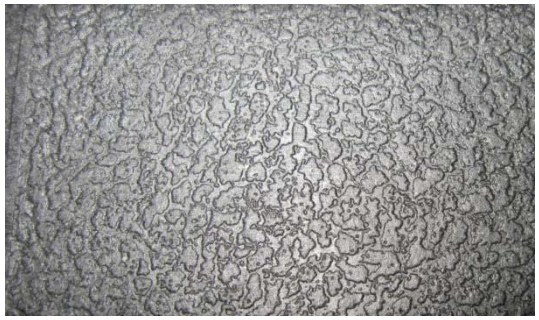
Part thickness

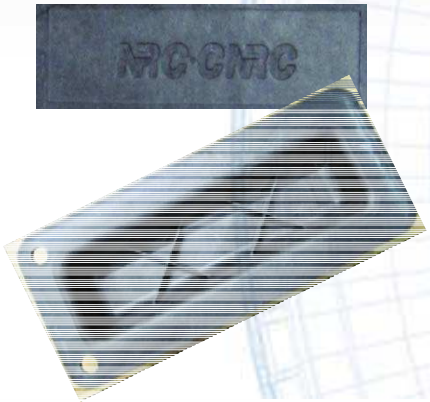
Lightweighting of composites by injection foaming at the laboratory scale

Chemical Blowing Agents (CBAs) vs. MuCell technology - PP composites

	CHEMICAL FOAMING, 2% CBA					MUCELL FOAMING, 0.3% PBA				
Sample	**Weight Reduction (%)**	**FS (SD) (MPa)**	**FM (SD) (MPa)**	**IS (SD) (kJ/m²)**	**HDT (SD) (°C)**	**Weight Reduction (%)**	**FS (SD) (MPa)**	**FM (SD) (MPa)**	**IS (SD) (kJ/m²)**	**HDT (°C)**
Foamed samples based on PP / 15 wt.% CF / 15 wt.% TMP / 5 wt.% CA										
Unfoamed	NA	92.3 (2.2)	4370 (98)	3.51 (0.33)	150 (3)	NA	106 (0.41)	5539 (477)	4.12 (0.22)	NE
Foamed	14 %	88.5 (3.4)	4599 (208)	3.34 (0.22)	152 (0.6)	6.6 %	84 (2.2)	4637 (219)	3.23 (0.18)	NE
Foamed sample based on PP / 22.5 wt.% CF / 7.5 wt.% TMP / 5 wt.% CA										
Unfoamed	NA	102.2 (1.5)	5676 (106)	4.59 (0.16)	152 (5)	NA	124 (1)	8030 (335)	5.08 (0.16)	NE
Foamed	14 %	95.9 (4.2)	5650 (231)	4.55 (0.24)	146 (5)	6.9 %	107 (3)	6704 (241)	4.39 (0.16)	NE







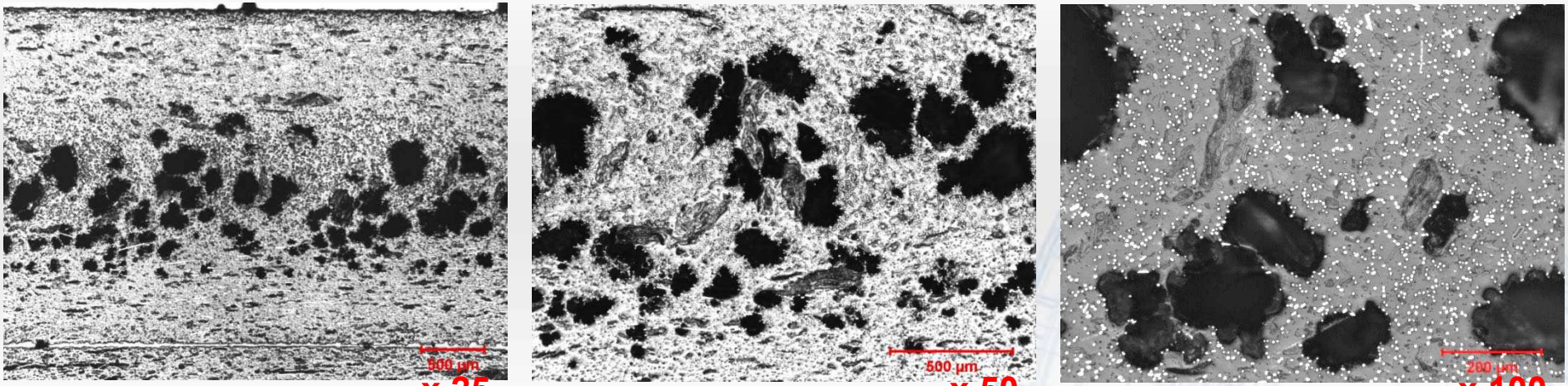


Lightweighting of composites by injection foaming at lab scale

PP composites foamed with CBA vs. MuCell foamed samples

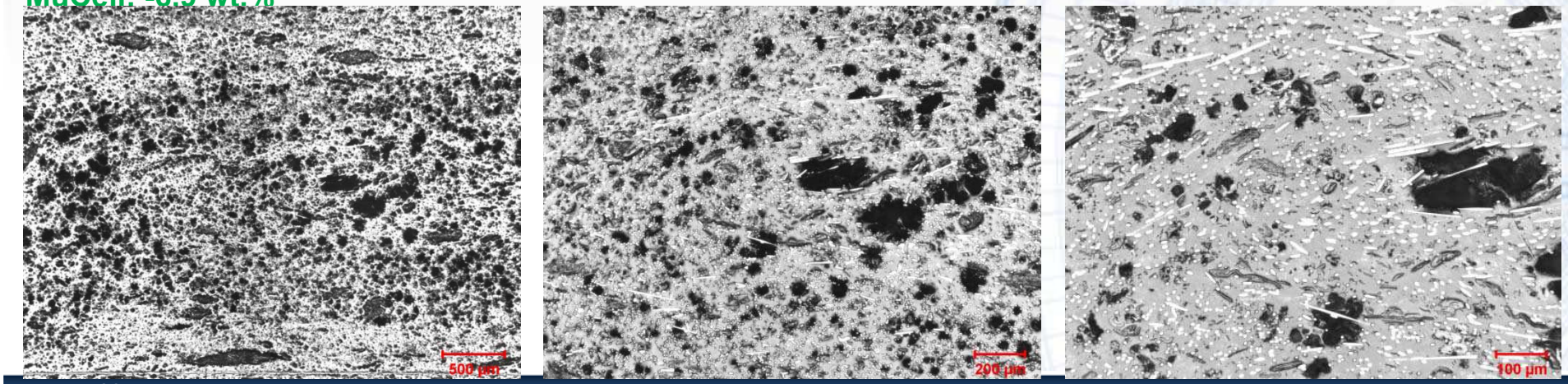
Foam Morphology - OM

CBA: -14 wt.% **Parts foamed based on PP / 22.5 wt.% CF / 7.5 wt.% TMP / Y wt.% CA3**



x 25 x 50 x 100

MuCell: -6.9 wt.%

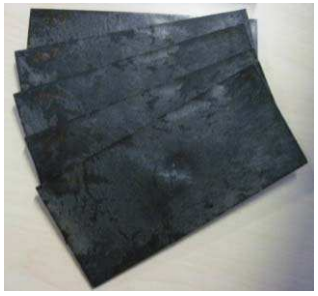


NRC·CNRC

Lightweighting of composites by injection foaming at the laboratory scale

Chemical Blowing Agents (CBAs) vs. MuCell technology - PA6 composites

	CHEMICAL FOAMING, 4% CBA					MUCELL FOAMING, 0.3% PBA				
Sample	**Weight Reduction (%)**	**FS (SD) (MPa)**	**FM (SD) (MPa)**	**IS (SD) (kJ/m²)**	**HDT (SD) (°C)**	**Weight Reduction (%)**	**FS (SD) (MPa)**	**FM (SD) (MPa)**	**IS (SD) (kJ/m²)**	**HDT (°C)**
Foamed samples based on PA6 / 15 wt.% CF / 15 wt.% TMP / Y wt.% CA										
Unfoamed	NA	163 (12)	7375 (201)	3.27 (0.63)	206 (12)	NA	163 (10)	7780 (142)	3.12 (0.45)	NE
Foamed	9.1 %	144 (5)	6626 (120)	3.42 (0.28)	203 (102)	13 %	134 (7)	7817 (350)	2.64 (0.24)	NE
Foamed sample based on PA6 / 22.5 wt.% CF / 7.5 wt.% TMP / Y wt.% CA										
Unfoamed	NA	184 (1.5)	8029 (145)	4.77 (0.37)	205 (7)	NA	194 (7)	9363 (293)	5 (0.22)	NE
Foamed	11 %	161 (4)	7486 (234)	4.40 (0.26)	202 (4)	12 %	164 (6)	9957 (307)	4.13 (0.28)	NE







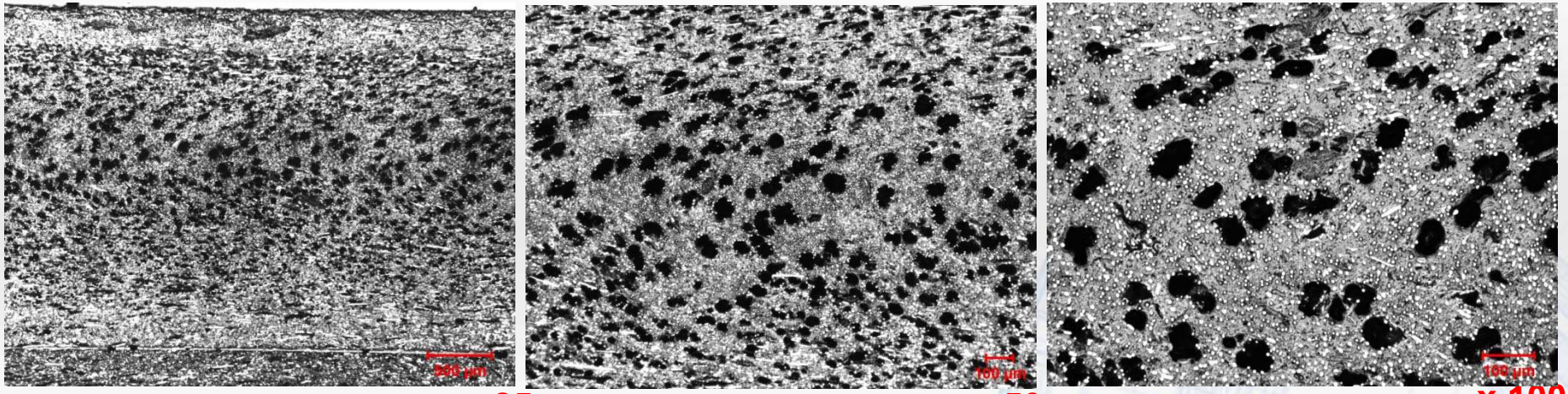


Lightweighting of composites by injection foaming at the laboratory scale

PA6 composites foamed with CBA vs. MuCell foamed samples

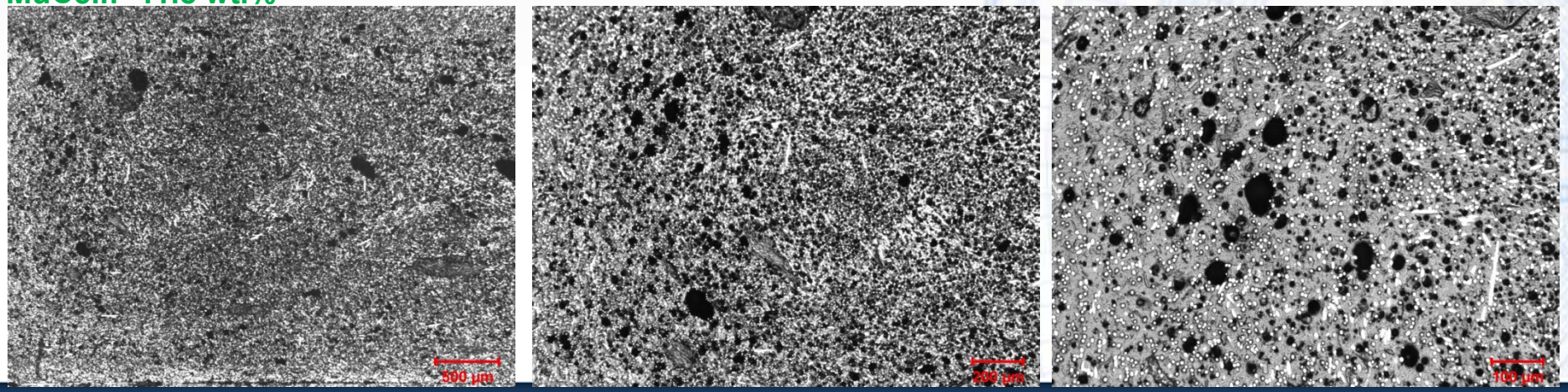
Foam Morphology - OM

CBA: -11.4 wt.% **Parts foamed based on PA6 / 22.5 wt.% CF / 7.5 wt.% TMP / Y wt.% CA**



x 25 x 50 x 100

MuCell: -11.8 wt.%



Excellent Coefficients of Linear Thermal Expansion (CLTE) for the unfoamed and foamed PP and PA6 composites

Material description	CLTE (10^{-5} / K)	CLTE (10^{-5} / °C)
PP composites		
Ford material: PP homopolymer / 20% GF	-	3.50
Ford material: PP homopolymer / 30% GF	-	2.00
X% PP / 22.5% rCF / 7.5% TMP / Y% CA3 (unfoamed)	12.02	2.16
X% PP / 22.5% rCF / 7.5% TMP / Y% CA3 (MuCell foamed)	19.53	3.52
X% PP / 22.5% rCF / 7.5% TMP / Y% CA3 (CBA foamed)	7.35	1.32
PA6 composites		
Ford material: PA6/ 15% GF / 25% minerals	-	3 to 5
X% PA6 / 22.5% CF / 7.5% TMP / Y% CA (unfoamed)	13.58	2.44
X% PA6 / 22.5% CF / 7.5% TMP / Y% CA (MuCell foamed)	12.09	2.18
X% PA6 / 22.5% CF / 7.5% TMP / Y% CA (CBA foamed)	7.26	1.31
PP/PA6 composites		
PP/PA - 6.5 - 9.5% glass fibres		3 to 8
X% (70% PP / 30% PA6) / 22.5% rCF / 7.5% TMP / Y% CA1 (unfoamed)	4.76	0.86

The evaluation was done at a TA Instruments' laboratory in Germany. ASTM E228 / a DIL 802 horizontal dilatometer were used. Temperature interval for testing was from -50 up to 100°C.

Injection-molding and injection-foaming of parts at the industrial scale – use of CBAs

Trials at Roush, Livonia, MI., USA

Injected parts:

- PP virgin
- PP-based biocomposite
- PA6 virgin
- PA6-based biocomposites

Ford

IP plenum bracket component



PP virgin



PP composites - unfoamed



PA6 virgin



PA6 composites

Injection-molding and injection-foaming of parts at the industrial scale – use of CBAs

PP parts: weight reduction of 5 to 9.2 %



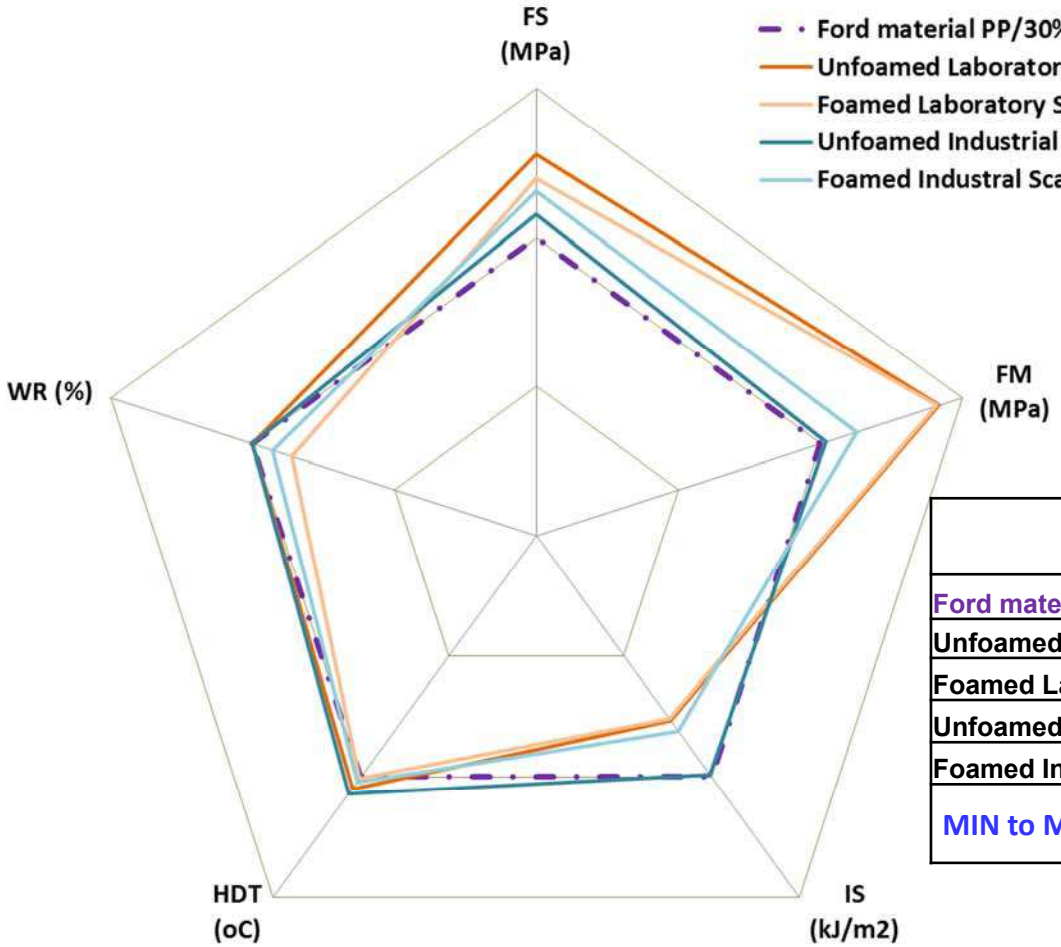


PA6 parts:weight reduction of 11-12 %



Injection-molding and injection-foaming of parts at the industrial scale – use of CBAs

Characterization of PP foamed parts



	FS (MPa)	FM (MPa)	IS (kJ/m²)	HDT (°C)	WR (%)
Ford material PP/30%GF	80.0	2500-4000	2.3-6.0	105-145	NA
Unfoamed Lab Scale	102.2	5676	4.6	152	NA
Foamed Lab Scale	95.9	5650	4.6	146	14
Unfoamed Industrial Scale	86.2	4087	5.9	155	NA
Foamed Industrial Scale	92.4	4510	4.9	148	5-9.2
MIN to MAX VARIATION	+8 to +28%	+2 to +42%	-24 to -1%	+1 to +7%	-5 to -14%

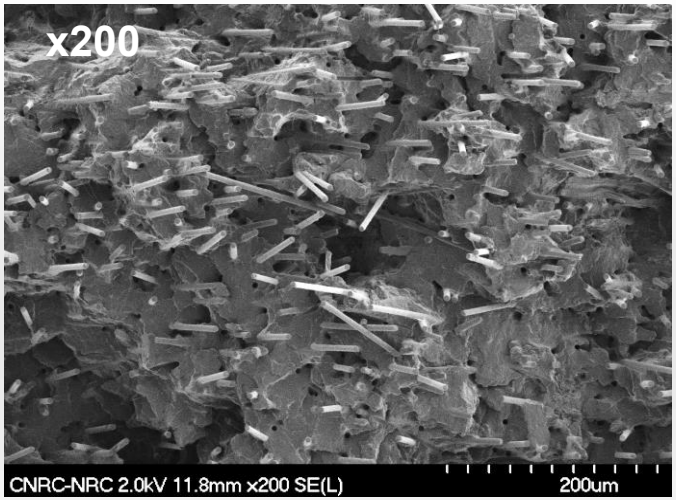
Benefits

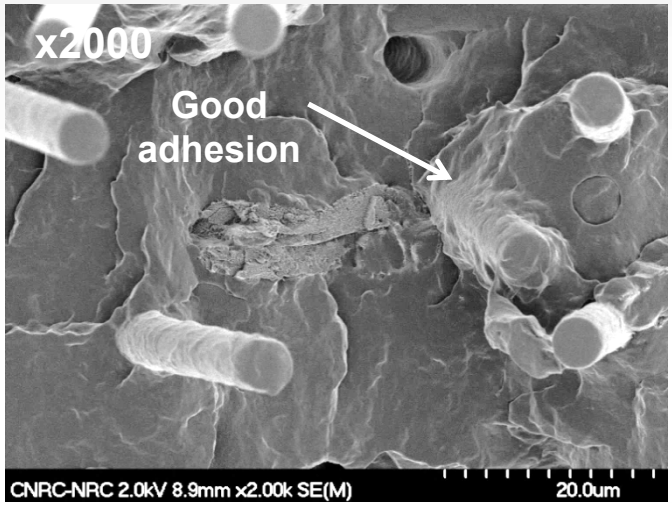
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Injection-molding and injection-foaming of parts at the industrial scale – use of CBAs

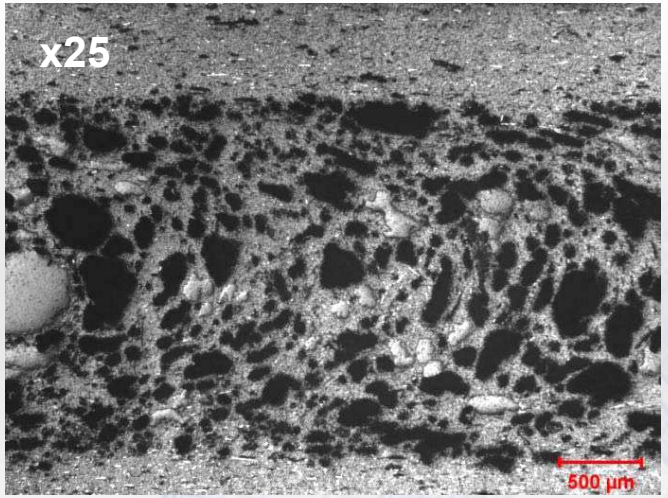
SEM on surfaces from impact fracture tests

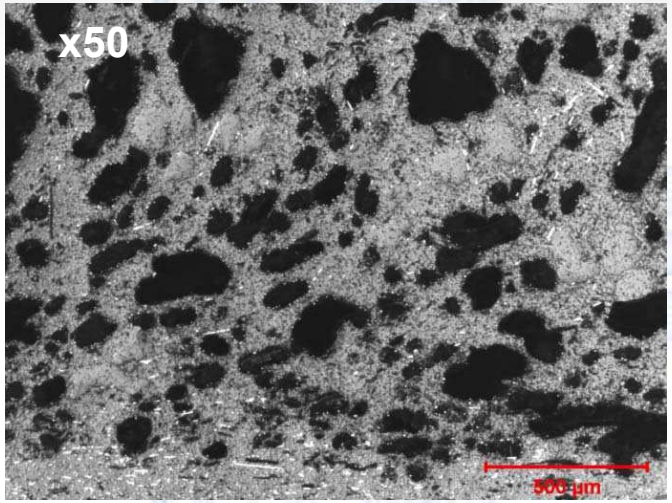
Good adhesion between PP and fibers





OM on polished surfaces



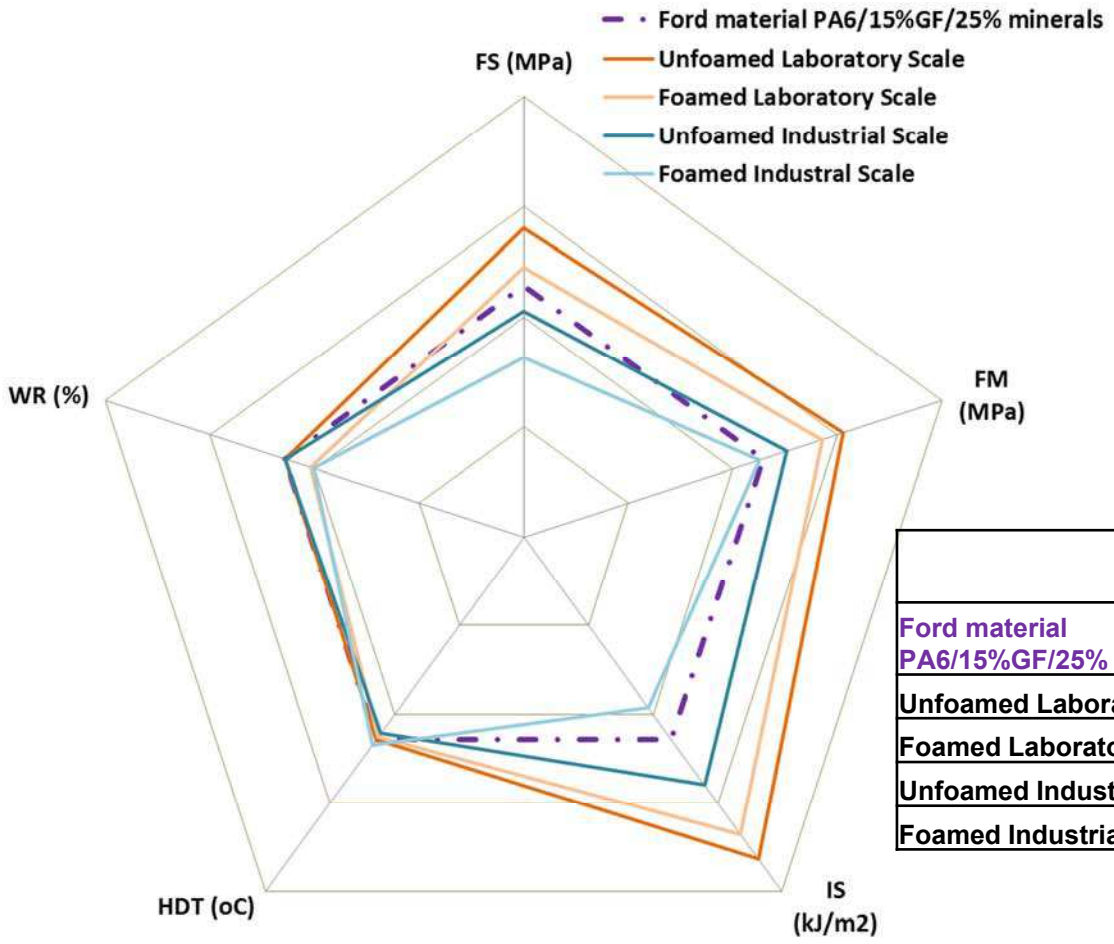


Uniform foaming in the volume of PP injected part

NRC·CNRC

Injection-molding and injection-foaming of parts at the industrial scale – use of CBAs

Characterization of PA6 foamed parts



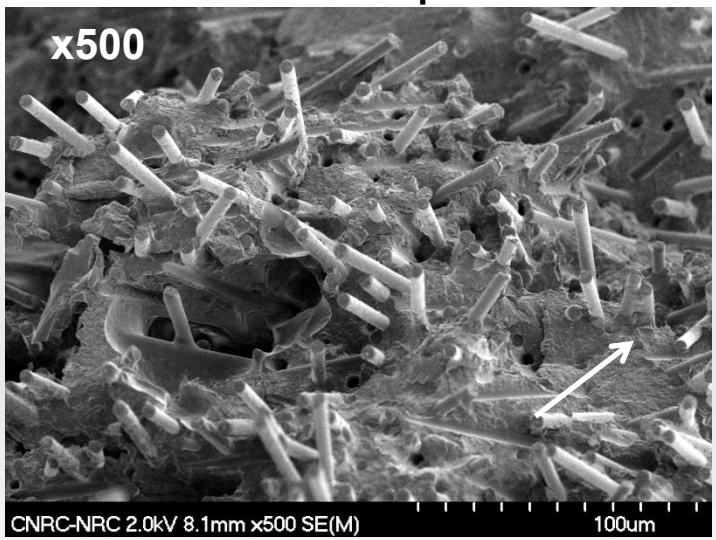
	FS (MPa)	FM (MPa)	IS (kJ/m²)	HDT (°C)	WR (%)
Ford material PA6/15%GF/25% minerals	-	6000	3.00	205	NA
Unfoamed Laboratory Scale	184	8029	4.77	205	NA
Foamed Laboratory Scale	161	7486	4.40	202	-11
Unfoamed Industrial Scale	135	6593	3.67	198	NA
Foamed Industrial Scale	107	5907	2.53	210	-12

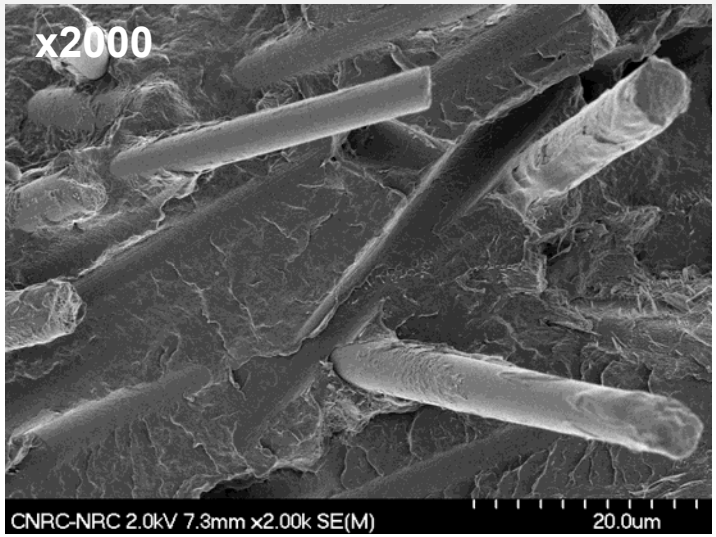
Injection-molding and injection-foaming of parts at the industrial scale – use of CBAs

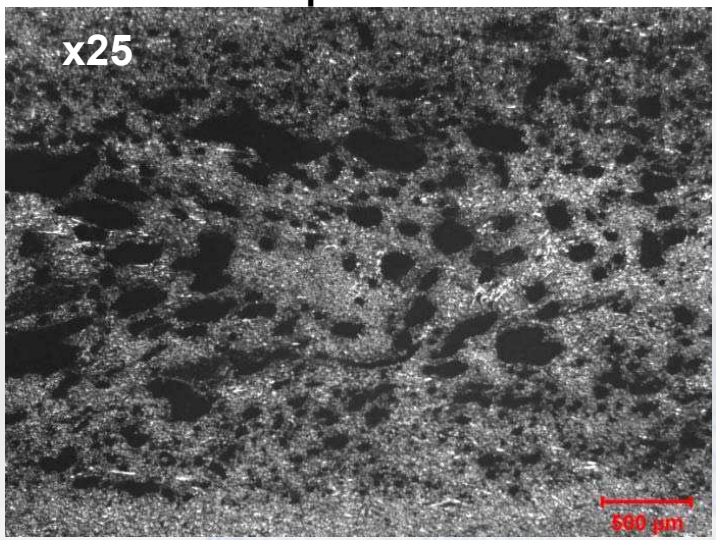
SEM on surfaces from impact fracture tests

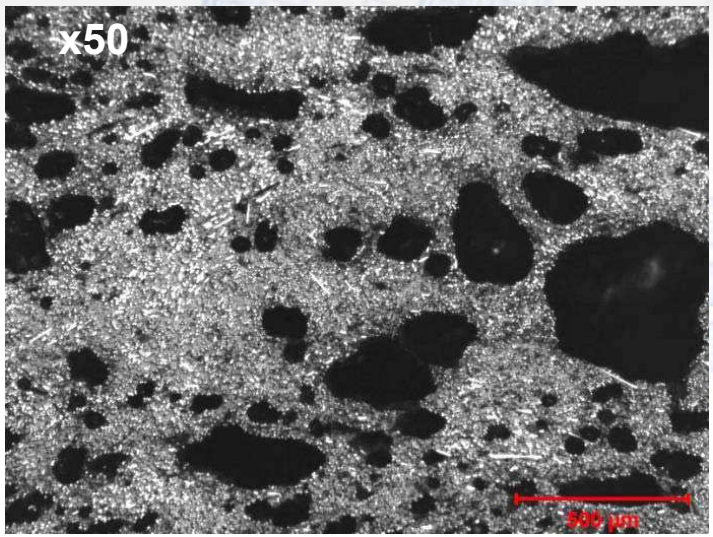
OM on polished surfaces

Mild - Good adhesion between PA6 and fibers
No coupling agents was used









Uniform foaming in the volume of PP injected part

NRC·CNRC

Cost evaluation of PP- & PA6-based composites

Some formulations of developed PP composites could have similar or lower prices than the existing market composites

COMPOSITE FORMULATION		US$/lb
Reference PP / 30 wt.% GF		**1.5**
PP / 5 wt% rCF / 5 wt.% TMP / CA	Unfoamed	1.31
	Foamed	1.18
PP / 10 wt% rCF / 10 wt.% TMP / CA	Unfoamed	1.61
	Foamed	1.45
PP / 15 wt% rCF / 15 wt.% TMP / CA	Unfoamed	1.92
	Foamed	1.73

COMPOSITE FORMULATION		US$/lb
Reference PP / 30 wt.% GF		**1.5**
PP / 7.5 wt% rCF / 2.5 wt.% TMP / CA	Unfoamed	1.50
	Foamed	1.35
PP / 15 wt% rCF / 5 wt.% TMP / CA	Unfoamed	2.01
	Foamed	1.81
PP / 22.5 wt% rCF / 7.5 wt.% TMP / CA	Unfoamed	2.51
	Foamed	2.26

The developed PA6 composites have very competitive prices

COMPOSITES FORMULATION		US$/lb
Reference PA6 / 15 wt.% GF / 25 wt.% minerals		**2.75**
PA6 / 5 wt% rCF / 5 wt.% TMP / CA	Unfoamed	2.66
	Foamed	2.39
PA6 / 10 wt% rCF / 10 wt.% TMP / CA	Unfoamed	2.81
	Foamed	2.53
PA / 15 wt% rCF / 15 wt.% TMP / CA	Unfoamed	2.97
	Foamed	2.67

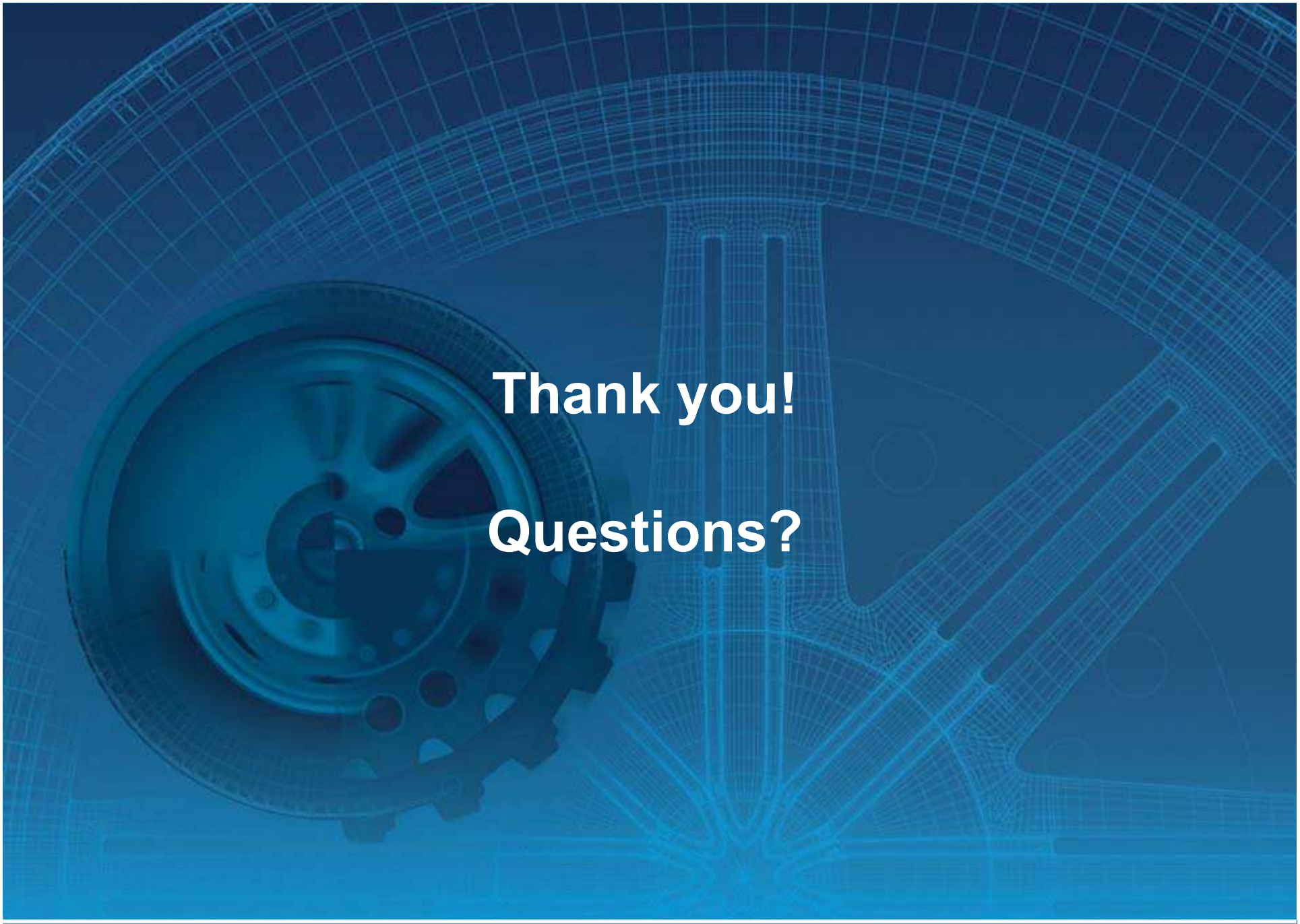
COMPOSITE FORMULATION		US$/lb
Reference PA6 / 15 wt.% GF / 25 wt.% minerals		**2.75**
PA6 / 7.5 wt% rCF / 2.5 wt.% TMP / CA	Unfoamed	2.85
	Foamed	2.57
PA6 / 15 wt% rCF / 5 wt.% TMP / CA	Unfoamed	3.21
	Foamed	2.89
PA6 / 22.5 wt% rCF / 7.5 wt.% TMP / CA	Unfoamed	3.56
	Foamed	3.20

- A price of 8 US$/lb and a weight reduction of 10 % of foamed parts were considered
- The evaluated costs do not include the cost of compounding and injection-foaming.

Conclusions

Successful development of sustainable composites containing combinations of rCF / cellulosic fibers which compete with and could replace Ford composite grades used in interior applications, such as PP & PA6 minerals filled or glass fibers reinforced.

- Integrate up to 30 wt.% recycled and renewable content;
- Are up to 10 % lighter than conventional reference materials;
- Have neutral or lower cost compared to conventional materials;
- Have at least the same mechanical performance, thermal performance and dimensional stability as conventional PP & PA6 filled with minerals or reinforced with glass fibers
- Are durable and recyclable.


Thank you!
Questions?