Biocomposites and bioblends based on engineering thermoplastics for automotive applications

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BIOCOMPOSITES AND BIOBLENDS BASED ON ENGINEERING THERMOPLASTICS FOR AUTOMOTIVE APPLICATIONS

NRC, Your Key Partner!

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National Research Council Canada

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OUTLINE

- **About National Research Council Canada**
- **Engineering polymers in automotive applications**
- **NRC's green vision**
- **Materials, processes and characterization**
- **Bio-based PA6 and ABS compounds:**
  - **Lower-cost** biocomposites
  - **Lighter** biocomposites
  - **Greener** bioblends and biocomposites
- **Summary**

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About NRC:

- Government of Canada's premier **Research & Technology Organization**
- Over 3,550 full-time employees
- Provides a broad array of technical and R&D services to the industry
- Supports innovation finance for SME via Industrial Research Assistant Program (IRAP)

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NRC: Scientific Divisions

Emerging Technologies	Engineering	Life Sciences
Information and Communications Technologies	Aerospace	Aquatic and Crop Resource Development
Measurement Science and Standards	Automotive and Surface Transportation (AST)	Human Health Therapeutics
Herzberg Astronomy and Astrophysics	Construction	Medical Devices
Security and Disruptive Technologies	Energy, Mining and Environment	
	Ocean, Coastal and River Engineering	

NRC-AST at a glance:
5 sites
275 full time employees
Over 200 partners and clients

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NRC: Automotive and Surface Transportation Market Sectors


Biomass


Military Vehicles


Automobile & Light Duty Trucks


Bus/Coach


Rail


Heavy-duty Vehicles

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NRC: Automotive and Surface Transportation Market Driven Programs

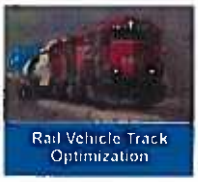

Lightweighting


Vehicle Propulsion Technologies


Composites and Plastics for Transportation


Advanced Manufacturing


Design Systems


Rail Vehicle Track Optimization


Fleet Forward 2020

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Engineering polymers in automotive applications

Industry Trends: to alleviate the weight, to reduce the cost and to use more sustainable materials.
Proposed solutions: to replace the metal and glass fiber composite parts by PA and ABS bio-compounds having similar performances.

PA-based parts represent around 36 lb/car


Engine Covers


Rocker valve covers


Gear shifts


Oil Pan Module

Airbag Containers
Bumper brackets
Door handles
Fans
Air ducting
Fuel caps and lids
Exterior mirrors
Front-end grilles
Wheel covers and trim
and others

ABS-based parts represent around 30 lb/car


Grilles


B/C Pillars


Overhead consoles


Spoilers

Instrument panels
Fascia panels
Bumpers
Interior door assemblies
Interior door handles
Seating assemblies
Badges
Dashboard
Interior/exterior trims
and others

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NRC's green vision

- Substitution of mineral-filled and glass fiber-reinforced engineering thermoplastics by biocomposite counterparts;
- This substitution of petroleum-based compounds and composites by biocomposites containing cellulosic fibers can allow weight and cost reductions;
- The use of injection foaming process allows to further reduce the weight and the cost of the eco-parts.
- The substitution of a part of the PA6 or ABS by a bioplastic is a way to increase renewable content.

NRC offers solutions for cost competitive, greener and lighter : PA6 and ABS biocomposites with equivalent thermal & mechanical performance as conventional PA6- and ABS-based parts.


Door carrier


Battery Trays, Tube in floor


Bumpers


Front-end Carriers

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Materials

Polymers:

- PA6: Injection molding / extrusion grade, Ultramid B27 from BASF.
- ABS: Lustran Elite HH 1627, injection molding grade for high-heat automotive applications.
- PLA: 8302D, amorphous grade from Nature Works, selected as the bio-sourced minor phase.
- Coupling agents were used.
- Properties of PA6 and ABS commercial automotive grades were used in graphs for comparison purposes:
  - PA6 / 30% mineral field: Ultramid B3M6 from BASF
  - PA6 / 30% glass & mineral: Ultramid B3WGM24 from BASF
  - ABS / 30% talc: LNP™ STAT-LOY™ AX06484 from Sabic
  - ABS / 30% GF: LNP™ STAT-LOY™ AF306 from Sabic

Fibers:

- Cellulosic fibers contents: up to 40%wt.
- Short flax: was supplied by Schweitzer Mauduit Canada.
- Thermo-mechanical pulp (TMP): was supplied by SEC Papier Masson WB.
- Wood fibers (WF) in the form of dices (WoodForce): were supplied by Sonae Industria.

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Processing & Characterization

Compounding line:

Testing:

- Morphology: Scanning Electron Microscopy (SEM)
- Tensile properties (TS, TM, e%) - ASTM D638
- Impact strength (IS_{izod}) - ASTM D256
- Heat Deflection Temperature (HDT) - ASTM D648

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Bio-based PA6 compounds

Lower-cost biocomposites
Lighter biocomposites
Greener bioblends and biocomposites

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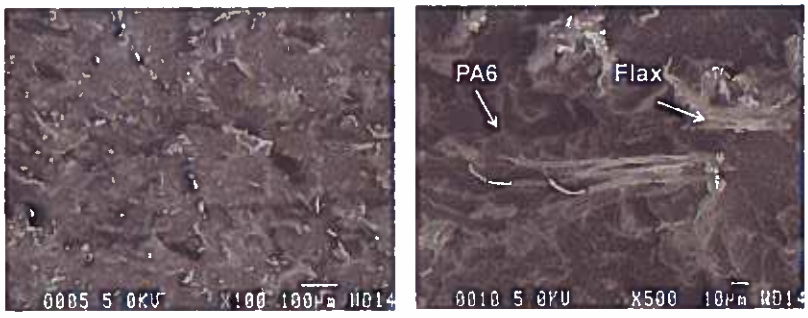
Lower-cost PA6 biocomposites
PA6 containing cellulosic fibers

Excellent interfacial adhesion



x100 **x500**

Morphology of PA6 / 20 wt.% flax biocomposites

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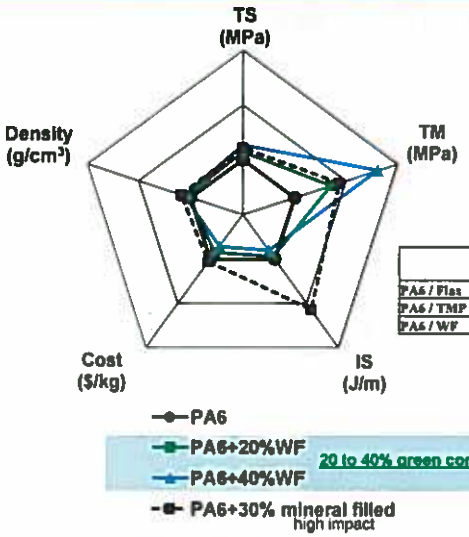
Lower-cost PA6 biocomposites
PA6 containing cellulosic fibers



Approximate prices ($/kg) on the market :

Virgin PA6 (CAD/kg)	PA6 / 30 wt.% minerals (CAD/kg)	Flax CAD/kg)	TMP (CAD/kg)	WF (CAD/kg)
4.9	5.3	1.0	0.3	1.5

Cost reduction

	Cellulosic contents			
	20 wt.%		40 wt.%	
	Cost (CAD/kg)	Cost reduction (%)	Cost (CAD/kg)	Cost reduction (%)
PA6 / Flax	4.2	16.0	3.4	32.0
PA6 / TMP	4.0	19.0	3.1	37.6
PA6 / WF	4.3	14.0	3.6	27.8

Replacing up to 40% of PA6 by cellulosic fibers results in 14-37% cost reduction.

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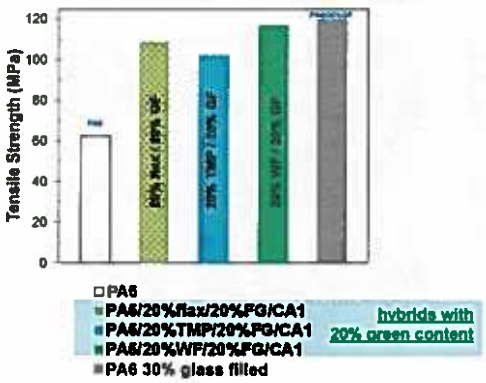
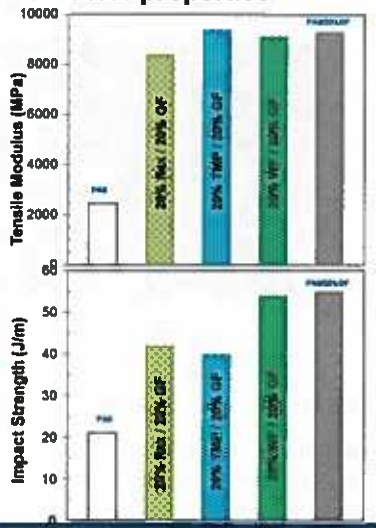
Lighter PA6 biocomposites
Glass fibers replacement by cellulosic fibers

PA6 hybrids with excellent mechanical properties





When 50% of glass fibers content is replaced by cellulosic fibers results in:
- Around 10% weight reduction;
- Preservation of mechanical properties.

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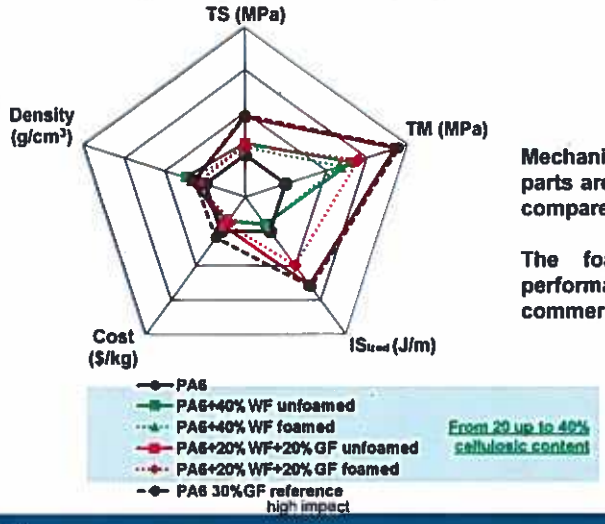
Lighter PA6 biocomposites
Processing: foaming by injection molding

Properties of PA6 biocomposites and hybrids: unfoamed and foamed



Mechanical properties of foamed parts are slightly lower (around 10%) compared at unfoamed ones.

The foamed parts have similar performances compared to commercial reference.

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Lighter PA6 biocomposites
Processing: foaming by injection molding

Morphology of PA6/20 wt.% cellulosic biocomposites:

Unfoamed

Foamed

Replacing from 20 up to 40% of PA6 by cellulosics results leads to 18-35 % cost reduction.

Furthermore, the PA6 biocomposites foaming allows a supplementary 10 % weight reduction which translates in additional 10 % material cost reduction.

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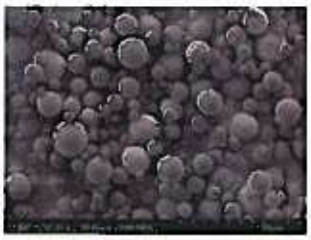
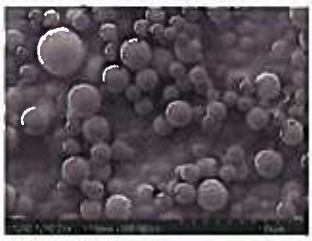
Lighter PA6 biocomposites
Hollow spheres as additives

Initial aspect of the hollow spheres:



iM30K: density of 0.60 g/cm³



iM16K: density of 0.46 g/cm³

Formulation of extruded composites:

PA6 B27	HS	Sawdust
90	10% iM30K	-
80	10% iM30K	10%
80	20% iM16K	-

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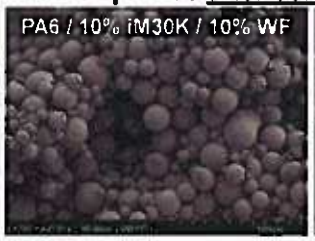
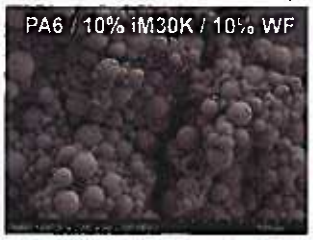
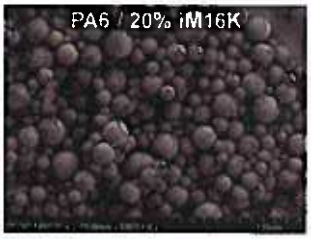
Lighter PA6 biocomposites
Hollow spheres as additives

Aspect of the hollow spheres <u>after compounding</u>:



Aspect of the hollow spheres <u>after injection molding</u>:





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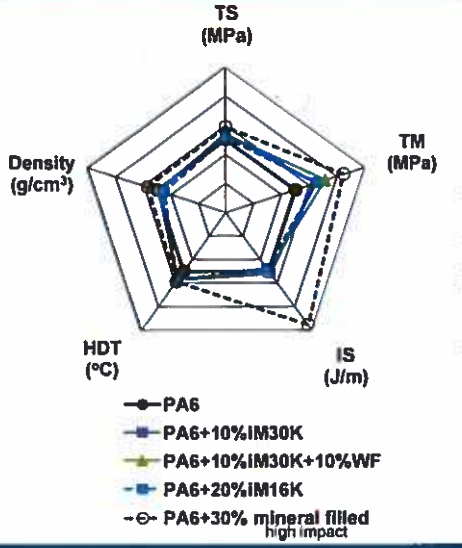
Lighter PA6 biocomposites
Hollow spheres as additives



- Similar performances to parts foamed in injection molding;
- Good mechanical properties;
- HDT around 190°C;
- 5% to 12% weight reduction comparing to pure PA6;
- 20% to 30% weight reduction comparing to minerals filled PA6 (commercial grade).

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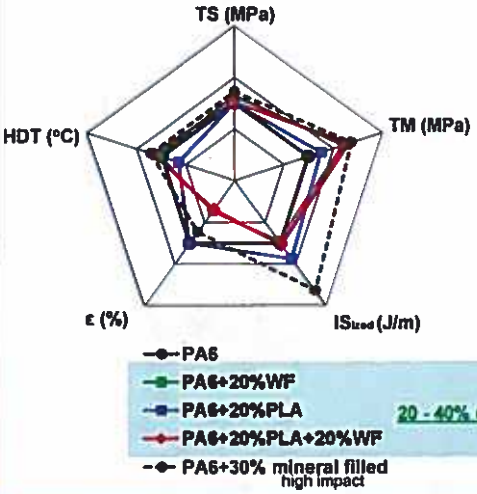
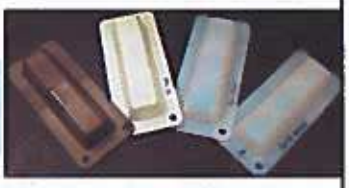
Greener PA6/PLA blends and biocomposites

Properties of PA6/PLA biocomposites with 20 wt.% cellulosic fibers



- <u>HDT increased from 160°C to 189°C for PA6/PLA/20%WF</u>
- ε% decreased as expected for biocomposites
- All other mechanical properties are higher than for PA6 alone and similar to reference PA6/30% mineral filled.



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Bio-based ABS compounds

Lower-cost biocomposites
Lighter biocomposites
Greener bioblends and biocomposites

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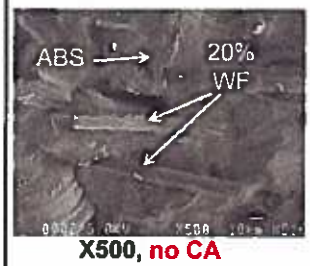
Lower-cost ABS biocomposites
ABS containing cellulosic fibers

Good interfacial adhesion when using CA



X500, no CA

X500, with CA

X1000, with CA

- Very good fiber distribution/dispersion.
- There is no adhesion between ABS, hydrophobic polymer, and hydrophilic cellulosic fibers in the absence of the coupling agent.
- The fracture was produced throughout the cellulosic fiber in the presence of the coupling agent.
- Therefore, the use of an adequate coupling agent will allow to increase this adhesion and therefore mechanical properties of ABS biocomposites.

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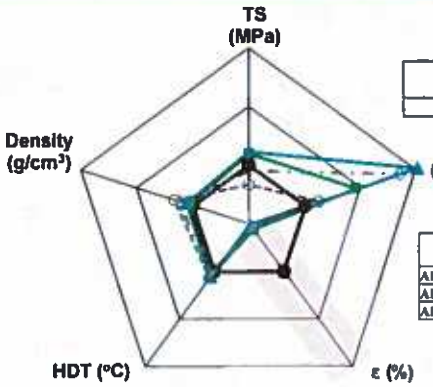
Lower-cost ABS biocomposites
ABS containing cellulosic fibers



Approximate prices ($/kg) on the market :

Virgin ABS (CAD/kg)	ABS / 30 wt.% talc (CAD/kg)	Flax (CAD/kg)	TMP (CAD/kg)	WF (CAD/kg)
3.6	3.6	1.0	0.3	1.5

Cost reduction

	Cellulosic contents			
	20 wt.%		40 wt.%	
	Cost (CAD/kg)	Cost reduction (%)	Cost (CAD/kg)	Cost reduction (%)
ABS / Flax	3.1	14.5	2.6	29.0
ABS / TMP	2.9	18.3	2.3	36.7
ABS / WF	3.2	11.6	2.8	23.2

Replacing up to 40% of ABS by cellulosic fibers results in a 10-36% cost reduction.

- ABS - reference
- ABS / 20 wt.%WF
- ABS / 40 wt.%WF
- ABS talc filled commercial grade
- ABS / 30 wt. % GF commercial grade

20 to 40% green content

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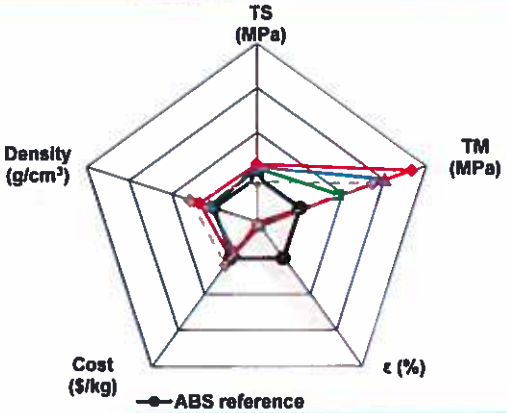
Lighter ABS biocomposites
Replacement of glass fibers by cellulosic fibers



Advantages in using cellulosic fiber that replace partially or totally the glass fibers :

- Equivalent tensile properties;
- Lower material density;
- Around 15% cost reduction comparing to ABS/30% glass fibers commercial grade.

- ABS reference
- ABS / 20 wt.% WF
- ABS / 40 wt.% WF
- ABS / 20 wt.% WF / 20 wt.%GF
- ABS / 30 wt.% GF commercial grade

20 to 40% cellulosic content

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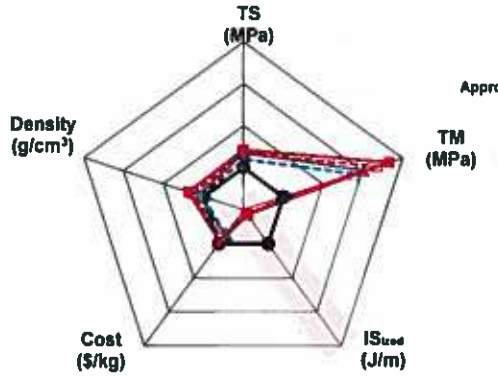
Lighter ABS biocomposites Processing: Injection foaming

Excellent mechanical properties and cost for foamed ABS based biocomposites



Approximate prices ($/kg) on the market of polymers and cellulosics:

ABS	WF
3.6	1.5

Cost and weight reduction

Cellulosic contents:	20%	40%
Price ($/kg) – ABS/WF	3.2	2.8

Replacing up to 40% of ABS by cellulosics results is a 12-25% cost reduction.

ABS biocomposites foaming allows a further 8% weight reduction which translates in a supplementary 8% reduction of material cost .

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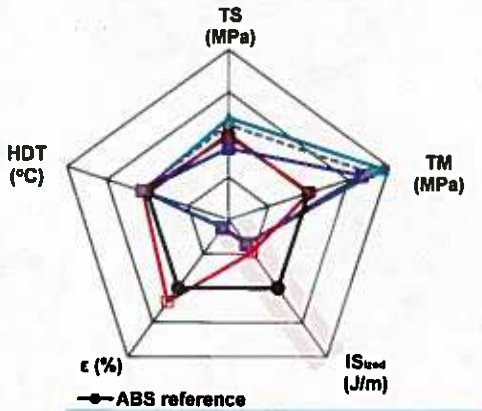
Bioblends and biocomposites based on Greener ABS/PLA blends

Properties of ABS/PLA based biocomposites with 20 wt.% cellulosic fibers:



- HDT increased up to 92°C for ABS/PLA/20%WF
- ε% and IS decreased as expected for biocomposites

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Summary

- NRC bio-based biocomposites are:
  - Equivalent in terms of mechanical and thermal properties to conventional compounds / composites used currently in automotive;
  - Lower-cost due to a content up to 40 wt.% of renewable resources;
  - Lighter due to:
    - Partial or complete replacement of glass fibers by cellulosics fibers;
    - Foaming in injection molding;
  - Greener when a bioplastic, such as PLA, replaces a part of the PA6 or ABS matrix.

- NRC also developed for automotive part applications:
  - PP and PP/PLA based biocomposites with cost and weight reductions;
  - PA6, ABS and PP based biocomposites with continuous cellulosic fibers using D-LFT process

- These **lower-cost, lighter and greener biocomposites** could replace the petroleum compounds and composites in automotive applications.

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Thank you!

Scientific and technical contributions
Karen Stoeffler, team leader
Michel Carmel, technical officer / injection molding
Florence Perron, technical officer / morphology
Yves Simard, technical officer / compounding
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