Biocomposites and bioblends based on engineering thermoplastics for automotive applications

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BIOCOMPOSITES AND BIOBLENDS BASED ON ENGINEERING THERMOPLASTICS FOR AUTOMOTIVE APPLICATIONS

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National Research Council Canada

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OUTLINE

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- Engineering polymers in automotive applications
- NRC green vision
- Materials, processes and characterization
- Bio-based PA6 and ABS compounds:
  - Low-cost biocomposites
  - Lighter biocomposites
  - Greener bioblends and biocomposites
- Summary of the achievements

About NRC:

- The main Research & Technology Organization in Canada
- 2013-14 budget: **$ 820 M &** Over **3,400** full-time employees
- 4 divisions: Emerging Technologies, **Engineering**, Life Sciences, Industrial Research Assistance Program (IRAP)
- Wide variety of disciplines and broad array of services and support to industry

National Research Council Canada
A Research & Technology Organization

- Mission-oriented providers of innovation services to firms and governments (**R&D services**, **technical services, consortiums, Industrial Research Assistance Program**);
- **Bridges gap** between early stage R&D and technology deployment;
- Dedicated to building **economic competitiveness** and improving **quality of life.**

NRC: Automotive and Surface Transportation

- **Research and technology development:**
  - Fuel efficient vehicles
  - Efficient and sustainable manufacturing
  - Vehicle fleet operation

- **Clients spanning the entire supply chain:**
  - OEMs, Tier 1, Tier 2, material suppliers, etc.
  - Automotive, trucks, mass transit, rail, military
  - Vehicle fleet operation

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

Automotive and Surface Transportation Market Driven Programs


Lightweighting


Vehicle Propulsion Technologies


Industrial Biomaterials


Advanced Manufacturing


Design Systems


Rail Vehicle Track Optimization


Fleet Forward 2020

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 with PA and ABS bio-compounds with similar performances.

PA-based parts represent around 36 pounds/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 pounds/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

NRC green vision

- Substitution of mineral-filled and glass fiber-reinforced engineering thermoplastics with 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, Tubs in floor


Bumpers


Front-end Carriers

Materials

Polymers:

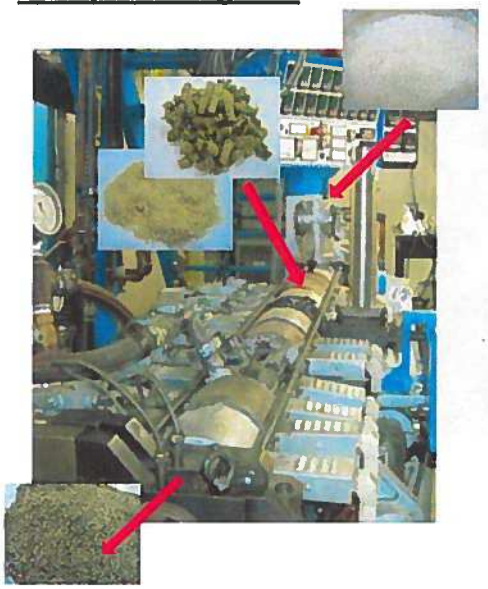
- PA6: injection molding / extrusion grade, Ultramid B27 from BASF.
- ABS: Lustran Elite HH 1827, is an injection molding grade for high-heat automotive applications.
- PLA: 8302D, an amorphous grade from Nature Works, was selected as the bio-sourced minor phase for the production of petro/bio hybrids.
- Coupling agents were used.
- Properties of PA6 and ABS automotive grades were used in graphs for comparison purposes.

Bio-reinforcements and reinforcements :

- 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.

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

Bio-based PA6 compounds

Low-cost biocomposites
Lighter biocomposites
Greener bioblends and biocomposites

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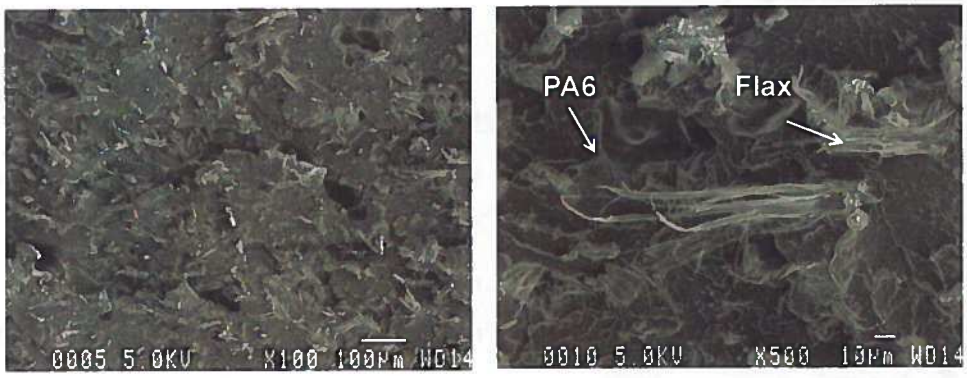
Low-cost PA6-based biocomposites
PA6 partial replacement with cellulosics

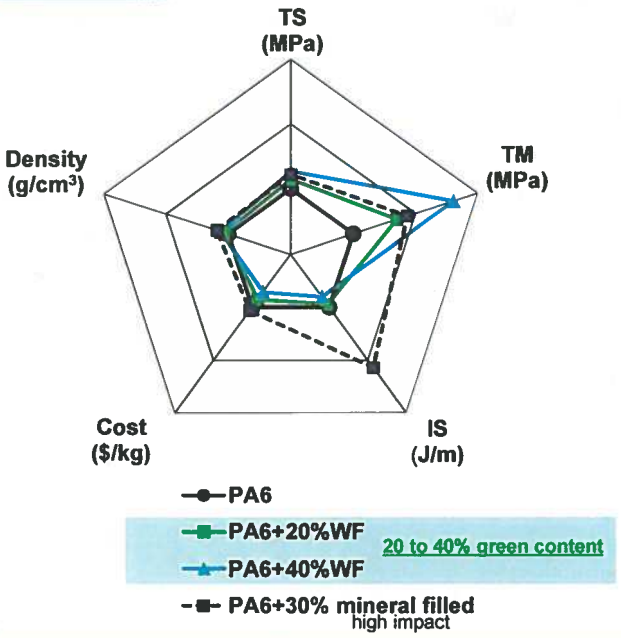
Excellent interfacial adhesion



x100 **x500**

Morphology of PA6/20%flax biocomposites

Low-cost PA6-based biocomposites
PA6 partial replacement with cellulosics



Approximate prices ($/kg) on the market :

PA6	PA6 / 30% minerals	Flax	TMP	WF
4.9	5.3	0.7	0.5	1.5

Cost reduction

Cellulosic contents:	20%	40%
Cost ($/kg) – PA6/Flax	4.1	3.3
Cost ($/kg) – PA6/TMP	4.1	3.2
Cost ($/kg) – PA6/WF	4.3	3.6

Replacing up to 40% of PA6 by cellulosic fibers results is a 18-35% cost reduction .

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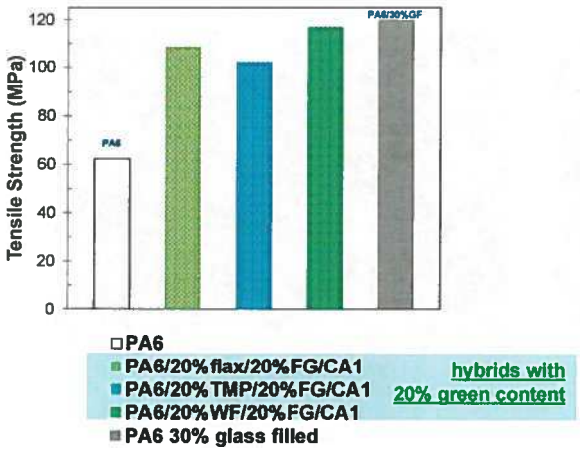
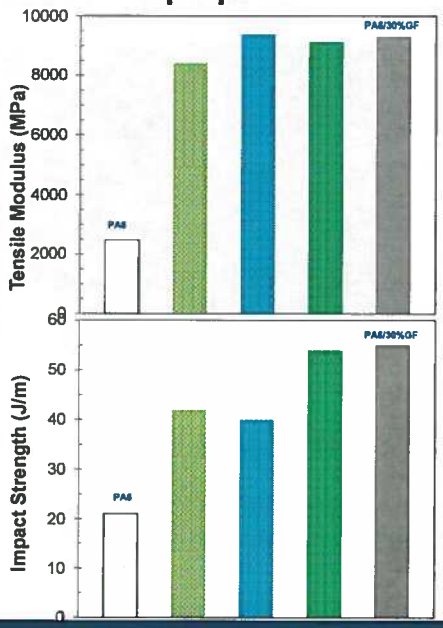
Lighter PA6-based biocomposites
Glass fiber replacement by cellulosic fibers

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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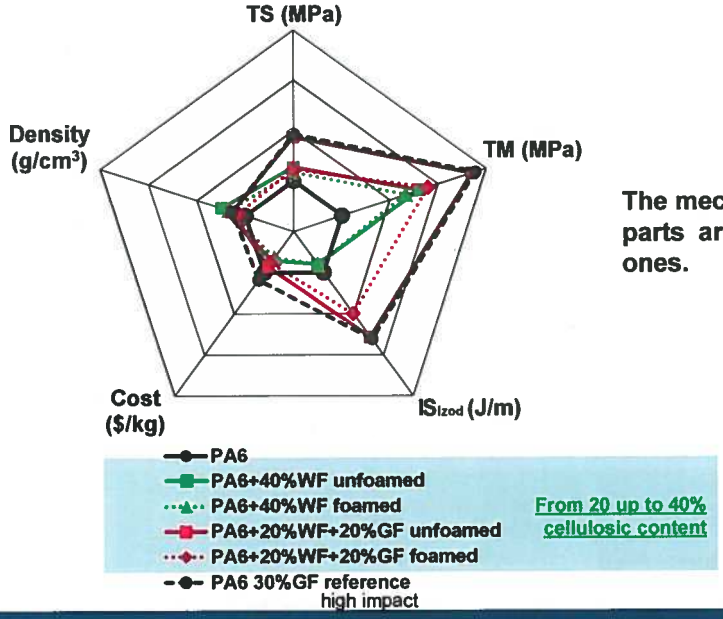
Lighter PA6-based biocomposites
Processing means: Injection foaming

Properties of PA6 biocomposites with 40% WF and hybrids: unfoamed and foamed



The mechanical properties of foamed parts are equivalent with unfoamed ones.

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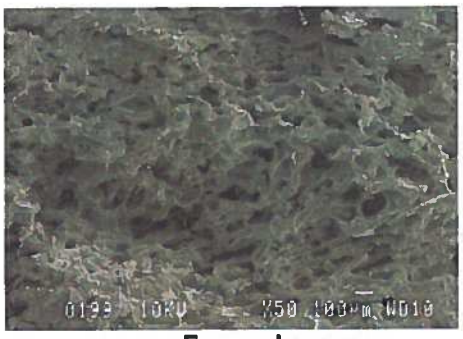
Lighter PA6-based biocomposites
Processing means: Injection foaming

Morphology of PA6/20% cellulosic biocomposites:

Unfoamed



Foamed

Replacing from 20 up to 40% of PA6 by cellulosics results in a 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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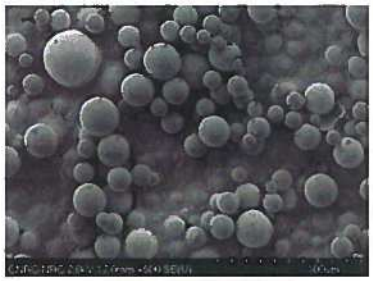
Lighter PA6-based biocomposites
Hollow spheres as additives

Initial aspect of the hollow spheres:

iM30K: density of 0.60 g/cm³



iM16K: density of 0.46 g/cm³

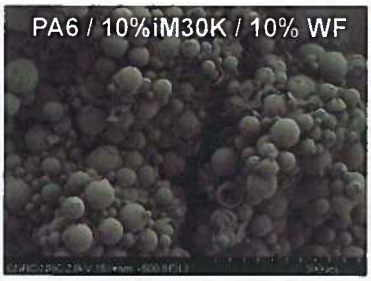
Formulation of extruded composites:

PA6 B27	HS %	Sawdust %
90	10% iM30K	0
80	10% iM30K	10%
80	20% iM16K	0%

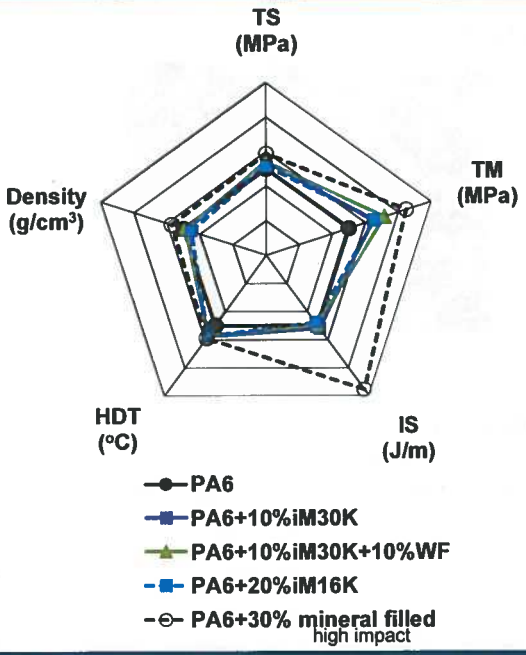
Lighter PA6-based biocomposites
Hollow spheres as additives

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

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



Low-weight PA6-based biocomposites
Hollow spheres as additives



- Excellent mechanical properties;
- HDT increased from 160°C up to 190°C;
- 5% to 12% weight reduction comparing with virgin PA6;
- 20% to 30% weight reduction comparing with PA6 filled minerals

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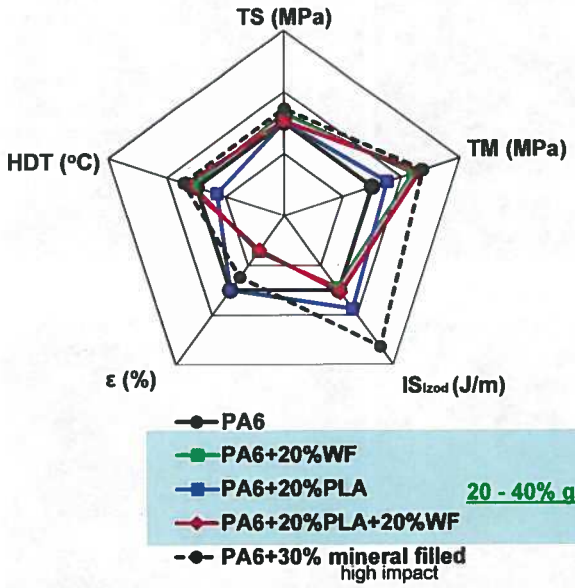
Greener PA6/PLA blends and biocomposites

Properties of PA6/PLA biocomposites with 20% cellulosic fibers



20 - 40% green content

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

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Bio-based ABS compounds

Low-cost biocomposites
Lighter biocomposites
Greener bioblends and biocomposites

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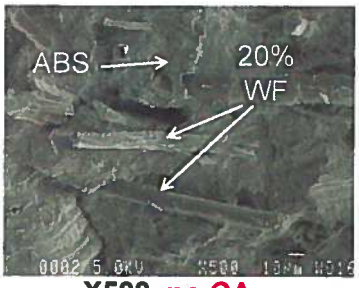
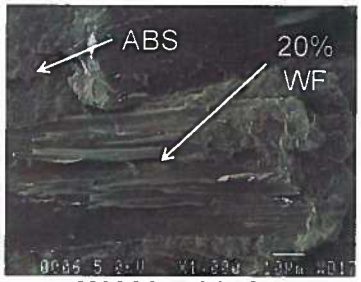
Low-cost ABS-based biocomposites
Partial ABS replacement with cellulosics

Good interfacial adhesion when using CA



X500, no CA

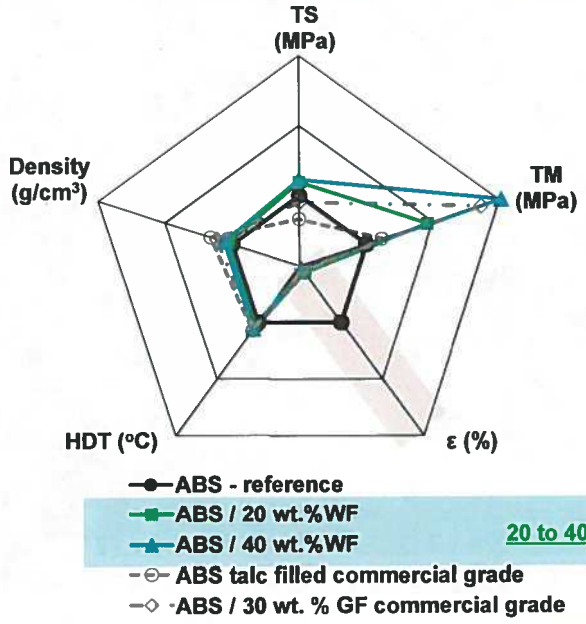
X500, with CA



X1000, with CA

- Very good fiber distribution/dispersion.
- There is no adhesion between the ABS, hydrophobic polymer, and the 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 the mechanical properties of the biocomposites.

Low-cost ABS-based biocomposites
Partial ABS replacement with cellulosics



20 to 40% green content

Approximate prices ($/kg) on the market :

ABS	Flax	TMP	WF
3.6	0.7	0.5	1.5

Cost reduction

Cellulosic contents:	20%	40%
Cost ($/kg) – ABS/Flax	2.7	2.5
Cost ($/kg) – ABS/TMP	3.0	2.4
Cost ($/kg) – ABS/WF	3.2	2.8

Replacing up to 40% of ABS by cellulosic fibers results in a 10-33% cost reduction .

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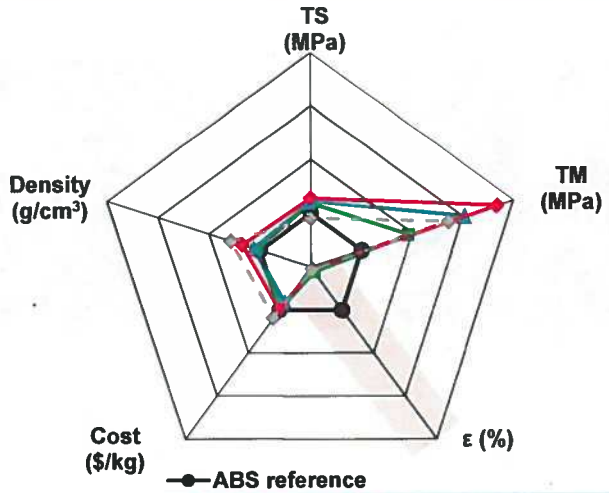
Lighter biocomposites based on ABS
Replacement of glass fibers with cellulosic fibers



20 to 40% cellulosic content

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

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

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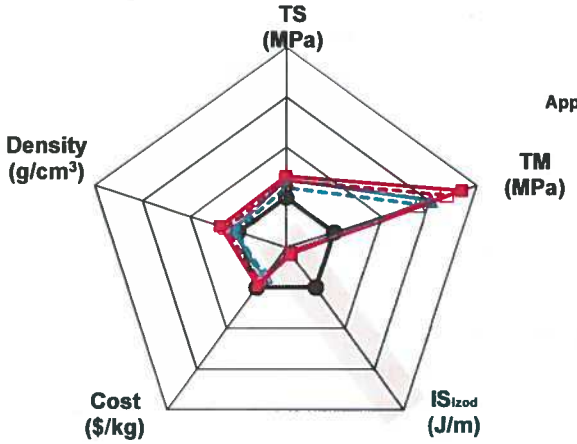
Lighter biocomposites based on ABS
Processing means: Injection foaming

Excellent mechanical properties and cost for foamed ABS based biocomposites



- ABS - reference
- ABS / 40 wt.% WF unfoamed
- ABS / 40 wt. % WF foamed
- ABS / 20 wt.% WF / 20 wt.% GF unfoamed
- ABS / 20 wt.% WF / 20 wt.% GF foamed

From 20 up to 40% cellulosic content

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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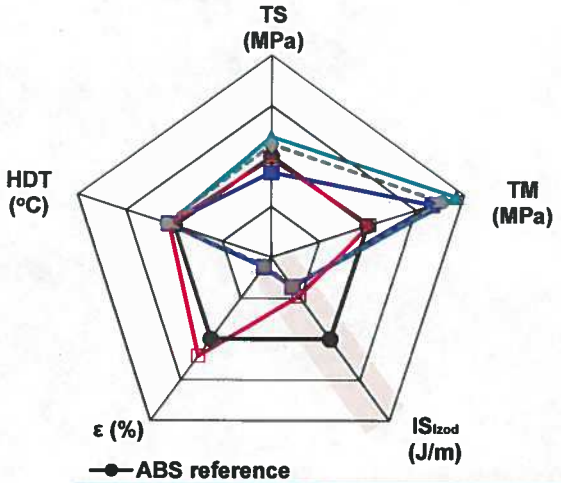
Bioblends and biocomposites based on ABS/PLA blends

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



- ABS reference
- ABS / 20 wt.% WF
- ABS / 10 wt.% PLA
- ABS / 10 wt.% PLA / 20 wt.% WF
- ABS / 30 wt.% GF commercial reference

20 & 30% green content

- HDT increased from 85 up to 92°C for ABS/PLA/20%WF
- ε% and IS decreased as expected for biocomposites

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Summary of the achievements

- NRC bio-based biocomposites are:
  - **Equivalent in terms of mechanical and thermal properties than those of conventional materials used currently in automotive;**
  - **Low-cost due to a content up to 40 wt.% of renewable resources;**
  - **Low-weight due to:**
    - **Partial or complete replacement of glass fibers by cellulosics fibers;**
    - **Foaming in injection molding;**
  - **Greener when a bioplastic 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

- NRC can help you formulate and process **low-cost, lighter and greener biocomposites and bioblends** according to the specifications of your products.

Thank you!

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