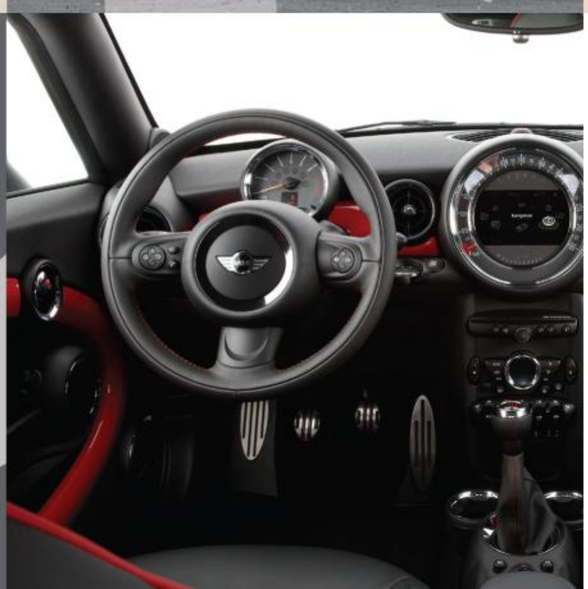


Renewable Composites for Automotive Applications

February 2013

Alex Baltazar, Ph.D.
Product & Process Development

Edmonton, Alberta

About MAGNA

We are a global supplier of automotive systems with design, engineering and manufacturing capabilities

Partnership

MAGNA EXTERIORS & INTERIORS

- In 2012, we partnered with the following organizations in an initiative to develop high performance polymer composites for high-volume automotive applications using renewable fibers

- The government of Alberta, through Alberta Innovates-Bio Solutions, joined the Centre for Research & Innovation in the Bio-economy (CRIBE) in supporting this important project

- The technology developed will be the result of collaborative efforts together with Alberta Innovates-Technology Futures (AITF), the National Research Council (NRC) and Alberta Bio-materials Development Centre (ABDC)

Government of Alberta
Agriculture and Rural Development

CRIBE

Alberta Innovates Technology Futures

Alberta Innovates Bio Solutions

ONTARIO BIOAUTO COUNCIL

NRC·CNRC Canada

ABDC
Alberta Biomaterials Development Centre

Main Objectives

- Address global requirements for cost and weight reduction in automotive parts with high performance polymer composites reinforced with renewable fibers
- Develop the product technology required to integrate Canadian-sourced forestry products into exterior and interior automotive applications
- Match or surpass the required mechanical and physical properties offering a lower cost and lighter weight option
- Improve fuel economy for consumers in a cost-effective and sustainable solution
- Maintain and create jobs in the automotive and pulp and paper industries with Canadian-sourced renewable materials
- Preliminary results are being generated but no detailed information available for disclosure at this time

Renewable Composites for Automotive Applications

Natural Fiber: Definition

"Naturally occurring fibres from plants and animals, which can be easily processed into yarn for textiles"

Common Fund for Commodities

Works well for some fibers

Cotton

Wool

Yarn

Doesn't work for others

Feathers

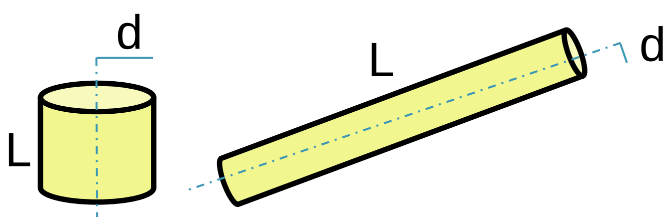
Wood Fiber & Pulp

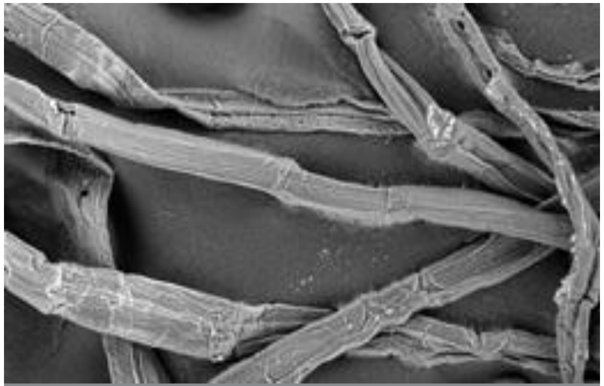
http://www.fao.org/docrep/011/i0709e/i0709e00.htm

Natural Fiber: Characteristics

Fiber Characteristics

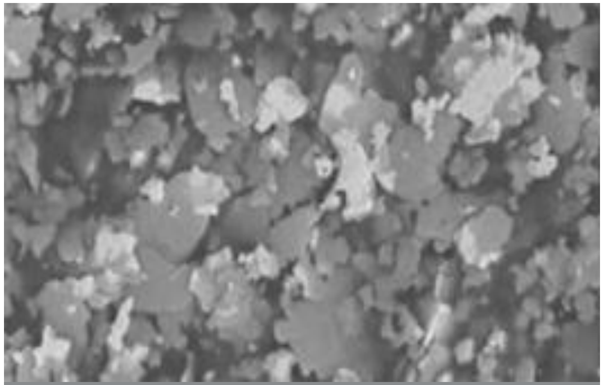
- High aspect ratio (l/d)
- High tensile strength
- Flexibility





Wood Fiber

⌀: 30 µm
L: > 1,000 µm



Wood Pulp

⌀: > 100 µm
L: < 800 µm

http://www.fao.org/docrep/011/i0709e/i0709e00.htm

Natural Fiber Crops: Uses

- **Natural Fiber Crops, a source of:**
  - Food – e.g. hemp seed
  - Fibers – e.g. flax twine, rope
  - Building material – e.g. wood

- **Archeological evidence:**
  - Textiles – 4,000 years, China
  - Wheat straw-clay bricks – 3,000 years
  - Many others uses for native crops in different parts of the World (Abaca in the Philippines, etc.)

- **First artificial fiber produced from wood:**
  - France: > 120 years ago

Abaca

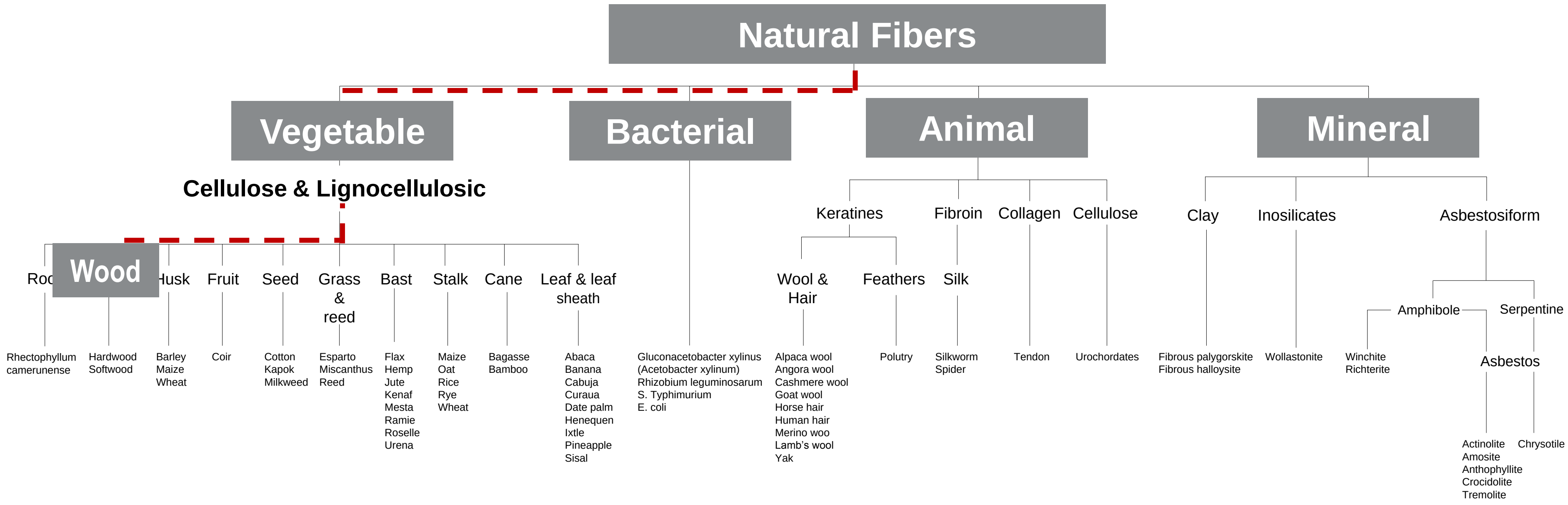
Hemp seeds

Clay brick

Flax rope

Artificial fiber

Natural Fiber Classification - Origin

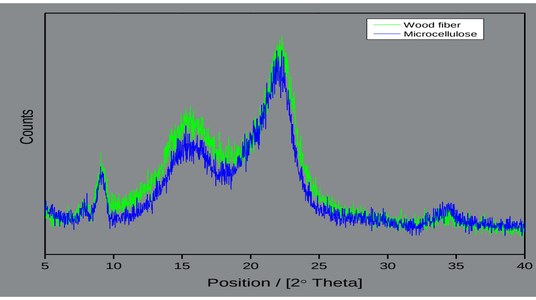


Natural Fibres For Automotive Applications. Handbook of Natural Fibres Vol. 2. Processing and Applications (Ed. Ryszard M. Kozlowski), Woodhead Ltd., A. Baltazar, M. Sain, 2012

Vegetable Fibers: Material Advantages

MAGNA EXTERIORS & INTERIORS

Reinforcing capability
Homogeneous quality
Semi-crystalline material
Surface properties can be modified

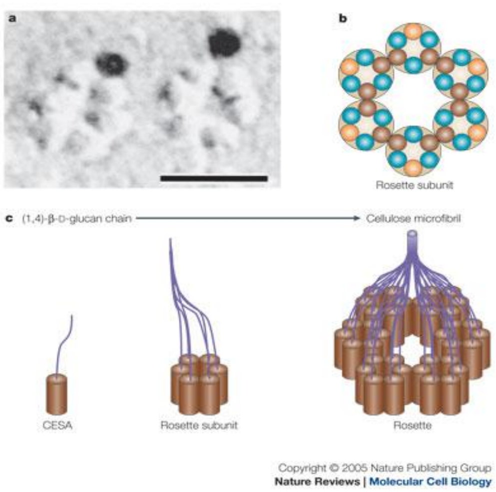


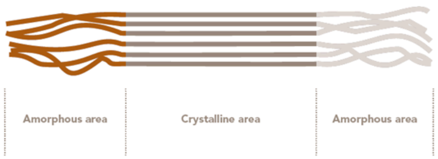
- **Lower Density (g cm^{-3})**
  - Glass Fiber: ~ 2.5
  - Wood Fiber: ~ 1.5

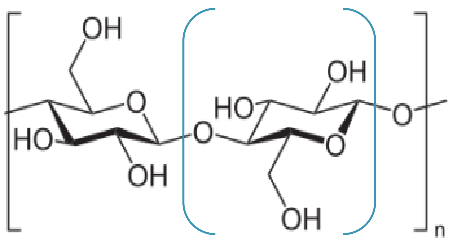
- **Lower Cost ($/lb)**
  - Glass Fiber: ~ $ 1.00
  - Wood Fiber: ~ $ 0.50

– **Lower Energy Consumption (MJ/kg)**
  - Glass Fiber Mat: ~ 55.0
  - NF Mat: ~ 10.0

- **Huge Availability**
  - Forestry, Marine, Agricultural Sources
  - Estimated 3,000 BN t worldwide







Cellulose chains are produced in the plant cell by terminal complexes or rosettes in a packed or random fashion thus forming crystalline and amorphous regions

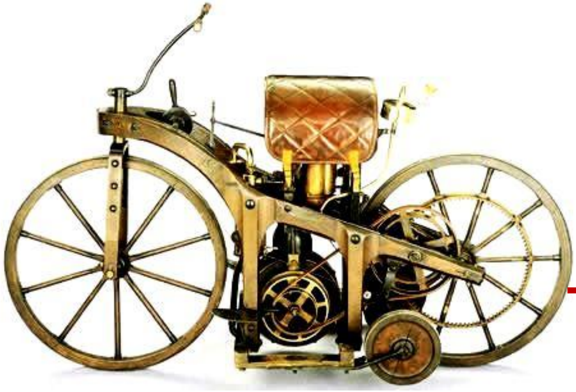
Crystallite size and lattice perfection have an effect on the optical, mechanical, thermal and chemical properties

Natural Fibres For Automotive Applications. Handbook of Natural Fibres Vol. 2. Processing and Applications (Ed. Ryszard M. Kozlowski), Woodhead Ltd. 2012, Baltazar A, Sain M, 2012
Cosgrove, D. J. (2005). "Growth of the plant cell wall." Nature Reviews Molecular Cell Biology 6(11): 850-861. http://www.nature.com/nrm/journal/v6/n11/fig_tab/nrm1746_F3.html

Natural Fiber: First Vehicle Applications

2,600 BC – the Standard of Ur shows four-wheel vehicles - archeological evidence suggest the use of wood

1941 - Ford Motor Company used hemp, ramie, wood flour and other NF in a phenol-formaldehyde resin



1885 – Daimler-Maybach motorcycle used a solid wooden structure

1962 – VEB Trabant used cotton waste in a phenol resin

Natural Fiber: Vehicle Applications

MAGNA
EXTERIORS & INTERIORS

1990s - Renewable & sustainable fibers, coconut fibers in backrests, head restraints, seat cushions and sun visors
Flax, sisal and abaca fiber-reinforced parts

THE UNIVERSITY OF WARWICK

WMG
Innovative Solutions

F3 Racing Car - Made from recycled water & juice bottles, renewable polymers, carrot, flax and hemp fibers, soy-based foam seats

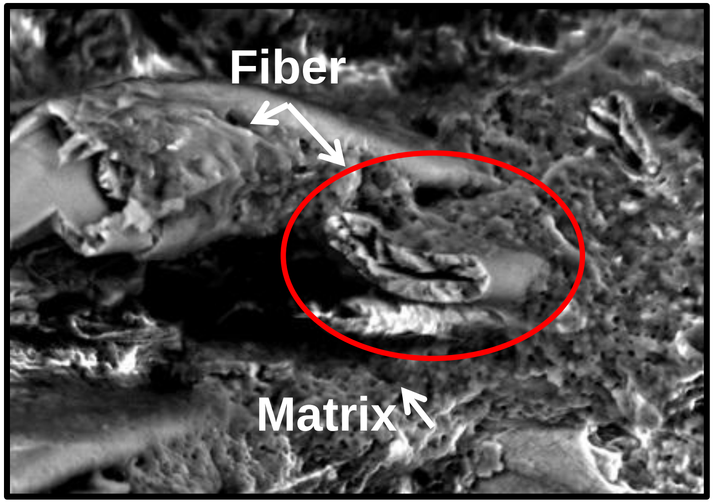
worldF3rst
A force for sustainable motor racing
RACING

Fiber-Reinforced Polymer Composite: Definition

- Fiber-reinforced polymer composites encompass:
  - fibrous phase embedded into a
  - polymer matrix phase, and a
  - fiber-matrix interface

  - typically anisotropic:
    - properties depend on the direction measured

  - typically synergistic effect:
    - properties are much greater than the individual phases

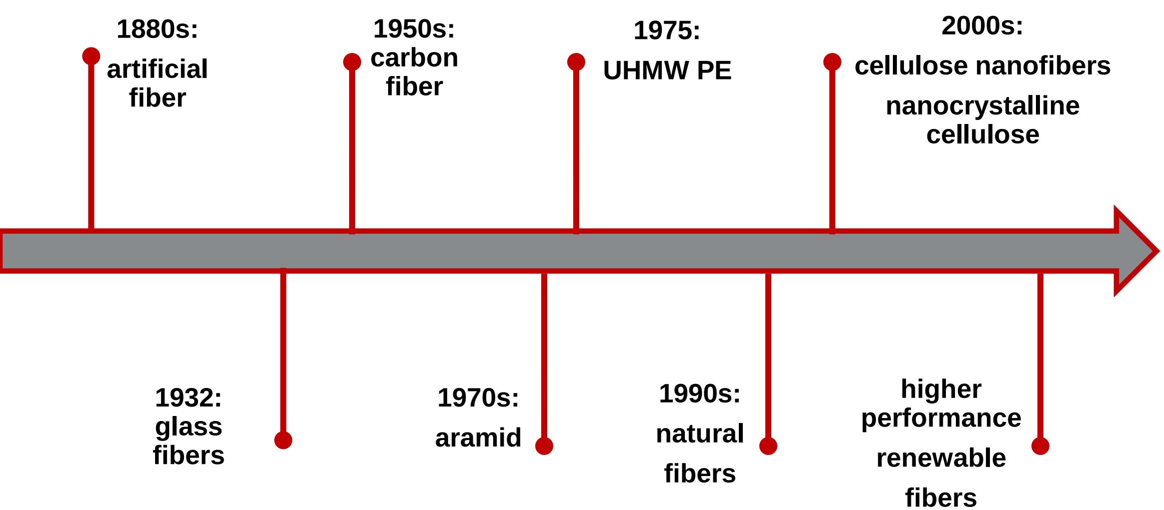


VDI - Plastics in Automotive Engineering, Mannheim, 21. 2012; VDI – Plastics in the Automotive Engineering of the Future, 17. 2011; ALTECH NXT PP: Higher Temperature PP-based Composite Provides Nylon/PA-level Performance at Lower Weight & Economic Feasibility, SPE, ACC Conference, Sep. 13, 2012, ALBIS Group

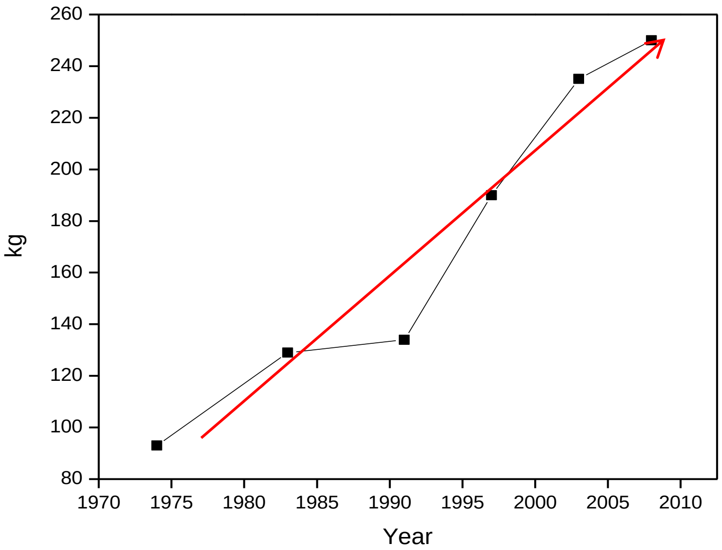
Fiber-Reinforced Polymer Composite: Growth

MAGNA EXTERIORS & INTERIORS

- Use of fiber-reinforced polymer composites will continue to grow in the automotive industry



Evolution of reinforcing fibers in polymer composites



Historical use of polymers in a specific vehicle

VDI - Plastics in Automotive Engineering, Mannheim, 21. 2012; VDI – Plastics in the Automotive Engineering of the Future, 17. 2011; ALTECH NXT PP: Higher Temperature PP-based Composite Provides Nylon/PA-level Performance at Lower Weight & Economic Feasibility, SPE, ACC Conference, Sep. 13, 2012, ALBIS Group

Why develop Natural Fiber Polymer Composites?

MAGNA EXTERIORS & INTERIORS

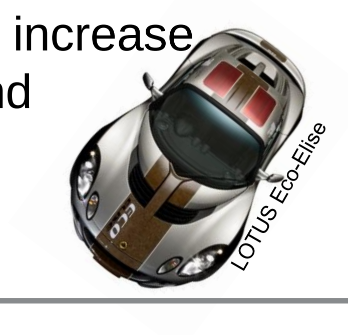
- Massive vehicular stock worldwide:

International Energy Agency (iea)

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD)

800 million in 2002 → 1.0 billion in 2010 → 2.5 billion by 2050

- Huge strain on the environment and depletion of non-renewable resources
- Need to find new ways to increase efficiency, renewability and sustainability of current automotive systems and materials



~10 % CO_2 emissions produced by a car in its lifespan come from vehicle manufacture

~10 % energy used by a car in its life span is required for its manufacturing

- **Natural fiber polymer composites offer the potential to be:**

  - **Low cost**
  - **Renewable**
  - **Socio-economically sustainable**
  - **Similar or better in performance**

VDI - Plastics in Automotive Engineering, Mannheim, 21. 2012; VDI – Plastics in the Automotive Engineering of the Future, 17. 2011; Dargay et al 2007 in Natural Fibres For Automotive Applications. Handbook of Natural Fibres Vol. 2. Processing and Applications (Ed. Ryszard M. Kozlowski), Woodhead Ltd. 2012, Baltazar A, Sain M, 2012

Reasons for Change? Global Requirements

New forestry-based products must help achieve:

INDUSTRY

- Cost savings
- Increase vehicle fuel economy
- Reduce component weight
- Reduce demand of non-renewables
- Increase recycling rate in ELVs
- High volume production
- Lower energy input
- Environmentally friendly
- Socio-economically sustainable

LEGISLATION

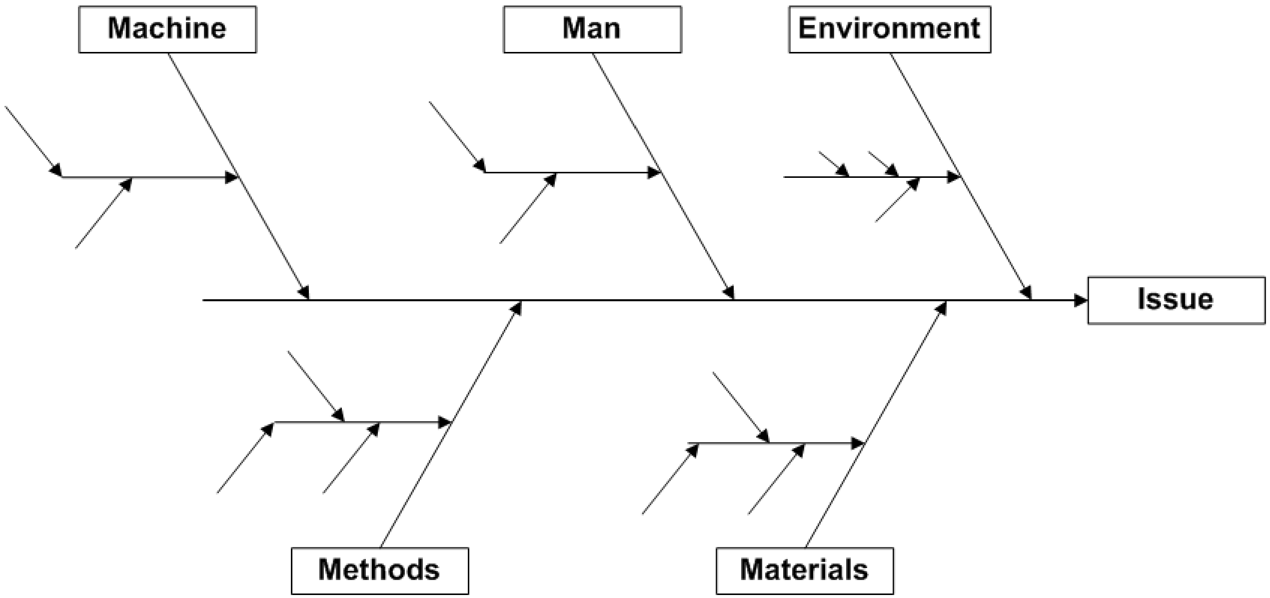
- Corporate Average Fuel Economy
  sets higher fuel efficiency targets:
  - Now: 26.4 mpg
  - 2025: 54.5 mpg

- CO_2 targets – (EC) 443/2009
  sets targets and penalties for CO_2 emissions:
  - 2015: 130 g CO_2/km
  - 2020: 95 g CO_2/km

- ELV – (EC) 2000/53/EC
  increases the recovery rate of vehicles by 2015:
  - 85 wt.% recyclable/reusable (min)
  - 10 wt.% incineration (max)
  - 5 wt.% landfill (max)

Where Do We Start? - Some Technical Issues

Some Technical Issues of Wood Fibers
Low thermal resistance
Odor after processing
High moisture absorption
Low fungi resistance
Difficulties in feeding & metering
Low fiber-matrix adhesion
Low fiber dispersion



Fishbone (Ishikawa) diagram provides a good tool to find the root cause of the problem

Where Do We Start? - Sourcing & Testing

Together with AITF and R&D partners we work on:

- **Selecting the right wood fiber:**
  - Hardwood
  - Softwood
  - Wood Species
  - Pulping Methods
  - Availability on large scale
- **Analytical Characterization:**
  - Thermal
  - Physical
  - Chemical
  - Geometry
  - Mechanical
  - Volatile Organic Compounds
- **Processing suitability:**
  - Health & Safety
  - Feeding & Metering
  - Processing Technologies

Alberta Innovates Technology Futures

Wood chips.
All the Wood Fibers were sourced in Canada

http://www.pelletstoves.ie/page26.php

Where Do We Start? - Processing

We identified specific applications and processing technologies suitable for wood fiber polymer composites:

- Traditionally processing is similar to glass-fibre polymer composites
- We developed a method that avoids wood fiber thermal and mechanical degradation that results in significantly better composite performance
- The goal will be to increase percentages of wood fiber for further optimized performance

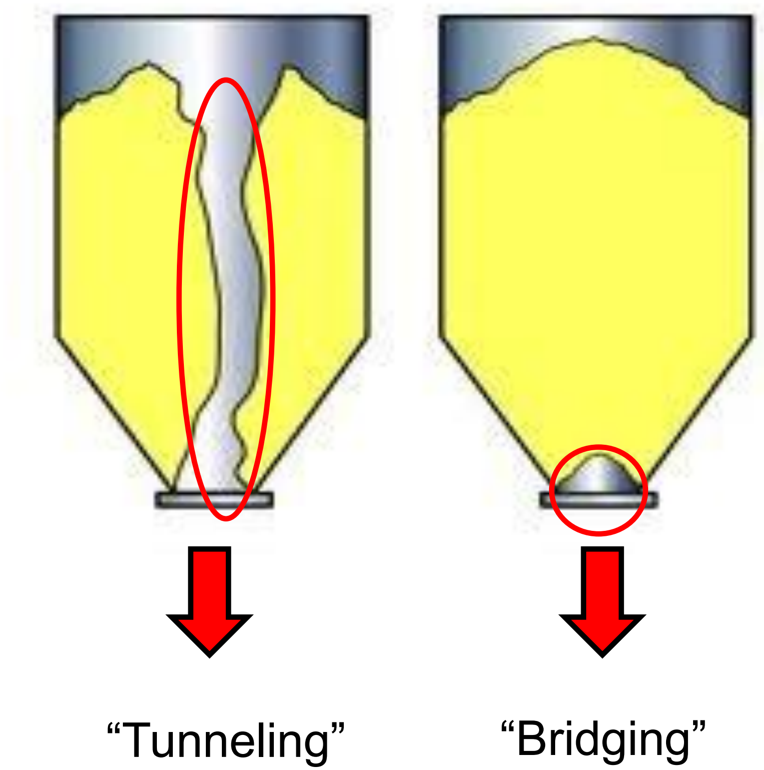
Many applications for wood fiber polymer composites can be found in Exterior and Interior parts

Where Do We Start? - Metering & Feeding

MAGNA EXTERIORS & INTERIORS

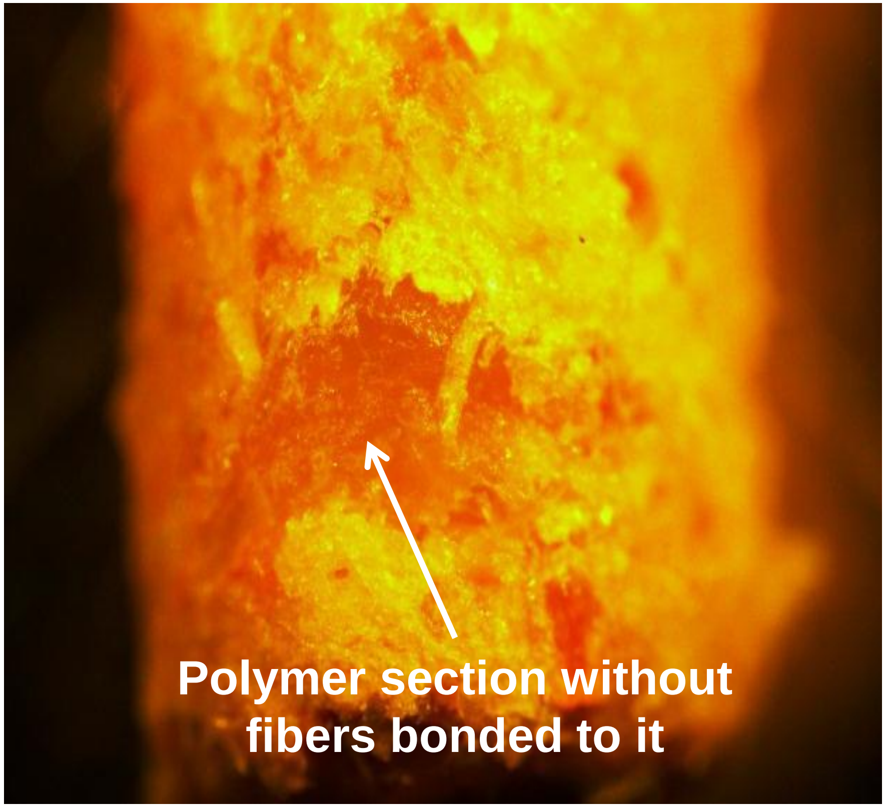
- Wood Fibers have low bulk density
- Bulk density:
  - ratio of mass to volume that includes interparticulate void volume
  - is not a material property, it can change during material handling, transportation and storage
  - depends on the spatial arrangement of particles; cohesive strength, geometry and other factors
  - typically low bulk density materials produce erratic flow in conventional metering and feeding systems
- We developed a way for accurately metering & feeding WF that allows for reproducible results

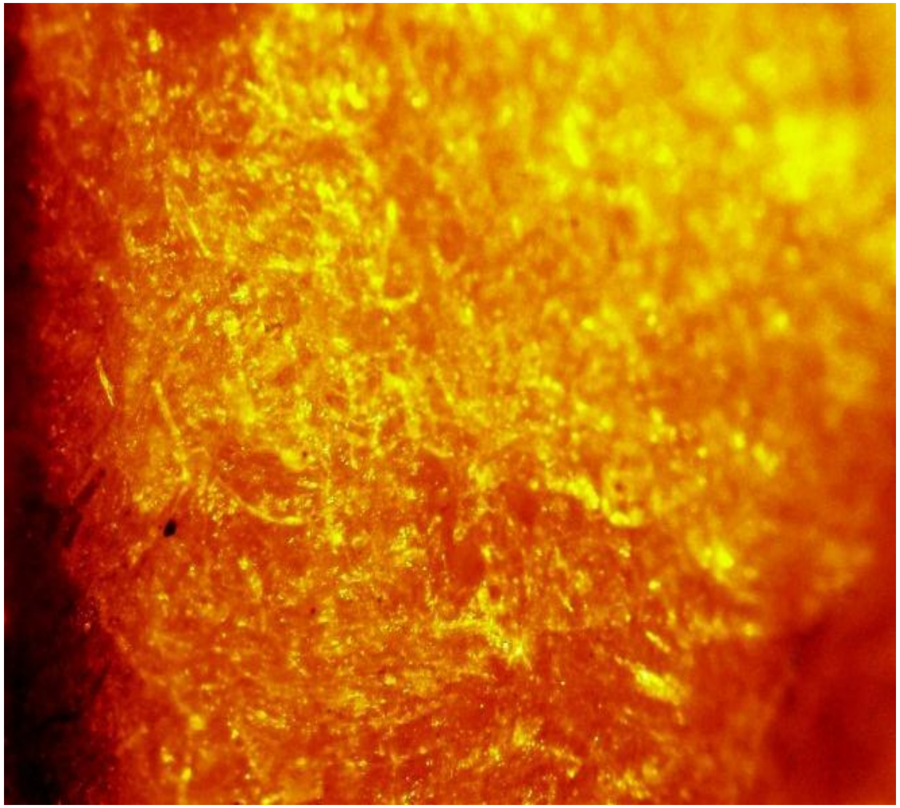
Erratic Flow Examples



Where Do We Start? - Dispersion in the Matrix

Partial	Full





Dispersing WF in the polymer was achieved successfully during the initial part of the R&D through a synergistic effect

Conclusions & Acknowledgements

MAGNA EXTERIORS & INTERIORS

- **Global requirements for cost and weight reduction of auto parts can be addressed in part with high performance polymer composites reinforced with renewable fibers**
- **In certain applications, glass fiber can be substituted with renewable fibers while providing the required mechanical and physical properties and offering a lower cost and lighter weight option**
- **This in turn will provide improved fuel economy for consumers in a cost-effective, sustainable solution**
- **This initiative will help create jobs in the automotive and pulp and paper industries**

Alberta Innovates Technology Futures

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The future is ours to make.