



Lightweighting of Automotive Vehicles


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CANMET MTL; Natural Resources Canada

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CANMET MTL



MTL is a federal laboratory reporting to the **Minerals and Metals Sector** of the department **Natural Resources Canada (NRCan)**

MTL's Mandate for research in automotive issues within NRCan:

- Energy efficiency
- Greenhouse gas emission reduction
- Value-added use of materials
 - steel, aluminum, magnesium, other metals, polymer-based materials
- Industry Competitiveness and Productivity
 - auto industry strongly linked into the Canadian economy
- Efficient use of natural resources

Canada's Natural Resources – *Now and for the Future*

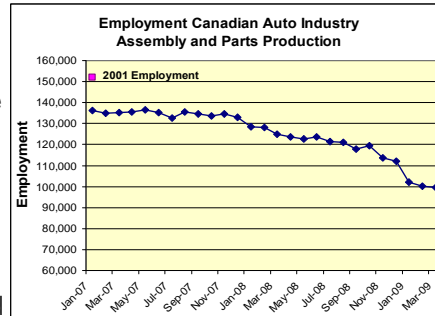
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Auto Industry in Canada



- The automotive industry is Canada's largest manufacturing sector (2006 data ...)

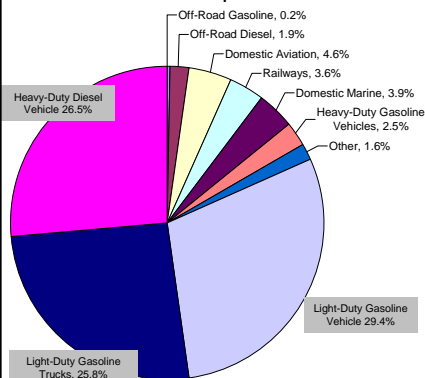
 - 12 percent of manufacturing GDP
 - 24 percent of manufacturing trade
 - Employed 158,302 people in automotive assembly and component manufacturing, 336,212 in distribution and aftermarket sales and service.
 - One in seven jobs in Canada; and one in six jobs in Ontario, are related to the automotive industry



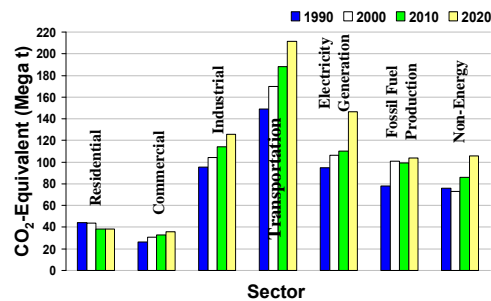
Emissions



😊 Passenger vehicles + light trucks
~55% of transportation emissions



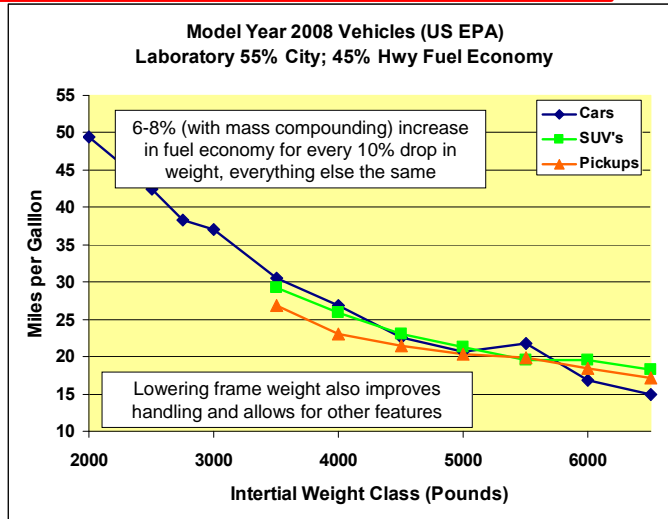
Source: Canada's GHG Emissions from Transportation in 2004



😊 Transportation sector
Heaviest contributor to GHG emissions

Source: NRCAN, Canada's Energy Outlook: 1996 - 2020

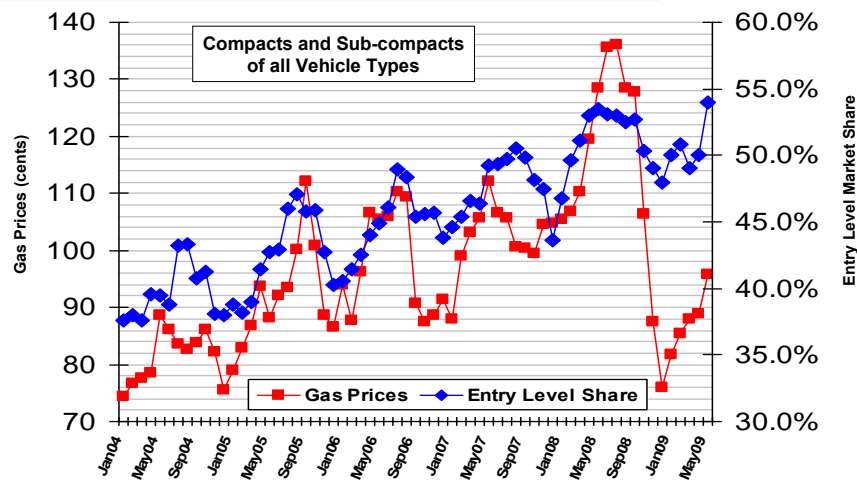
Weight Vs Fuel Efficiency



Canadian Consumer Preferences


Entry Level Market Share vs. Gas Prices

Jan. 2004 – May 2009




Source: MJ Ervin & Associates, DesRosiers Automotive Consultants Inc.

Light weight options



- Light weight structures
- Powertrain
- Innovations in manufacturing process
 - Heat treatment development
- Component design




BMW Group **Technical Features**
Intelligent Light Weight Construction

Aluminum Hood
Magnesium Center for Instrument Panel
Cast Aluminum Front Strut Tower
Intelligent use of Ultra High Strength Steel

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Structure



Lightweight Materials Goal: *By 2015, validate the cost-effective 50% reduction of the weight of passenger vehicle body and chassis systems with safety, performance, and recyclability comparable to 2002 vehicles*

Light Duty Vehicle -
Materials Road Map

Heavy Duty Vehicle -
Materials Road Map

Source:
USDOE

Properties and Manufacturing Goals

Multi-material Enabling Goals

Modeling and CMS Goals

AHSS Research Topics

Mg Research Topics

Al Research Topics

Etc.

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Structural Materials

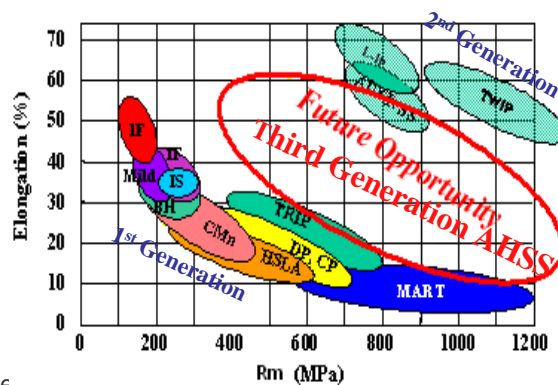


- New Generation Steels
 - Development of UHSS (TWIP and TRIP)
 - Dynamic properties and welding of AHSS
- Light metals
 - Advanced Magnesium Technologies
 - Aluminum alloys
- Composites

Advanced High Strength Steels Development



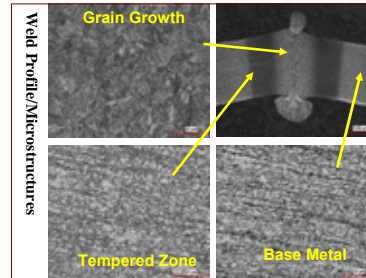
- Conventional High Strength Steel (Ferrite based)
- 1st Generation (Ferrite Based)
 - TRIP, DP, CP,
 - Martensitic, Bainitic
- 2nd Generation (Austenite Based)
 - TWIP
 - L-IP (High Al)
 - Austenitic Stainless steel
- 3rd Generation (Multiphase)
 - Potential constituent phase
 - Martensite, Ultrafine grained ferrite
 - Austenite



New Generation Steels



- Design and process lean steel to avoid additional costly alloying elements
- Avoid additional heat treatments such as soft annealing or tempering
- Optimize strength and ductility by microstructure control
- Advanced thermomechanical processing to exploit phase transformation, recrystallization and controlled cooling to tailor microstructure and properties
- Maintain compatibility with enabling technologies: weldability, coatability and formability (hydroforming), etc

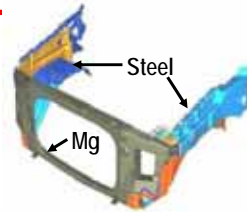
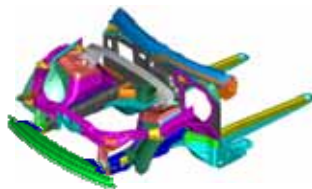


USAMP Mg Front End Design - Summary



Unibody (BFI, Cadillac)

Body on Frame (F-150)



Steel baseline design
79 Parts & 84.3 kg

Magnesium design
35 Parts & 46.1 kg

**38.2 kg mass reduction (45%)
44 part reduction (55%)**

Steel baseline design
16 Parts & 70.7 kg

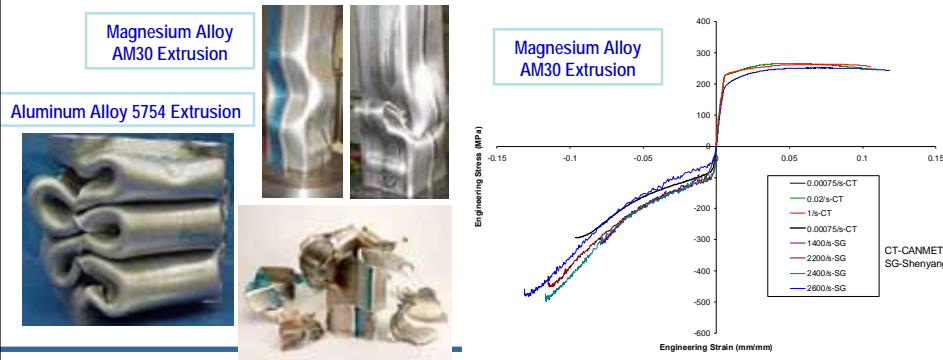
Magnesium design
3 Castings & ~37.5 kg

**33.2 kg mass reduction (47%)
13 part reduction (81%)**

Crashworthiness



- Despite the initial buckling deformation, all three Mg alloys showed pervasive fracture in crash loading, which is less desirable for automotive applications compared to Al or steel

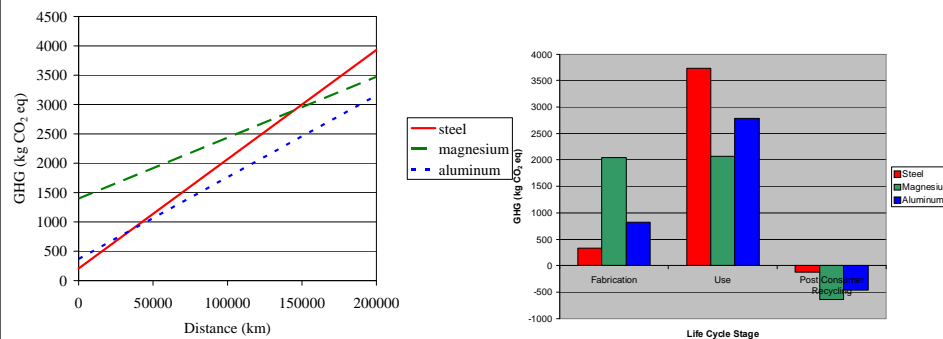


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LCA - Global Warming Potential



- Alain Dubreuil, CANMET MMSL, NRCAN
- Sujit Das, Oak Ridge National Laboratory



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Diesel engines



- 45 million cars were produced in 2002
- 60% gasoline engines in aluminum (weight savings 50%)
- Europe was switching to diesels
 - 39% all cars (14 million) sold in 2003 were diesels
 - France 67%, Austria 71%
 - Daimler-Chrysler was 80% diesel in 2003
 - Turbo-charged common rail diesel
- Significant growth in diesel engines is expected for NA
- If North American SUVs and light trucks were switched to diesel, the energy and emissions would be reduced by 15%. In 1996, a cast iron V8 and transmission weighed 700 lbs.

Materials for powertrain (passenger vehicles)

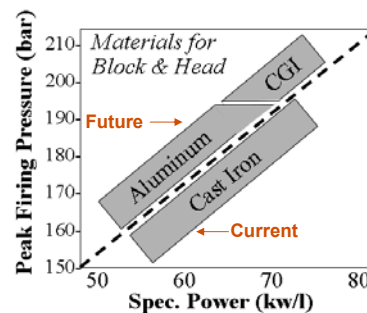


Aluminum alloys


- Al-Si-Mg alloys (ex: A356, A357)
 - good ductility, lack of strength >250°C
- Al-Si-Mg-Cu alloys (ex: A356 + 0.5% Cu)
 - good ductility, retaining strength between 200-250°C
- Al-Si-Mg-Cu alloys with Mn, Zr, V, Ti and Cr
 - (ex: A356+1%Cu+0.15%Zr+0.15%Cr and A319+0.15%Mn+0.25%V+0.15%Zr)
 - lower ductility, higher YS and creep at 250°C

Cast Irons

- Gray iron
- Compacted graphite iron
- Ductile iron



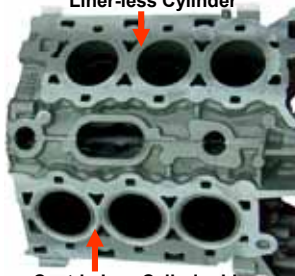
Advantages of Al-made Components for Gasoline Engines



1. Application of light weight alloys

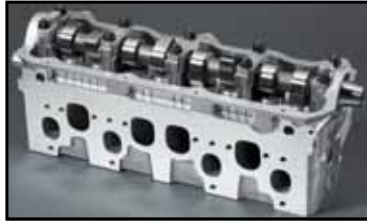
Powertrain

Liner-less Cylinder




3.0l V6 Engine Block (Al-Si-Cu alloy)

Cast-in Iron Cylinder Liners



Heat resistant Al Cylinder Head (Al-6%Si-3%Cu alloy)




Forged Al Piston (Al-11%Si-3%Cu-0.5%Mg alloy)

- ☺ 30% Engine downsizing
- ☺ 10-15% less engine weight
- ☺ 10-20 % less CO₂ emissions

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Al Castings for Engine Applications in Passenger Vehicles



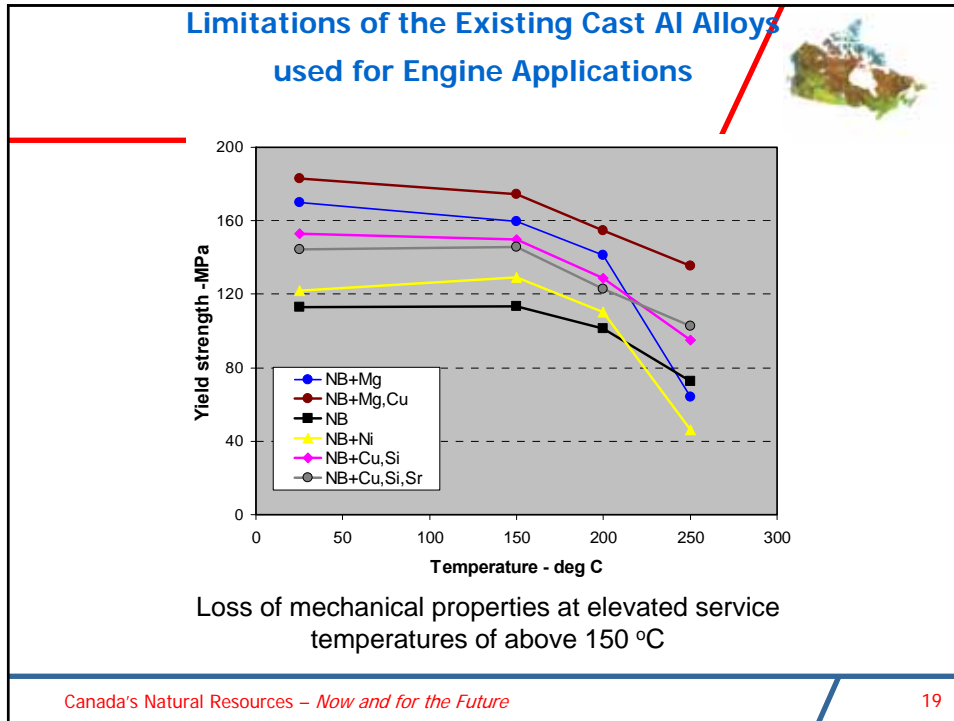
Components	Engine Block	Cylinder Head	Piston
Alloy System	Al-Si-Mg-(?) Al-Si-Cu-(?)	Al-Si-Mg-(?) Al-Si-Cu-(?)	Al-Si-Cu-Ni-(?)
Operating Temperature (°C)	135	250	400
Operating Pressure (bar)	-	>180	-
HCF (MPa)	180	140	>200
Creep $\sigma_{0.1/100}$	-	44	-
SDAS (μm)	20	20	-
Process	LPSP, HPDC	SPM	SPM, Forging
<p><i>LPSP - Low Pressure Sand Package</i></p> <p><i>SPM - Semi-Permanent Mold</i></p> <p><i>HPDC - High Pressure Die Casting</i></p>			

Limitations:

Elevated operating temperature and internal pressure disqualify existing Al alloys for small, turbocharged, energy efficient automotive engines

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Examples of Aluminium Cast Components for Automotive Powertrain Applications

Alloy	390 (Al-18%Si)
Casting process	LPPM
Heat treatment	T5

LPPM – Low Pressure Permanent Mold

↓ ↓

V6 3.2l cylinder block V8 4.2l cylinder block

Alloy	DiASil (Al-20%Si)
Casting process	Vacuum HPDC
Heat treatment	T6

HPDC – High Pressure Die Casting

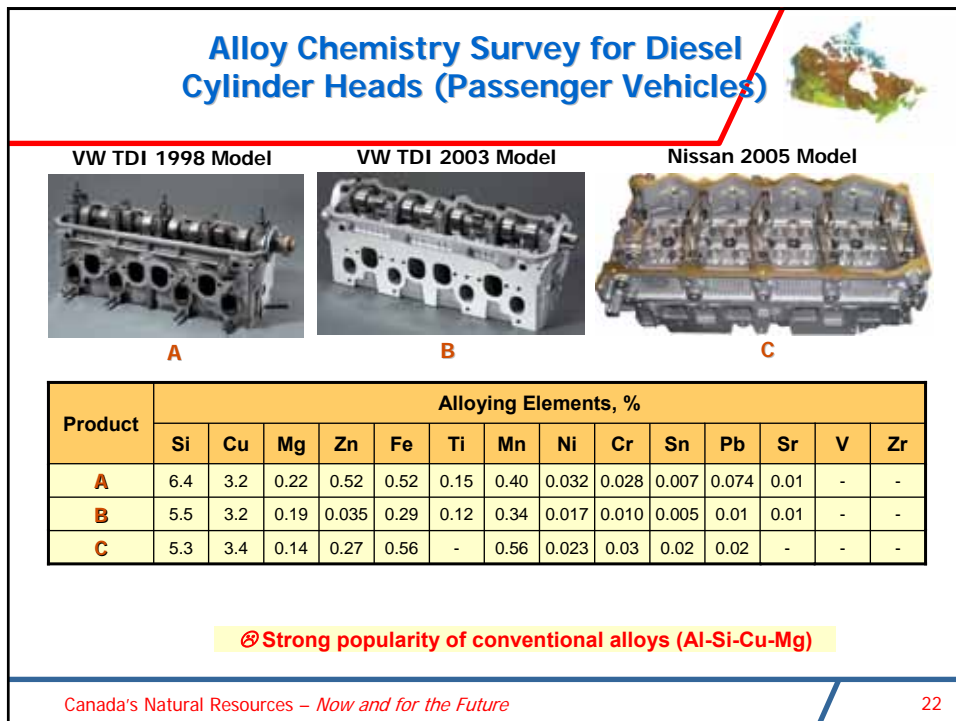
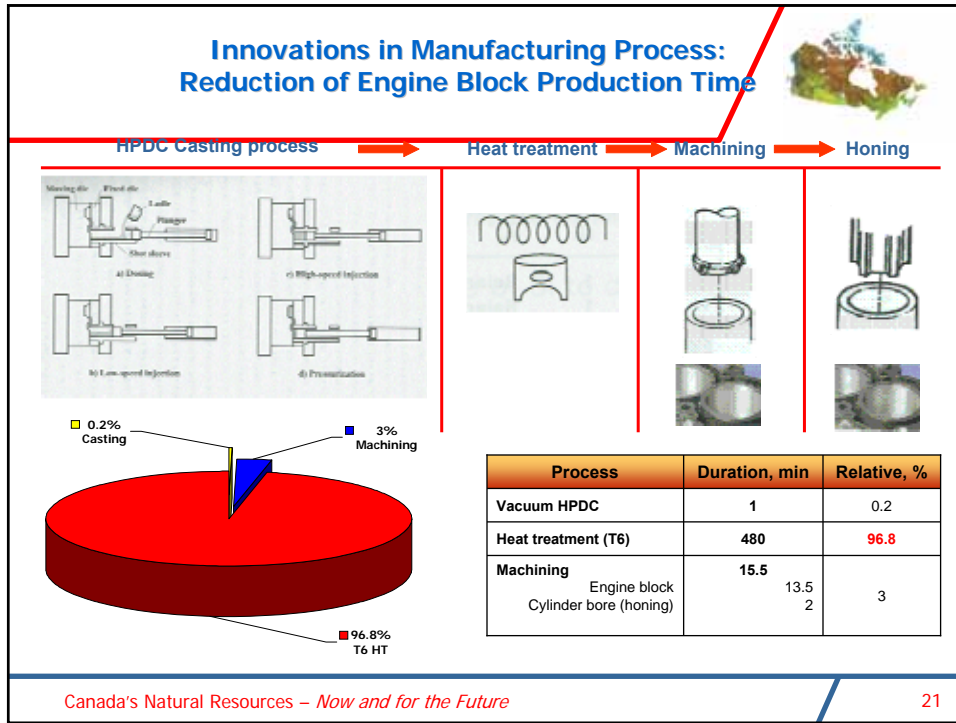
Yamaha Majesty

The 250cm³ cylinder block

100x

J. L. Jorstad, The Progress of 390 Alloy: From Inception until Now, AFS Transaction 2009, 09-152SA
 Courtesy of: Essen Motor Show 2007; MTM Audi A5 V6 and WorldCarFans.com; Audi V8

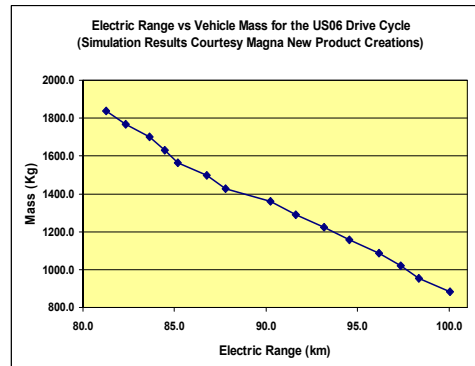
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Summary



- Light weighting is seen as important for reducing emissions and improve fuel efficiency
- Developments in materials are enabling the light weighting possible
- Safety and durability are the major issues to be resolved before large scale implementations are possible



Weight reduction will be critically important to the large-scale introduction of vehicles with alternative energy powertrains