Green Manufacturing

with focus on
the automobile

Lecture prepared with the able assistance of Nel Dutt, TA

Green Manufacturing: A Strategic Priority

In the not-too-distant future, environmentally benign manufacturing will become one of industry's greatest strategic challenges, not only from an engineering perspective, but also from a business and marketing perspective.

Many large, multinational companies are cognizant of impending overseas (Europe & Japan) environmental regulations and growing consumer demand for a new generation of environmentally friendly products, and they are beginning to formulate their response. Some have embraced the notion that green products and green production techniques are a competitive weapon.

But many manufacturers, especially smaller ones in the United States, are lack in acknowledging and addressing the environmental concerns of governments and consumers.
Green Manufacturing

The center for Green Manufacturing at the University of Alabama defines the goal of green manufacturing as:

“To prevent pollution and save energy through the discovery and development of new knowledge that reduces and/or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products or processes.”

In Bridge to a Sustainable Future (April 1995), the Clinton White House defined an environmental technology as a technology that

“- reduces human and ecological risks,
- enhances cost effectiveness,
- improves process efficiency, and
- creates products and processes that are environmentally beneficial or benign.”

Areas of applications of green manufacturing:

- Lean manufacturing
  - attention paid to waste generated along the way
  - energy reduction in streamlined logistics
- Materials reuse, recycling
- Green plastics (biodegradable)
- Product design
  - use of recycled materials
  - design for service, disassembly and recycling
- Green chemistry
  - avoidance of toxics
  - harmless solvents
  - solventless technologies
- Semiconductor, electronics
  - more benign manufacturing processes
- Automobile design and manufacture
Application: Vehicle Redesign

“A "car-efficiency revolution" that could move the world beyond oil is in the making, as automakers start shifting to lighter weight materials, sleeker aerodynamics, hybrid-electric propulsion, and non-petroleum fuels.”

- Amory B. Lovins, Rocky Mountain Institute

• Transportation is key to greening global industries.
  The two most energy-consuming activities in the United States are building heating/cooling/ventilation and road transportation.
• Transportation consumes much of the earth’s resources.
  Until recently, the automobile industry was the largest economic activity after agriculture. In dollar terms, it has now been passed by the electronics industry but remains largest in terms of materials consumption.
• A fundamental change in vehicle design, manufacture & use is required.

Partnership for a New Generation of Vehicles (PNGV)

In 1993, the Clinton Administration established the Partnership for a New Generation of Vehicles (PNGV), a cooperative research and development partnership aimed at creating a prototype “super-efficient” car. It brought together the Big Three Automakers (General Motors, Ford and then-DaimlerChrysler), eight federal agencies (mostly DoE), and universities.

PNGV was divided into 3 stages, with the final stage leading automakers to bring to market by 2003 a vehicle achieving 80 miles per gallon. This goal was not achieved because the program was cancelled in 2001 by the Bush Administration at the request of the automakers.

FreedomCAR and Vehicle Technologies (FCVT)

FCVT, the successor or PNGV, is run by the Department of Energy (DoE) and aims to develop “leap frog” technologies that will provide Americans with greater freedom of mobility and energy security, while lowering costs and reducing impacts on the environment.

More specifically, the program funds projects related to plug-in hybrid cars, with related R&D in battery technologies.
US Effort for Vehicle Redesign

- Utilize green manufacturing techniques to redesign cars
- Ultra Light Steel Auto Closures (ULSAC) Advanced Vehicle Concepts funded the project
- Stringent criteria for design evaluation
- Selected two common types of cars

Objectives

"The purpose of the ULSAB-AVC was to demonstrate the ability of steel to produce a structurally efficient, environmentally sound, safe, affordable automobile. Environmental benefits derive from efficient power and drive systems, structurally efficient, rigid structures and reduced overall vehicle mass."

- Reduce emissions, fuel consumption, cost
- Save energy
- Meet safety criteria
Project Information

- Automotive conference in 2002
- Toyota wanted to reduce the footprint of automobile.
- Global steel industry takes environmental responsibility
- Partnered with steel industry to design cars
  - that are compact and midsize sedans
  - that use gasoline or diesel

Project Specifications

- Cars must have better mileage and better safety measures
- Use of high-tech steel and modern manufacturing techniques
- Decision not to replace steel with alternate materials
  - more than three times as expensive
  - not as safe, strong, flexible
  - increased environmental risk
  - decreased recyclability
  (for composite materials)
Project Goals

- Crashworthiness
- Reduce total vehicle mass
- Reduce CO₂ emissions and increase fuel efficiency
- Increased structural performance (bending and torsional rigidity and normal mode frequency)
- Affordability
- Source reductions (reduced emissions through manufacturing less steel)
- 100% recyclability

Design as many parts as possible in common between the larger (PNGV) and smaller (C-Class) vehicles.
Redesign parts so as to minimize the amount of material (ex. have outer surface double-up as structural component)

Frameless Door Design

Perform crash tests with computer simulations rather than on actual prototypes (saves time and material)

CAE Crash Simulation
Engine Results

• Engine: Both the gasoline and diesel engine concepts were selected from currently available state-of-the-art engine technology based on:
  – total vehicle target mass of the PNGV-class models
  – requirements for acceleration, cruising speed, and CO$_2$ emissions

PNGV = Partnership for New Generation of Vehicles

• The designs can be adapted to incorporate future engine technologies, e.g. fuel cells and hybrid engines.

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<th>at rpm</th>
<th>max torque</th>
<th>at rpm</th>
<th>mass</th>
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Emission Results

• CO$_2$ emissions calculated based on:
  – The higher total vehicle mass of the reference vehicle
  – The specified drive cycles

• The analysis indicates that:
  – Target CO$_2 < 100$ g/km can be achieved
    (currently 155 g/km for the average car and 250 g/km for an SUV)
  – Applies to both engine variants
Results: Summary

• Overall
  – lighter vehicle: 100 lbs compared to 140-150 lbs
  – 100% recyclable

• Estimated annual savings if these cars were used:
  – Reduced fuel consumption: 171,330,000 gallons
  – Carbon savings: 1.3 million metric tons of CO₂
  – Source reduction (less steel used): > 70,000 tons per year
Smart Car: Europe’s Vision

- Size: 8.21' x 5' x 5'
- Weight: 1500 lbs/ 682 kg
- Fuel types: diesel, leaded/ unleaded petrol, biofuels
- Models: 7
- Cost: starting @ $ 25,000
Smart Design & Engineering

- Smart (Swatch Mercedes Art) car is the brainchild of Nicolas Hayek, CEO of Swatch

- Hayek wanted to produce a car that would be fun, cheap and simple yet environmentally sound, with electric or hybrid power

- Design for assembly given particular attention; almost everything outsourced; Assembly time is 4.5 hours

- Car designed to be highly modular, with modules / parts attached to a rigid integral "tridion" body frame

Smart Design & Engineering

Main systems suppliers

- Magna: Space Frame
- Magna Uniport (Ymos): Doors
- Surtema Eisenmann: Paintshop
- Bosch: Front Powertrain, Breaks, Lights
- Mannesmann VDO: Cockpit
- Dynamit Nobel: Plastic Body Panels (see also Krauss-Maffei)
- Krupp Automotive Systems: Rear Powertrain

- Almost no inventory on hand; company assembles and rolls out cars

- Focus on logistics, testing and transportation
Smart Safety

- Smart Car is much safer than other cars of the same size because of its “Tridion steel safety shell”
- Protects inside of car
- Forms Chassis
- Meets “Top Gear” BBC’s crash test requirements
- 3* NCAP crash rating

Smart Car manufacturing and assembly plant in Hambach, France

designed to minimize transportation, time and by-products
Want to change the color for the evening?

Sale display in glass towers “vending machine”

Smart Savings

- 95% recyclable
- Fuel efficiency: 60 mpg vs. 30 mpg (SUV)
- Very modular: easy to assemble, disassemble
- Specialized production lines: less emission and production waste
- Parking: needs less space
- Materials: efficient materials use