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CRADA --Recycling End-of-Life Vehicles of the Future

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11/10/08

Why Recycle?

- *Development of cost-effective recycle strategies and technologies supports the deployment of advanced lightweighting materials*
- *Increased use of recycled/renewable materials is one of the three technology specific Materials goals for 2010*
- *Recovery and reuse of polymers and other advanced materials from ELV will---*

  ---Increase materials supply options/decrease costs for automakers

  ---Decrease the carbon footprint of lightweighting materials over product life-cycle

  ---Conserve the embodied energy of these materials

Strategic Framework

Economic use of advanced lightweight materials for automotive construction will be enhanced by both prompt recycling of scrap materials during manufacture, as well as recycling of end-of-life vehicles incorporating such materials.

Cost structures for materials such as aluminum and magnesium are strongly impacted by availability and cost of usable alloy scrap and retention of critical alloy properties.

For high- value materials such as carbon-fiber composites, there may be questions of capability to retain physical properties consistent with re-use applications.

Statutory mandates in a global economy and environmental considerations also dictate a need to recover or make usable many non-metallic materials that are not presently recycled. Development of viable strategies for control of materials of concern is also critical to enhancing recyclability.

Recycle Effort Structured as a CRADA

- Organizing Theme
  - To achieve greater fuel-efficiency and safety, today's cars incorporate an increasing share of innovative lightweighting materials. While these materials greatly enhance efficiency during vehicle use, they can present special challenges to recycling
- ELV CRADA Partners (US ELV CRADA Team)
  - Argonne National Laboratory/ U.S. Dept. of Energy
  - American Chemistry Council—Plastics Division
  - USCAR's Vehicle Recycling Partnership, LLC.
- Objectives
  - Enable optimum recycling of all current and future automotive materials
  - Remove recycling barriers to use of advanced, lightweight materials
  - Continue to enable market driven vehicle recycling

Present CRADA Background

- *Scope of the CRADA*
  - *a) examination of issues that prevent recycling*
  - *b) identification of technology to enable recycling*
  - *c) development and demonstration of technologies to recover resources and materials*
  - *d) examination of options for design modifications to provide for more effective recycling*
  - *e) examination of alternative materials to increase recycling*
- *Initial focus of research--- Post-shred technology*
- *Present focus of research---Lightweighting metals (Aluminum, Magnesium and Titanium*

A Brief History of Collaboration

- 1994 **First** CRADA (among VRP, Argonne and APC)
  - Dismantling
  - Seat foam recycling
- 1997 **Second** CRADA among VRP, Argonne and APC
  - Demonstration of Argonne froth flotation technology (post-consumer appliance plastics)
- 1999 DOE PNGV (now FreedomCAR) funds
  - Argonne --- polymer matrix composite recycle
  - Aluminum Alliance --- LIBS alloy sorting
- 2001 ELV Recycle Roadmap released
- 2003 **Third** CRADA among VRP, Argonne and APC
  - Sustainable recycling
- 2008 Extension of the existing CRADA in progress

Current R&D Portfolio of the CRADA Team Evolved from a Stakeholder Workshop. The workshop determined that-

- *The recyclability of ELVs is presently limited and several technical and economic barriers need to be overcome to increase recovery and recycling*
  - *Lack of commercially proven technology to cost-effectively separate, identify and sort materials*
  - *Lack of profitable post-use markets*
  - *Collection infrastructure exists*
- *Development of technology to recycle today's materials will provide the basis for recycling of future materials*
- *Initial focus should be on post-shred technology*
- *Industry-wide collaboration is needed*
- *Worldwide technology needs to be tracked and information disseminated to users*

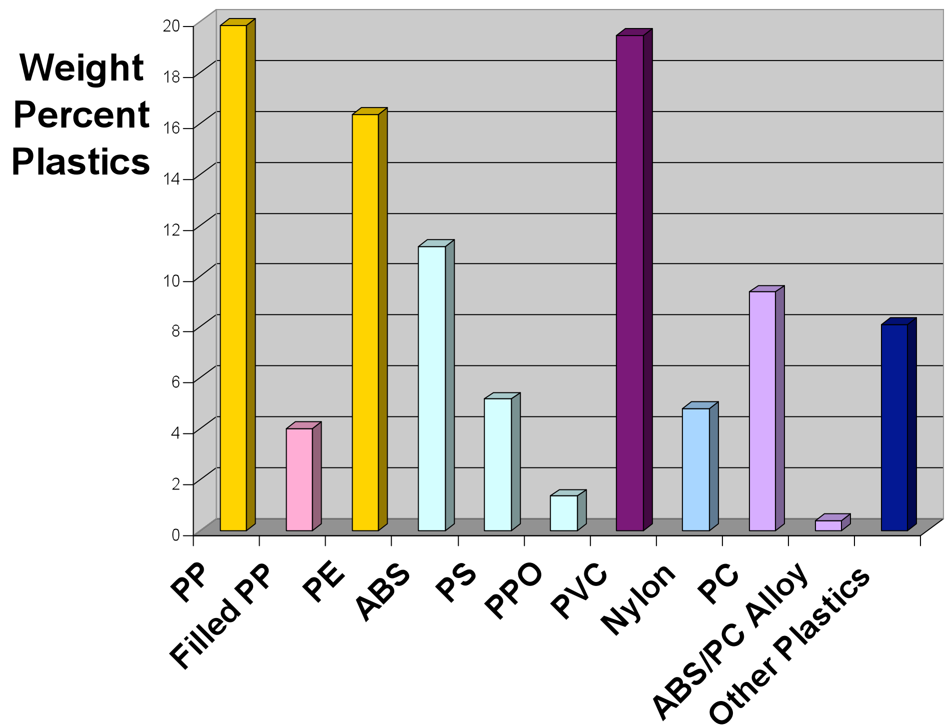
Projects Initiated Include…

- *Baseline Assessment of Recycling Systems and Technology*
  - *Literature review, bibliography, technology assessment*
  - *Life-cycle studies of "post-shred" technologies*
- *Post-shred Materials Recovery Technology Development and Demonstration*
  - *Technology Development and Benchmarking*
    - Mechanical Separation Technology
    - Thermo-chemical Conversion Technology
- *Compatibilization/compounding Evaluation of Recovered Polymers*
  - *Physical properties testing*
  - *Mold trials*
- *Development of Technology for Removal of PCBs and Other Substances of Concern*
- *Website Development to facilitate information dissemination*

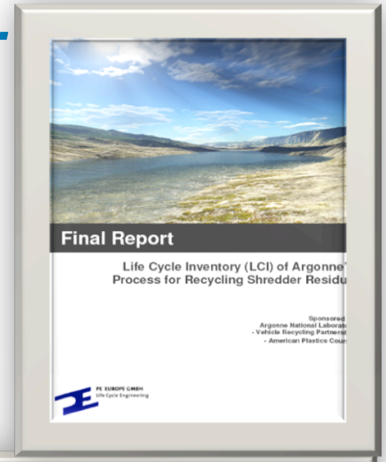
Background--What is Shredder Residue?

- Shredder residue is the waste resulting from the shredding of cars, other durables, and scrap metal to recover metals for recycling. It contains polymers, residual metals, wood, glass, sand, dirt, etc.
- Over 5 million ton/yr generated in the U.S.

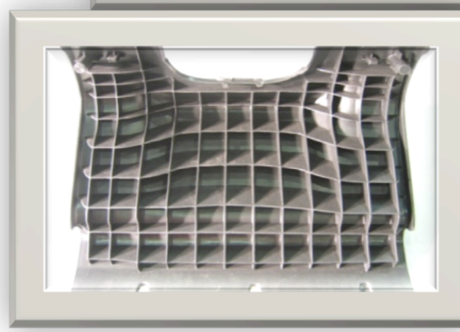
Starting Shredder Residue



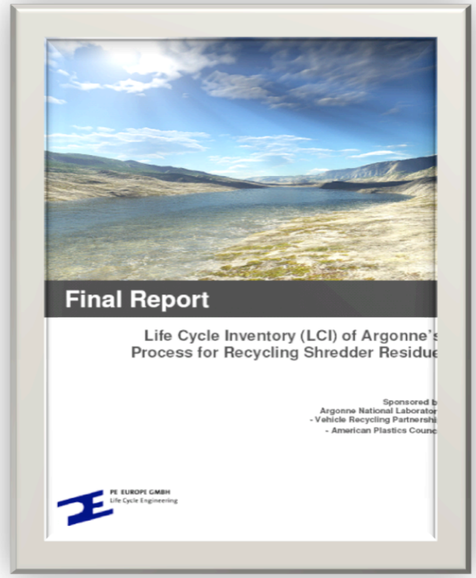
CRADA Team Major Accomplishments Include…



- *Developed a shredder residue recycling process*
- *Developed a modular LCA software package for evaluation of alternative recycle technologies*
- *Confirmed the technical feasibility of*
  - *recovering and reusing polymeric fractions from shredder residue*
  - *converting shredder residue to liquid hydrocarbons*
  - *converting polyurethane foam from shredder residue to polyol initiators*
- *Successfully tested (on small scale) a process for PCBs control*
- *Developed a Web-site for information dissemination*
- *Recognized by the GPEC (Global Plastics Environmental Conference) Award for 2007, Enabling Technologies in Processes & Procedures,* Environmental Division, Society of Plastics Engineers



CRADA Accomplishments- Baseline Assessment of Recycling Systems and Technology



- *Developed a modular life-cycle Analysis (LCA) software package for evaluation of alternative recycle technologies and conducted LCAs on-*
  - *Salyp's process*
  - *Changing World Technologies' Process*
  - *Argonne's process*
- *Conducted a thorough literature review and technology assessments of processes under development for recycling materials from shredder residue and prepared two documents*
  - Recycle bibliography
  - Technology review document

End-of-Life Vehicle Recycling:
The State of the Art of Resource Recovery from Shredder Residue
Report #: ANL/ESD/07-810
by
B.J. Jody and E.J. Daniels
Energy Systems Division,
Argonne National Lab

CRADA Accomplishments-Post-Shred Materials Recovery Technology Development and Demonstration

- The objective is to develop, demonstrate and benchmark technology for the cost-effective recovery of lightweighting materials, including plastics, and other materials from post-shred residue
- Built a 2 ton/hr pilot plant and processed about 130 tons of shredder residue
- Confirmed the technical feasibility of
  - *recovering and reusing polymeric fractions from shredder residue*
  - *converting shredder residue to liquid hydrocarbons*
  - *converting polyurethane foam from shredder residue to polyol initiators*

Benchmarked Other Recycling Technologies

- Benchmarked the processes developed by-
  - Salyp NV
  - VW-SiCon
  - MBA Polymers

- Benchmarking has been completed on numerous unit operations for concentrating plastic fractions such as:
  - Water tables
  - Mineral jigs
  - Kinetic Density Separator (KDS) (Recycling Avenue/Delft University)
  - Optical sorters
  - Electrostatic separators

Argonne Recycle Process R&D

- Designed, built and installed 1/10th scale pilot plant
- Processed 130 tons of shredder residue
- Recovered over 95% of the residual metals
  - 5-15 weight percent of the shredder residue
- Recovered 90% of the targeted polymers
  - 20-50 weight percent of the shredder residue

Argonne's Mechanical Separation Pilot Plant

Argonne Process R&D---Continued

- Designed, built and installed 1,000 lb/hr wet-density/froth flotation pilot plant
- Developed process operating conditions for selective separation of materials from the polymer concentrate
- Designed and built a 5,000 lb/hr flotation separation module

Argonne's Wet-Density/Froth Flotation Pilot Plant

CRADA Accomplishments- Compatibilization/Compounding Evaluation of Recovered Polymers---Objectives

- Evaluate the market opportunity for polymers recovered from shredder residue
  - Determined physical properties of recovered polymers
  - Conducted blending and pelletizing trials of the recovered polymers
  - Conducted mold trials using recovered polymers
- Identify limitations associated with the re-use of the materials as recovered and determine the need for post-processing technology to upgrade the recovered materials to meet market requirements

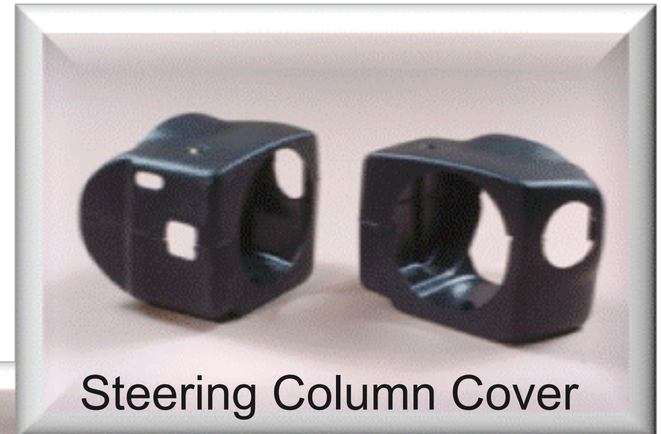
Determine Properties of Blended and Pelletized Materials --Argonne Recovered Polymers

- The recovered polyolefins were blended 25/75 with industrial regrind polypropylene and pelletized using standard equipment
- A 70% filled ABS concentrate was recovered
  - Properties testing confirmed that the quality was sufficient for mixing with virgin ABS at a ratio of 10/90
  - Upgrading is necessary for higher blending ratios

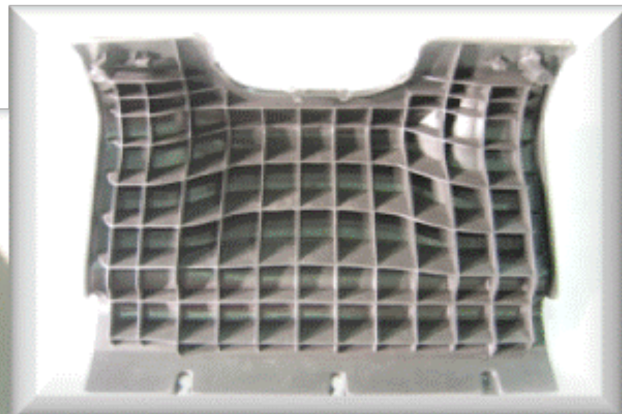
Property	Recovered F-ABS	Virgin ABS	90% V/ 10% R	75% V/ 25% R
MFR	3.9	6.5	7.6	6.4
Izod Impact	0.9	3.8	3.0	2.6
Flex Mod	324	296	299	302
Tensile strength at yield, psi	4982	5546	5392	5312
Elongation at rupture, %	2	56	9	6
DTUL, 264 psi, °F	162	165	166	164
Gardner Impact	0	>320	32	8
SG, g/cc	1.08	1.05	1.05	1.06

Mold Trials Confirm the Technical Feasibility of Re-use for Recovered Polyolefins---Argonne Recovered Polyolefins

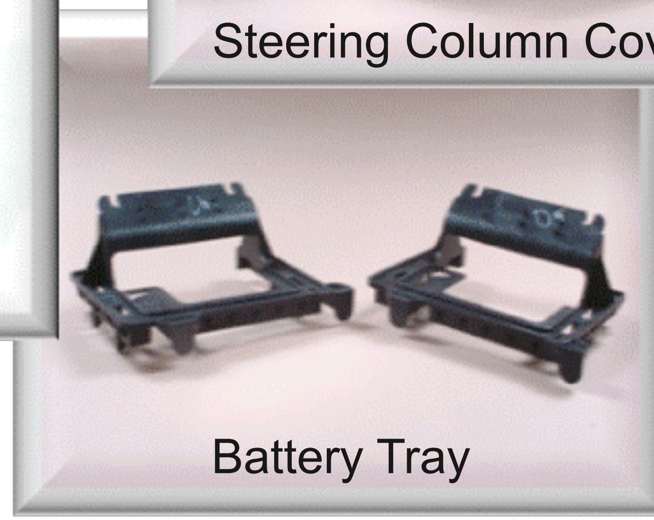
- Mold trials by MGV were successful for producing automotive parts from the polyolefins fraction at blend rates with regrind of 0%, 25%, 50%, & 75%



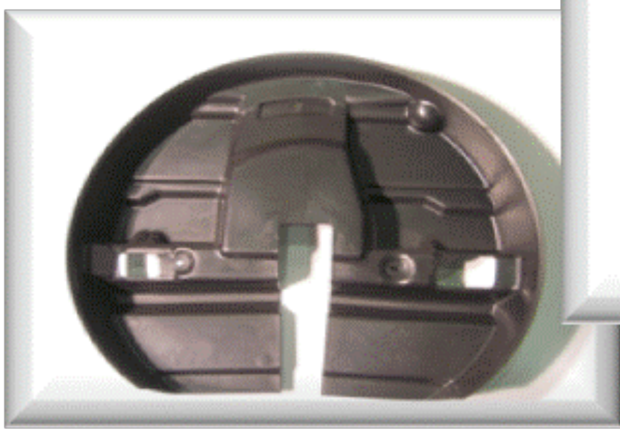
Steering Column Cover



Knee Bolster



Battery Tray



Spare Tire Base Plate

*Wheel well covers molded but not pictured

Compatibilization/Compounding Evaluation of Recovered Polymers---Conclusions

- Mold trials confirmed the technical feasibility of re-use for lightweighting automotive plastics
- The polyolefins were blended 25/75 with industrial regrind polypropylene and pelletized using standard equipment
- The physical properties of the polyolefins are comparable to a general purpose polypropylene
- The properties of the recovered filled ABS when mixed in a ratio of 10/90 with virgin ABS are comparable to the virgin ABS

Development of Technology for Removal of PCBs

- Objective
  - Develop viable strategies and technology for the control and minimization or elimination of polychlorinated biphenyls (PCBs) and other substances of concern (SOCs) from recycled automotive materials

- Approach
  - Identify efficient and environmentally acceptable process solutions for removal of contaminants, including PCBs, from materials recovered from shredder residue
  - Define variances in analytical procedures/test results for PCB analysis

Argonne Developed a Two-Stage Process for Cleaning of Recovered Plastics

- Tests were conducted at Argonne using a non-flammable organic solvent to clean polyolefin plastics recovered from shredder residue
  - Plastics were washed and rinsed under conditions (time and temperature) that minimized the absorption of the solvent by the plastics
  - The washed plastics were then treated to desorb the PCBs
- Reproducible results indicated that the PCBs could be removed to a concentration below 2 ppm in the polyolefins
- Tests were also conducted by other organizations

CRADA Accomplishments-Develop a Web-Based Information System

- Developed and launched a web-based information system to communicate the latest developments in automotive recycling technology to key stakeholders

  http://www.es.anl.gov/Energy_Systems/CRADA_Team_Link/Index.html

- Website is updated as more information becomes available

- Information on the website includes:
  - Overview of CRADA Team activities and publications including progress reports and brochures
  - Recycle bibliography
  - Technology review document
  - Related news and media events
  - Links to related sites

Thank you

Please Visit the U.S. ELV CRADA TEAM Website for more information

(www.es.anl.gov/Energy_systems/CRADA_Team_Link/Index.html)