1. INTRODUCTION

Automotive Lightweighting Materials R&D

As a major component of the U.S. Department of Energy's (DOE's) Office of FreedomCAR and Vehicle Technologies Program (FCVT), Automotive Lightweighting Materials (ALM) focuses on the development and validation of advanced materials and manufacturing technologies to significantly reduce automotive vehicle body and chassis weight without compromising other attributes such as safety, performance, recyclability, and cost.

The specific goals of ALM are to develop material and manufacturing technologies by 2010 that, if implemented in high volume, could cost-effectively reduce the weight of light-duty body and chassis systems by 50% with safety, performance, and recyclability comparable to 2002 vehicles.

ALM is pursuing five areas of research: cost reduction, manufacturability, design data and test methodologies, joining, and recycling and repair. The current Long-Range Plan for activities in these areas during the next 5 years is found at www.eere.energy.gov. Because the single greatest barrier to use of lightweight materials is cost, priority is given to activities aimed at reducing costs through development of new materials, forming technologies, and manufacturing processes. Priority lightweighting materials include advanced high-strength steels (AHSSs), aluminum, magnesium, titanium, and composites including metal-matrix materials and glass- and carbon-fiber-reinforced thermosets and thermoplastics. The inclusion of AHSSs is an example explaining the term "lightweighting" as opposed to "lightweight" in order not to imply focus on just lower density materials.

Collaboration and Cooperation

ALM collaborates and cooperates extensively to identify and select its research and development (R&D) activities and to leverage those activities with others. The primary interfaces have been and still are with entities of the "Big Three" domestic automotive manufacturers (DaimlerChrysler, Ford and General Motors), namely the FreedomCAR Materials Technical Team, the Automotive Composites Consortium (ACC), and the United States Automotive Materials Partnership (USAMP). These collaborations provide the means to determine critical needs, to identify technical barriers, and to select and prioritize projects. Other prominent U.S. partners include such organizations as the Auto/Steel Partnership of the American Iron and Steel Institute, the American Plastics Council, the Vehicle Recycling Partnership, and the American Foundry Society. ALM also coordinates its R&D activities with entities of other U.S. and Canadian federal agencies. Interactions with DOE's Office of Industrial Technologies Program (ITP), FCVT's High-Strength Weight Reduction (HSWR) Materials effort, and the Department of Natural Resources of Canada (NRCan) are especially important by virtue of overlaps of interests in lightweighting. Contacts with similar efforts in other countries besides Canada are being pursued. As mentioned below, projects at seven universities were initiated in FY 2005 under joint funding with the U.S. National Science Foundation (NSF), and another project at a university, jointly funded with DOE's Office of Science, continued.

Project Selection and Stages

In cooperation with USAMP and the FreedomCAR Materials Technical Team, a procedure has been established to help facilitate the development of projects in order to help move high-risk leveraged R&D to targeted research projects that eventually migrate to the original equipment manufacturers (OEMs) or suppliers as application engineering projects. R&D projects are assigned to one of three phases as depicted in the figure and defined below: concept feasibility, technical feasibility, and demonstrated feasibility. Projects are guided to meet the requirements of each phase before they move on to the next phase. Not all projects must go through these phases under ALM funding; some may enter the technical or demonstrated feasibility stages from efforts funded elsewhere.

Concept Feasibility: Concept feasibility projects should contain a specific idea to address a need or to create something new. Projects are usually exploratory and small in monetary requirements and time, typically less than $200,000 total over 1–2 years. Projects should provide a yes/no answer to the value of the idea. All projects are required to have a detailed research plan, budget, and timing. They can be ended before proceeding to technical feasibility if there is a lack of technical progress or if the preliminary business case turns out to be unfavorable.

Technical Feasibility: Technical feasibility projects should continue R&D for ideas with proven merit or potential. These projects should identify the key barriers to implementing the technology and focus on overcoming them. Technical feasibility projects should have well-defined, industrial OEM and/or supplier participation and pull. They are usually larger and longer term than the concept feasibility projects with typical investment in the $1M to $2M range and length of 2–3 years or more. Technical feasibility projects can be ended before proceeding to demonstrated feasibility if there is a failure to overcome the key barriers to implementation or if the cost or business case does not develop as favorably as initially assessed.

Demonstrated Feasibility: Technology projects that need larger scale validation may become demonstrated feasibility projects. Not all technical feasibility projects will need a demonstration or validation program. These projects are few in number, much larger in scale, and may involve component or system fabrication and tests. Support and leverage from the industrial OEMs and/or suppliers is a key requirement.

Stage progression for projects

Once selected, R&D projects are pursued through a variety of mechanisms, including cooperative research and development agreements (CRADAs), cooperative agreements, university grants, R&D subcontracts, and directed research. This flexibility allows the program to select the most appropriate partners to perform critical tasks. The ALM efforts are conducted in partnership with automobile manufacturers, materials suppliers, national laboratories, universities, and other nonprofit technology organizations. These interactions provide a direct route for implementing newly developed materials and technologies. Laboratories include Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL), Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), and Sandia National Laboratories (SNL). ANL oversees recycling efforts and ORNL provides overall technical support and coordination, including for the DOE cooperative agreement with USAMP. The National Engineering Technology Laboratory (NETL) provides external projects management including the cooperative agreement with USAMP.

Research areas and responsible organizations

Coordinated area	Organization
Production and fabrication of aluminum	HSWR, ITP, Natural Resources of Canada (NRCan)
Production and fabrication of magnesium	International Magnesium Association, NRCan, HSWR
Recycling, reuse, repair of automotive parts and materials	Vehicle Recycling Partnership, American Plastics Council
Fabrication of steel and cast iron	American Iron and Steel Institute, the Auto/Steel Partnership, HSWR
Fundamental materials research	DOE Office of Science, National Science Foundation (NSF)
High-volume composite processing	Department of Commerce—National Institute of Standards and Technology's Advanced Technology Program
Crashworthiness	Department of Transportation
Production and fabrication of composites	American Plastics Council

FY 2005 Accomplishments

The Structural Cast Magnesium Development (SCMD) project work advanced far enough that General Motors decided to introduce the project's focal component, a front engine cradle, shown below, in its 2006 Chevrolet Corvette. The magnesium version is 34% lighter than the 2005 production aluminum engine cradle it replaces. See report 2.G.

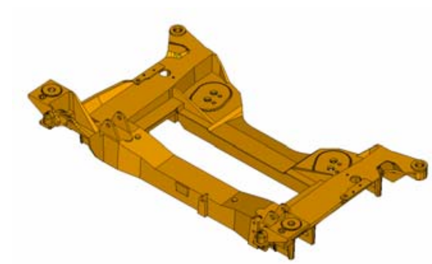

Image of Magnesium Front Engine Cradle

The Aluminum Consultants Group, in conjunction with PNNL, prepared a technical cost model that indicated that magnesium sheet produced by twin-belt casting and twin-roll casting probably can be economically viable for automotive applications. See report 2.J.

Bolstered by the successes in the SCMD and the Mg Powertrain Cast Components projects and the positive indications of the cost model above, the USAMP completed a strategic vision study outlining recommendations for North American automotive magnesium through the year 2020. The study will be published in 2006.

The Durability of Carbon-Fiber Composites project at ORNL concluded. A final report will be published in 2006. This culminates a ten-year campaign to develop and document initial, experimentally-based, durability-driven design criteria and damage-tolerance assessment procedures for representative fiber-reinforced polymer-matrix composite automotive structures in long-term (15 year) service. Earlier work on glass-fiber-reinforced epoxy-matrix composites provided enough assurance that commercial products developed. The later work of the campaign provided similar initial assurance for carbon-fiber-reinforced epoxy- and thermoplastic-matrix composites, and it is expected that, in time, commercial products in those materials will eventually emanate as well from further work by industry. See report 4.H.

The Active Flexible Binder Control System for Robust Stamping project built an advanced binder load control system and used it to successfully stamp liftgate panels from BH210 and DP500 steels, and A6111-T4 aluminum using the same set of tools (Fig. 1). The tryout time using the system was considerably less than those using conventional methods of reworking the die (welding, grinding, polishing and testing). Splits and wrinkles in stamped panels could literally be healed in minutes rather than in days by adjusting the tonnages of the appropriate cylinders. Prior efforts to make the liftgate from A6111-T4 using conventional methods were unsuccessful. Fig. 2 shows the dramatic benefits of using closed loop control in eliminating wrinkles in a large steel pan. See report 2.B.

Fig. 1 Liftgate panels made from two steels (BH210, DP500) and two aluminum (A6111-T4) batches (lower photo)

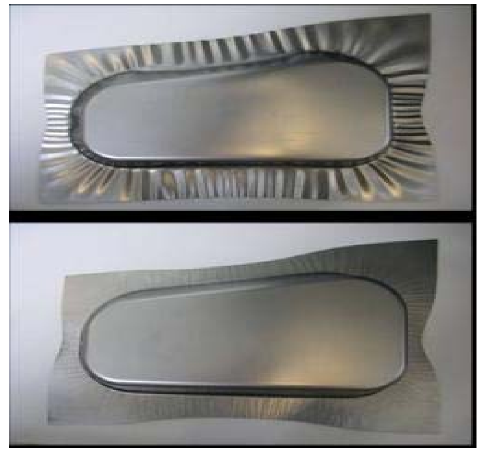

Fig. 2 Steel Pan drawn without (upper photo) and with (lower photo) closed loop control

A recent cost study performed by Camanoe Associates, in conjunction with PNNL, concluded that the use of a low-cost titanium ore as the feedstock source in a continuous reduction process could drive down the cost of titanium sponge and powder substantially to the point that it could be considered for application in standard automotive components. The continuous process used in conjunction with a low-cost feedstock can produce powder at $2.00/lb compared to the nearly $90/lb for conventional atomized powder. PNNL is currently leading a program to develop this low-cost titanium processing stream. Working with E.I. DuPont de Nemours and International Titanium Powder (ITP), PNNL has employed low-cost, ilmenite-derived titanium tetrachloride (of the type used for titanium dioxide paint pigment) as the precursor in ITP's Armstrong titanium synthesis process. The resulting titanium powders, while containing additional impurities (primarily tin and silicon), still appear capable of meeting strength and ductility requirements for a wide range of automotive applications. See report 2.K.

A new multi-participant thrust on computational modeling for predicting the processing-dependent structures and properties of fiber-reinforced polymer-matrix composites (FRPMCs) was initiated late in this fiscal year. The ALM is supporting applied work at PNNL on the modeling and experimental verification work at ORNL; PNNL is working closely with a software vendor to implement the modeling into commercial code usable by industry. The ALM and the National Science Foundation are jointly supporting work at seven universities that will serve, in time, to improve the fundamental bases of the modeling. The entire thrust is being guided by a steering committee of researchers from the automotive and plastics industries. See reports 4.K to 4.O.

One concern about the use of FRPMCs has been whether they could be disposed of properly at the end of the vehicle's useful life. ANL supplied Changing World Technologies (CWT) of West Hempstead, New York with 3,000 lbs of auto shredder residue (ASR) or "fluff" which is mainly composed of the plastics left after the metals have been separated from the shredded vehicle body. CWT added a depolymerization step before their existing thermal pyrolysis step already operating commercially for poultry waste. The fuel produced seems comparable to fuel oil used in ships or industrial plants and, at current prices of such fuel; the technology appears attractive enough for CWT to begin seeking funding for a full-scale plant to convert the ASR. See Report 7.E.

Future Direction

In FY 2002 and FY 2003, the FreedomCAR and Fuels Initiative formed from the 1994–2001 Partnership for a New Generation of Vehicles (PNGV). Thinking and planning on what replaces the ALM efforts that began in the PNGV in roughly 1999–2002 has continued since. The ALM and the FreedomCAR Materials Technical Team conducted a series of strategic reviews of various materials and manufacturing topics in FY 2004. Based on those reviews, carbon-fiber-reinforced polymer-matrix composites and magnesium will be emphasized in the next few years as they have the greatest weight-reduction potential, but there will be some efforts on AHSSs, titanium, and metal–matrix composites because these will contribute in niche roles to the overall FreedomCAR weight-reduction and cost neutrality goals. Material-crosscutting work in general manufacturing will continue to increase in joining, nondestructive evaluation (NDE), and recycling. Planning for the future NDE efforts will be concluded in 2006. Though technical feasibility (see figure above) projects will dominate as before, concept-feasibility and demonstrated-feasibility projects will also be pursued as will some university base-technology projects as mentioned above.