1. INTRODUCTION

As a major component of the U.S. Department of Energy's (DOE's) Office of FreedomCAR and Vehicle Technologies (OFCVT), the High-Strength Weight Reduction (HSWR) Materials Technology Development Area seeks to reduce parasitic energy losses due to the weight of heavy vehicles without reducing vehicle functionality, durability, reliability, or safety, and to do so cost-effectively. The development area is focused on the development of materials and materials processing technologies that can contribute to weight reduction. In addition, it is recognized that improved materials may enable implementation of other technologies that can further improve the fuel efficiency of the vehicles. Through many of its technology development programs, DOE supports the government/industry 21st Century Truck Partnership.

The specific goals of the HSWR Materials Technology Development Area are

- By 2010, reduce the weight of an unloaded tractor-trailer combination from the current 23,000 pounds to 18,000 pounds, a 22% reduction in weight.
- By 2010, develop and validate advanced material technologies needed to meet OFCVT goals.
- Enable significant reductions in the weight of other classes of heavy vehicles (10–33% reduction in vehicle weight, depending on performance requirements and duty cycles).
- Develop materials that exhibit performance, durability, reliability, and safety characteristics comparable to those of conventional vehicle materials and that are cost-competitive on a life-cycle basis.
- Be consistent with the materials regulation requirements to maintain environmental responsibility.

To reach the stated goals, the HSWR Materials Technology Development Area has been developing a broad spectrum of advanced materials technologies that can be applied to a wide array of body, chassis, and suspension components. The research required to develop these technologies is too high-risk to be pursued independently by the heavy vehicle industry because of substantial return-on-investment uncertainties. Research is focused on overcoming barriers to the widespread introduction of lightweight materials in the heavy vehicle industry. Major barriers exist in the following areas: cost; design and simulation technologies; manufacturability; prototyping and tooling; joining and assembly; and maintenance, repair and recycling. Priority materials include advanced high-strength steels, aluminum, magnesium, titanium, and composites such as metal matrix materials and glass- and carbon-fiber-reinforced thermosets and thermoplastics.

Research and development (R&D) activities are being conducted through a variety of contractual mechanisms, including cooperative research and development agreements (CRADAs), university grants, R&D subcontracts, and directed research. Research partners include heavy vehicle manufacturers (including member companies of the 21st Century Truck Partnership), first-tier and materials suppliers, national laboratories, and other non-profit technology organizations. Laboratories include Argonne National Laboratory (ANL), Idaho National Engineering and Environmental Laboratory (INEEL), Los Alamos National Laboratory (LANL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory

(PNNL). Research is coordinated with various organizations—both government and private—as shown in the following table.

Research Coordination

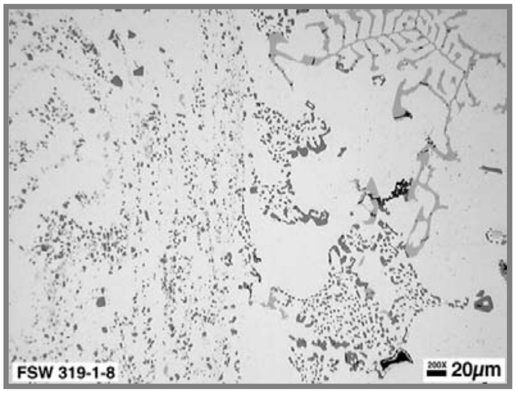
Technology Area	**Organization**
Production and fabrication of aluminum	The Aluminum Association, DOE-Industrial Technologies Program (ITP), Natural Resources of Canada (NRCAN), Automotive Lightweighting Materials (ALM) Technology Development Area
Production and fabrication of magnesium	International Magnesium Association, NRCAN, ALM Technology Development Area
Fabrication of steel and cast iron	American Iron and Steel Institute, the Auto/Steel Partnership, ALM Technology Development Area
Fundamental materials research	DOE Office of Energy Research, National Science Foundation
High-volume composite processing	Department of Commerce—National Institute of Standards and Technology's Advanced Technology Program, ALM Technology Development Area
Materials research for defense applications	Department of Defense
Materials research for space applications	National Aeronautics and Space Administration
Crashworthiness	Department of Transportation, ALM Technology Development Area
International vehicle material R&D	International Energy Association
Production and fabrication of titanium	The International Titanium Association, ALM Technology Development Area
Production and fabrication of composites	American Plastics Council

FY 2003 Accomplishments

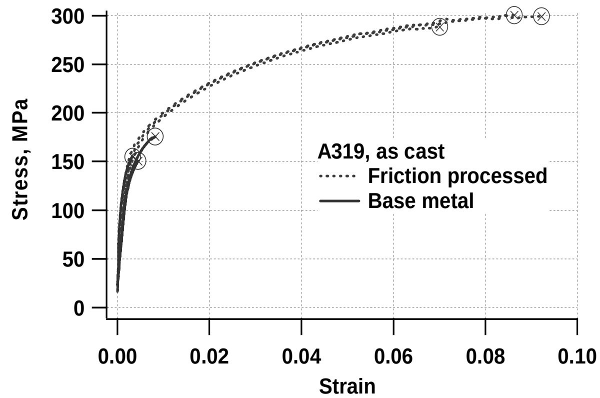
During 2003, ORNL issued a Request for Proposals for "Development of Technologies for Reduction in Weight of Class 7 and 8 Tractor Trailers." After review and ranking by an evaluation team, two proposals were selected to receive awards:

- The Liburndas Project, submitted by Heil Trailer International
- Development of High-Performance Lightweight Class 7–8 Truck Cab Using an Innovative New Formable Aluminum Foam Sandwich (AFS) Material, submitted by International Truck and Engine Corporation.

The use of friction stir processing technology to improve the surface properties of cast aluminum alloys is being investigated in collaboration with the Ford Motor Company and the South Dakota School of Mines. Results of the work demonstrate that friction stir processing can dramatically refine the size of particulate phases in aluminum A319 and distribute them more uniformly. The processing also closes open porosity in the treated volume. The ductility



Optical micrograph taken on the surface of a friction stir processing bead on A319 Al casting. The boundary between base metal and stir zone is approximately in the center of the micrograph; the base metal is on the right and the stir zone on the left.

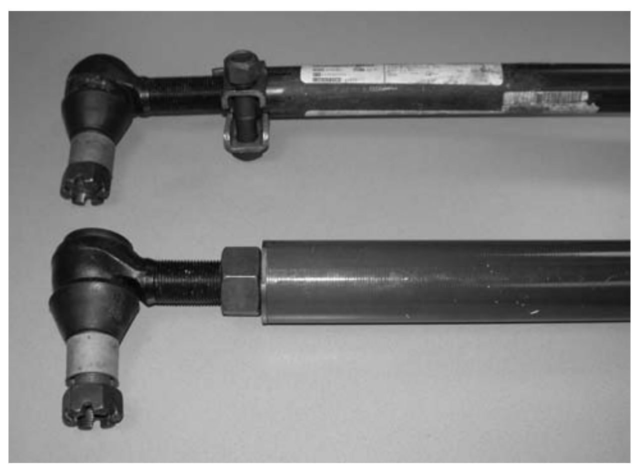


Stress-strain plot from room-temperature tensile tests of A319 base metal and friction stir processing stir zone.

and fatigue life of the cast materials was significantly increased. The surface property improvements could have important implications for the manufacturing of critical cast aluminum components for a wide variety of automotive applications.

The design phases were completed for three subcontracts to develop cab, body, and chassis structures of carbon-fiber-reinforced composites. Those projects have resulted in the early entry of composite tie rods into the commercial market and the development of the first truly low-cost carbon fiber sheet molding compound, which will have wide applicability in a number of applications. One project initially redesigned a component for manufacture using composite materials. The component redesign was accepted but the part was manufactured using aluminum, which saved about half the weight of the original design, was easier to manufacture, and met cost targets.

As part of a project to evaluate the design of an optimized hybrid materials frame that enables significant reduction in the weight of a pickup/sport utility vehicle (PU/SUV frame, DaimlerChrysler completed vehicle testing of the frame of a Durango SUV. The accelerated testing proved that the hybrid frame design had sufficient strength and durability to meet the vehicle performance requirements. Based on these positive results, the team is using a computer-aided engineering-based (CAE) approach and higher-risk manufacturing technologies to produce the next-generation frame, which is lighter than the previously tested frame and requires 35% fewer components.



Typical steel (top) and composite lateral link assemblies.

Next-generation frame design.

As advances in aerodynamic design and low rolling resistance tires combine to reduce the effective drag on trucks, demands on braking systems are increased. A project is evaluating the wear characteristics of advanced materials and surface treatments that enable weight reduction in truck brake components while equaling or improving their performance; it has conducted studies of a variety of candidate brake materials. Of these, titanium alloys offer a number of attractive characteristics, but their thermal conductivity and wear behavior must be enhanced. Surface coatings or treatments are expected to enable the materials to perform quite well as brakes. Further work is planned to develop a better understanding of the friction and wear behavior of titanium alloys and to evaluate several alternative coating methods.

PNNL recently completed a project with Freightliner, LLC, and Alcoa to investigate the use of large castings for advanced truck cab structures. A large cast component was developed and analyzed. The final design resulted in a 27% reduction in weight and a 70% reduction in part count. Under typical production assumptions, it appears that a large casting is cost-competitive with the baseline fabricated component.

Candidate brake disc materials after friction testing on the SSBT: commercially-coated titanium (upper left), experimental ceramic composite (upper right), uncoated titanium alloy (bottom).

Future Direction

The HSWR Materials Technology Development Area, for the most part, has addressed the near- and intermediate-term energy efficiency and safety technical needs of the heavy-duty (primarily class 7 and 8 trucks) transport sector in conjunction with the original equipment manufacturers and their suppliers.

Currently, DOE is placing increased emphasis on the identification and evaluation by systematic means of emerging energy-efficient materials, technologies, and processes that may initially be too long-term or too speculative for our industrial partners to explore at this time. If the initial evaluation proves sufficiently cogent technically, DOE will then seek to establish conventional collaborative efforts with one or more industry partners to further develop the technology toward maturity and eventual commercialization by industry.

Several materials thrust areas have been identified, and exploratory scoping efforts have been initiated within them. They are

1. advanced joining technologies,
2. titanium use in heavy duty structural and component applications, and
3. advanced surface modification technologies to tailor friction and wear characteristics and other surface-sensitive properties of materials.

In area 1, advanced joining, DOE seeks to develop effective joining technologies that can enable the increased use of attractive advanced materials such as metal matrix composites without the severe alteration of microstructure and degradation of properties that are attendant upon conventional joining methods. The latter generally involve heating the materials adjacent to the joint into the liquid state. This technique results in significant phase redistribution, among other modifications that are deleterious to the properties of the resulting joint.

In area 2, vigorous efforts are under way around the world that may result in the delivery of titanium feedstock at considerably lower costs than have prevailed up to this time. Anticipating this achievement, DOE has initiated activities to identify and develop applications of titanium and titanium alloys in various structural, engine, and transmission components for heavy vehicles because of their attractive lightweighting, high-strength, and high-temperature characteristics.

In area 3, advanced surface modification, a number of innovative technologies have been identified that can significantly reduce the friction coefficients and wear rates of many engine and transmission components of heavy vehicles. These can contribute to appreciable increases in the energy efficiency of the vehicles. In addition, optimizing lubricant-surface interactions through formulation modifications may enable a total increase in energy efficiency of up to 5% in addition to improvements that may be gained in the combustion process.

It is anticipated that collaborative efforts with the Automotive Lightweighting Materials Technology Development Area will be pursued where appropriate so that energy-efficient technologies may be developed expeditiously without duplication and introduced into both the heavy-duty and light-duty sectors to maximize the impact on reducing fuel consumption. The conventional near-term and intermediate-term R&D activities performed in conjunction with DOE's industrial partners will, however, continue to make up the bulk of the next year's project portfolio.

Dr. Sidney Diamond

Sidney Diamond
Technology Development Area Specialist
Office of FreedomCAR and Vehicle
Technologies
Energy Efficiency and Renewable Energy