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 the 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, durability, 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 2004 Accomplishments

Carbon-fiber-reinforced polymer composites have a great potential to reduce the weight of heavy vehicles. However, a number of technical and economic barriers prevent their widespread implementation. The National Composites Center is leading a team focused on enhancing the rapid implementation of lightweight composite materials in Class 7/Class 8 vehicles via the development of advanced composite support structures, specifically lateral braces. Mass reductions are targeted for 50%.

The effort is focused in four areas: modeling, prototyping, molding, and materials characterization. Integration of progressive failure analysis using the Genoa software has successfully predicted fatigue behavior and elastic constants of test composite materials. In addition, the Genesis software was used to successfully develop an optimized design based on weight savings, cost, and manufacturing. A prototype lateral brace was successfully designed and fabricated by resin transfer molding and aluminum tooling in less than 4 weeks.

A collaborative effort between ORNL and PNNL is focused on overcoming the technical issues associated with joining composite materials in heavy vehicles. The project supports the industry-led effort to develop advanced composite support structures, including chassis lateral braces and primary beams for Class 7 and 8 vehicles (Figure 1). The initial focus of research is development and validation of one or more joint designs for a composite structural member attached to a metal member that together satisfy the truck chassis structural requirements both economically and reliably and with requisite durability.

Figure 1. Optimized geometry for lateral brace smoothed and drafted for manufacturability.

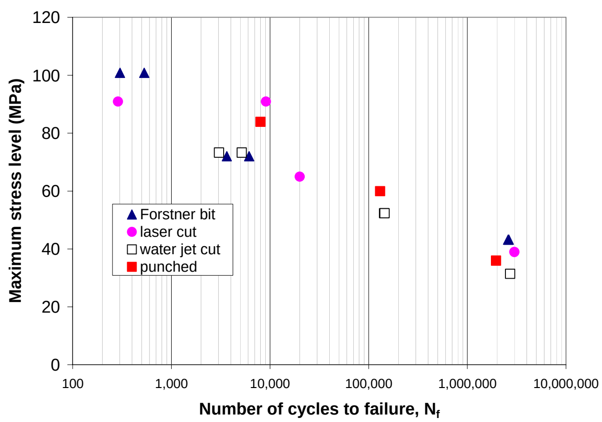

Figure 2. Fatigue testing results for specimens with holes fabricated with different methods.

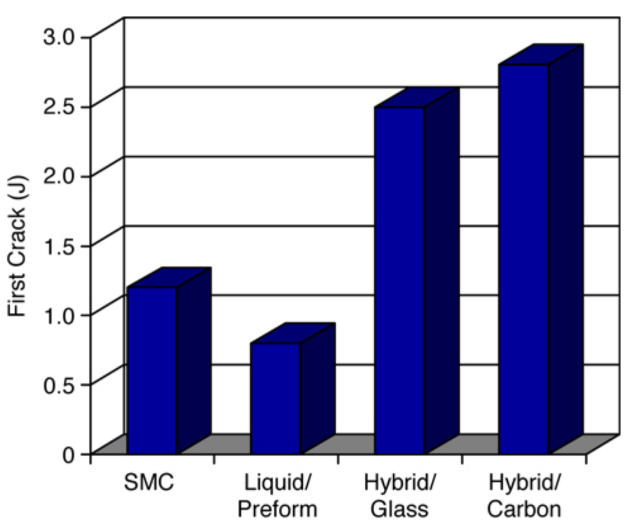

Figure 3. Resin system allowing excellent impact energy.

The multi-pronged approach includes evaluating a variety of hole fabrication techniques and their effects on subsequent performance (Figure 2); developing methods for detection of flaws and damage development during testing; static and fatigue testing under various environmental conditions; analyzing the effects of pre-load and bolt torque; and developing models for predicting the performance of joints. The results will be used to develop the first prototype composite component and joint for durability track testing in the latter part of 2005.

Selective reinforcement of large truck cab components with higher-stiffness carbon fibers has the potential to reduce both cost and weight simultaneously while maintaining structural functionality. PNNL is leading a collaborative project to develop robust methods of forming glass and carbon fiber materials together, while meeting Class A surface finish requirements and meeting thermal and structural performance requirements. A series of factors associated with optimizing details of the process technology are being addressed, and the CRADA partner is developing an approach to molding full-scale parts that will ultimately be tested in over-the-road trials. To date, the team has been successful in molding structural carbon fiber Class A components with a cost-effective hybrid fiber system that has demonstrated significant structural performance in fatigue and impact tests (Figure 3). In addition, it has achieved molding of very thin section panels, which resulted in attractive weight savings.

Magnesium alloys that have high specific strength (strength per unit of mass) are attractive materials for weight reduction. Presently, most magnesium use is limited to die-cast parts. Wrought magnesium alloys hold great promise for use in such components as hoods and doors. However, the need for a large number of processing steps and associated lengthy annealing times contributes to the high cost of sheet materials and presents one of the greatest barriers to the application of magnesium in these components. Researchers at ORNL, in collaboration with industry and universities, are applying infrared processing technology to reduce this barrier. A successful demonstration run made at a commercial rolling mill equipped with a bank of infrared lamps (Figure 4) produced materials with properties identical to those of materials produced with conventional techniques, but with much shorter annealing times and the potential for considerable cost savings. Future efforts will attempt to incorporate this technology with continuous twin roll casting to further reduce costs.

Figure 4. Infrared lamp rolling mill at Manufacturing Sciences, Inc., and close-up of magnesium alloy sheet exiting the roll gap.

As a result of a competitive solicitation, Heil Trailer International is working on a project to reduce the weight of an aluminum semi-trailer tanker by 20% through innovative design and the assimilation of composite materials into select components. Excellent progress has been made on the vessel design and finite element analysis Figure 5). Analysis, testing, and manufacturing studies have been completed successfully for the vessel and for the run gear/ fifth wheel/bumper/underride. It is anticipated that the first full-scale prototype will be completed in early 2005.

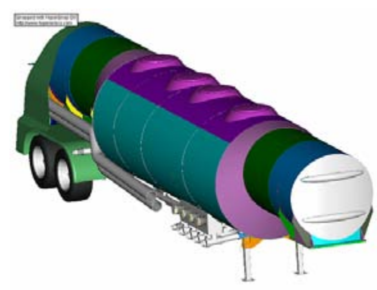

Figure 5. New-concept petroleum trailer

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 transport sector (primarily class 7 and 8 trucks) in conjunction with the original equipment manufacturers and their suppliers. Metals and their alloys still dominate the material usage in these arenas, but over the longer term, composites of many types are expected to receive wider and significant applications. The makeup of the research portfolio of this technology development area reflects the current industry needs and these future expectations.

As noted last year, several materials thrust areas have been identified, and exploratory efforts have been initiated within them. They are

1. Advanced joining technologies
2. Titanium use in heavy-duty structural and component applications
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. Several promising joining techniques are in the early phases of evaluation to determine if they can achieve the desired technical results. Economic assessment will follow to determine their cost competitiveness.

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 some of these applications, the significantly lower thermal conductivity of titanium may be an additional advantage for certain components.

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 interaction through formulation modification may enable a total increase in energy efficiency of up to 5% in addition to improvements that may be gained in the combustion process. These technologies have been ranked in terms of their projected relative salubrious effects and are currently being systematically characterized and tested. Data from this work are being prepared for presentation via oral presentations at professional society meetings and in published papers.

It is anticipated that collaborative efforts with the Automotive Lightweighting Materials Technology Development Area will be continued 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 project portfolio, with a modest number of projects of longer-term and more speculative nature.

It is interesting and probably significant to note that just when an experienced , knowledgeable practitioner in the field of technology conception and development feels that he has seen all the major advances that he might reasonably expect to encounter, his superbly motivated technical colleagues, young and old alike, discover and share new and remarkable technologies that promise greater efficiency gains, improved properties, and even lower costs than the conventional materials of current use. This wonderfully innovative and exhilarating process is more than influential enough to keep old workhorses in harness, vying with and eventually winning over a harried and unreceptive user public and a generally otherwise directed political bureaucracy.

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