8. MATERIALS CROSSCUTTING R&D

A. Technical Cost Modeling

Principal Investigator: Sujit Das
National Transportation Research Center
2360 Cherahala Boulevard
Knoxville, TN 37932-6472
(865) 946-1222; fax: (865) 946-1314; e-mail: dass@ornl.gov

Technology Area Development Manager: Joseph A. Carpenter
(202) 586-1022; fax: (202) 586-1600; e-mail: joseph.carpenter@ee.doe.gov
Field Technical Manager: Philip S. Sklad
(865) 574-5069; fax: (865) 576-4963; e-mail: skladps@ornl.gov

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Objectives

- Address the economic viability of new and existing lightweighting materials technologies.
- Develop technical cost models to estimate the cost of lightweighting materials technologies.

Approach

- Address the economic viability of lightweighting materials technologies supported by the ALM.
- Use cost modeling to estimate specific technology improvements and major cost drivers that are detrimental to the economic viability of these new technologies.
- Derive cost estimates based on a fair representation of the technical and economic parameters of each process step.
- Provide technical cost models and/or evaluations of the "realism" of cost projections of lightweighting materials projects under consideration for ALM funding.
- Examine technical cost models of lightweighting materials technologies that include (but are not limited to) aluminum sheet; carbon-fiber precursor and precursor processing methods; fiber-reinforced polymer composites; and methods of producing primary aluminum, magnesium, and titanium and magnesium alloys with adequate high-temperature properties for powertrain applications.

Accomplishments

- Completed a cost-benefit evaluation of the ALM's polymer composites efforts.

Future Direction

- Estimate the impacts of the remaining lightweighting materials areas (i.e., magnesium, steel, metal-matrix composites, aluminum sheet forming, and recycling) supported during the fiscal year 2000–2004 periods.
- Continue individual project-level cost modeling to identify specific technology improvements and major cost drivers that are detrimental to the economic viability of these technologies.

Benefit Evaluation of Polymer Composites

The focus during this fiscal year for this task has been on the benefit evaluation of ALM efforts supported during the fiscal year 2000-2004 periods. The polymer composites efforts, which accounted for a major share of the total ALM funding during the last five-year funding cycle, are only being considered this fiscal year for the benefits evaluation. The benefit evaluation of a specific lightweighting material area is based on a detailed evaluation of a few illustrative projects from that area. The following *five* illustrative projects (along with the major partners listed within parenthesis for each case) were selected from the list of 24 polymer-composites projects supported with a total funding level of around $68 million.

- Automotive Composites Consortium focal project 3 (ACC) (report 4.D);
- Durability of lightweight composite structures (ORNL) (report 4.H);
- Low-cost carbon fibers from renewable resources (ORNL) (report 3.A);
- Low-cost carbon fiber development project (Hexcel/ORNL); and
- Modeling of composite materials for energy absorption (LLNL/ORNL).

These projects mainly cover the carbon-fiber-reinforced polymer-composites focus area examining such issues as durability and safety, important for any lightweighting materials. The R&D projects reflect multiple partners involved in the R&D effort, e.g., national-laboratories-only versus national-laboratories and private-sector collaboration. In choosing the five projects, we also took into consideration the level of funding (one of the larger amounts funded in the polymer-composites area) and project status (e.g., projects completed and those on-going).

Due to the significant focus on the costs of carbon-fiber composites as a means to increase their viability as an option to the automakers, two projects dealing with costs were selected (low-cost carbon fibers from renewable resources and low-cost carbon-fiber development). Similarly, two projects, durability of carbon-fiber composites and modeling of composite materials for energy absorption, fall under the category of enabling technologies, focusing on durability and safety areas, respectively.

The remaining project—composite-intensive body structure for focal project 3—covers the area of polymer-composites manufacturing R&D, has one of the largest budgets, and is 100 percent cost-shared by the auto industry. In addition, it covers technology commercialization. The projects are also reflective of the differences in project partners, i.e., national-laboratories-only in the modeling of composite materials for energy absorption versus private-sector and national- laboratory collaboration in the low-cost carbon fiber development program. Only two projects, i.e., durability of carbon-fiber composites and low-cost carbon-fiber development program, have been completed.

An evaluation framework developed earlier with the goal of evaluating both short-run outputs and long-run outcomes of the R&D projects was selected. The framework consists of four methods using both qualitative and quantitative measures and they are: qualitative assessment, National Research Council indicators, quantitative benefits, and benefit-cost analysis. The first three types of benefits information were collected from the project participants through surveys, which assessed their views about the benefits of projects, including the number of publications produced and graduate students supported by the end of a project and long-term benefits (knowledge-level gained through the publications, human capital investment in graduate students' dissertations and theses produced, and increased international competitiveness of the Big 3 automakers). The benefit-cost analysis is used to monetize values for the benefits and costs of each project. The benefits are estimated based on the projected market penetration of carbon-fiber-composite materials in light-duty vehicles using a Delphi technique.

Overall, the results of the qualitative assessment are positive for the five projects. There was 100 percent agreement that technical objectives were met with the exception of two projects such as the composite-intensive body structure project for focal project 3 which remains to be completed. New knowledge was yielded from all five projects and, in general. collaboration was enhanced through research activities. If future collaboration were uncertain, issues related to proprietary concerns and finding the correct mix of technical skills were seen as impediments. As one would expect, there was less agreement on whether the results of the project were sufficient for carbon fibers to be a viable option for the automobile sector.

Results of the National Academy of Sciences' indicators show numerous publications (in the range of (9-40) in each R&D effort, where the number of publications appears to be related to the level of involvement of national laboratories and participants. There were mixed perceptions on whether the United States is leading internationally in research on the use of low-cost carbon fibers in the manufacturing of parts for the light-duty vehicles. Most participants indicated the United States was about even or following countries in the European Union or Japan. Nor is the United States perceived as leading in commercialization of carbon fibers in light-duty vehicles. However, there was agreement in all the projects (at least a majority of responses were greater than 50 percent) that the R&D efforts *will* improve the United States' international competitiveness.

The quantitative benefits revealed from this evaluation are quite impressive. Graduate students were involved in each project (maximum 5 per year in one project), even though the project may not have had an active university participant. In addition, patents and copyrights were applied for and received (and future applications are envisioned). Software packages were commercialized in some projects. The reaction of the Big 3 automakers has been favorable on the usefulness of the software.

The results of the economic analyses, primarily the benefit-cost ratios for each of the five projects, are shown in Table 1. The benefit-cost analysis takes into account energy, environmental, and security benefits. The project costs include both federal funding and private-sector matching funds. The base, moderate, and high cases represent low, medium, and high monetary values for energy, environmental, and security savings in Table 1. Note that estimated benefits are based on the projected market penetration of carbon fiber composite materials in light-duty vehicles using a Delphi technique. In every case, the benefit-cost ratios indicate significant benefits for these projects. The fiber development project tops the list, whereas, a significantly higher project cost causes the durability project to be at the bottom of the list. It must be noted, however, that several uncertainties are associated with these numbers, as is typical for benefit-cost analyses. First, the commercialization date and market penetration rates for each technology are uncertain besides the portion of total market penetration that can be accurately attributed to government funding. The analysis assumes dates for initial commercialization and market penetration rates that may or may not come true. Second, the projects reflect uncertainty in the level of benefits associated with each new vehicle that contains new lightweight materials. Third, uncertainties exist concerning the monetary values to be assigned to each benefit, e.g., values of reducing CO_2, oil imports, etc.). Fourth, investment costs to be borne by the automobile manufacturers and their suppliers to implement the new technologies are not fully captured in this analysis.

Table 1. Estimated Benefit-Cost Ratios of Five ALM Polymer-Composite Projects.

Project	Project Cost ($ millions)	B-C Ratio* Base Case	B-C Ratio* Moderate Case	B-C Ratio* High Case
DOE	68.3	29(25)*	62(45)*	124(75)*
Focal Project 3	5.1	90(79)*	193(140)*	388(233)*
Durability	7.2	41(36)*	94(68)*	195(117)*
Renewable Fiber	3.1	89(77)*	200(145)*	417(250)*
Fiber Development Program	3.6	134(117)*	279(202)*	548(329)*
Modeling	4.4	52(45)*	123(89)*	261(157)*

* Numbers inside parenthesis indicate benefit-cost ratios *without* taking into account environmental and security benefits.

Publications

1. "Life Cycle Impacts of Automotive Liftgate Inner," *Resources, Conservation and Recycling,* Vol. 43/4 pp 375-390, Mar. '05.
2. "Cost-Effectiveness of Carbon Reinforced Composite Automotive Part Manufacturing Technologies," presented and published in SAMPE 2005/Long Beach Conference Proceedings, May 1-5, 2005 in Long Beach, CA.