8. MATERIALS CROSSCUTTING R&D

A. Technical Cost Modeling

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Objectives

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

Approach

- Address the economic viability of lightweight 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 lightweight materials projects under consideration for ALM funding.
- Examine technical cost models of lightweight 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

- The cost-benefit evaluation of the Phase II ALM projects funded during the fiscal year FY 2000-2004 period was completed by focusing on the remaining lightweight materials areas besides polymer composites.

Future Direction

- Provide specific assessments in support of the cost modeling and the life-cycle analysis tasks for the multinational magnesium front-end research and development project (see 2.K).

- 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 Non-Polymer Composites ALM Program Area

The focus during this fiscal year for this task has been to complete the benefit evaluation of the Phase II ALM projects (i.e., fiscal year 2000 -2004) started during the last fiscal year by evaluating the remaining ALM lightweight- materials areas. Only three remaining lightweight- materials areas have been considered during this fiscal year, i.e., aluminum, magnesium, and high-strength steel, since in other remaining lightweight materials areas, either the effort has been too limited or projects are still in their infancy. As before, the benefit evaluation of a specific lightweight-material area is based on a detailed evaluation of a few illustrative projects from that area. The following *four* illustrative projects (along with the specific lightweight-materials area represented and major partners listed within parenthesis for each case) were selected from the list of 32 non-polymer composites projects supported with a total funding level of around $60 million.

- Active flexible binder control system for robust stamping (aluminum – Ford)—see 2.B,
- Lightweighting front structures (advanced high-strength steel – Auto Steel Partnership)—see 2.W,
- Magnesium powertrain cast components (magnesium – General Motors)—see 2.H, and
- Structural cast magnesium development (magnesium – General Motors)—see 2.G.

These four projects complement five projects considered earlier in the polymer-composites area and mainly focus on the material application in a specific demanding area of automotive applications. The R&D project teams reflect multiple partners (including OEM suppliers and national laboratories) involved in the R&D effort, although these projects were led by a major OEM in most cases above. In choosing the four projects, we also took into consideration the level of funding (e.g., two of the largest funded projects in the magnesium area) and project status (e.g., projects completed and those on-going).

The magnesium projects selected not only are the two largest projects funded in this material area, but both are nearing completion and have had the greatest industry participation. Because aluminum is a relatively mature automotive material, the focus of the selected aluminum project has been on the stamping issue and the application of results to aluminum and other competing lightweighting materials. Despite the introduction of more advanced high-strength steels in light-duty vehicles, challenging areas such as joining, failure, and structural part manufacturing continue. Several ALM projects have been initiated to address these issues in coordination with the Auto/Steel Partnership. Only one project – lightweighting front structures – selected in this area is a technology-validation project and is the beneficiary of other projects supported in this area.

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 a specific lightweight material in light-duty vehicles using a Delphi technique.

Table 1. Estimated Benefit-Cost (B-C) Ratios of Nine ALM Projects.

Table E.S.6: Benefit-cost Ratios				
Project	**Project Cost ($ millions)**	**B-C Ratio Base Case***	**B-C Ratio Moderate Case***	**B-C Ratio* High Case**
Composites				
DOE (carbon-fiber composites)	66.4	41 (35)	78 (60)	147 (104)
Composite-intensive body structure development for focal project 3	5.1	126 (108)	236 (183)	447 (318)
Durability of carbon-fiber composites	7.2	61 (52)	120 (93)	235 (168)
Low-cost carbon fiber from renewable resources	3.1	124 (106)	245 (190)	479 (341)
Low-cost carbon-fiber development program	3.6	188 (161)	341 (265)	631 (449)
Modeling of composite materials for energy absorption	4.4	73 (62)	150 (117)	301 (215)
Non-Composite Lightweighting Materials Projects				
DOE (aluminum)	32.9	425 (324)	669 (508)	1034 (794)
Active flexible binder control system for robust stamping	1.5	3217 (2360)	5207 (3950)	8540 (6563)
DOE (magnesium)	14.6	106 (90)	259 (199)	606 (417)
Magnesium powertrain cast components	4.3	156 (131)	424 (327)	1023 (696)
Structural cast magnesium development	8.2	34 (29)	86 (67)	198 (134)
DOE (High-strength steel)	10.5	472 (407)	818 (644)	1476 (1056)
Lightweighting Front Structures	3.1	804 (694)	1443 (1136)	2672 (1908)
*Numbers inside parenthesis indicate benefit-cost ratios without taking into account environmental and security benefits.				

These four methods complement the benefits matrix developed for DOE's reports to Congress mandated under the Government Performance and Results Act of 1993 (GPRA). Our framework, besides GPRA requirements, also includes realized knowledge benefits and costs, yet to be reported to Congress, through the qualitative assessment (knowledge gains) and through the coverage of publications and presentations, project deliverables, patents and graduate student support.

Overall, the results of the qualitative assessment are positive for the four projects considered. Nearly all respondents in three of the four non-composites projects believed his or her respective project had met its technical objectives with the exception of one case because the project was still on-going or the investigators were involved in only one task and could not speak for the entire project. Almost all investigators believed that their project yielded knowledge. One-third or fewer investigators believed that their respective projects would have occurred in the absence of DOE participation and/or funding, attesting to the crucial role of DOE. Several of these investigators noted that they would have had lower amounts of funding in the absence of DOE support. Respondents noted that DOE's participation fosters collaboration, attracts major participants, and is necessary because costs are too great for any single firm to bear. In two of the four projects—*lightweighting front structures* and *structural cast magnesium development*—participants agreed unanimously that collaboration was enhanced; while in the remaining projects, solid majorities of participants—83% and 93%—believed collaboration to have been enhanced. It is surprising to note that only 60% of participants in the *structural cast magnesium development* project believing the project results will be incorporated into product design, given that the 2006 model year Corvette Z06 already uses a magnesium engine cradle that emanated from the project. Cost of the material was identified as a barrier to wide-scale introduction of these lightweight materials, with the exception of the lightweighting front structures project which used advanced high-strength steel. Other prominent barriers were manufacturing/performance issues and the corporate culture of the Big Three automakers (e.g., a resistance to change).

Results of the National Academy of Sciences' indicators show numerous publications (in the range of (4-119) in each R&D effort where the number of publications is primarily dependent on the number of participants per research project. It is noteworthy that projects with heavy involvement from the private sector can publish extensively. Graduate students were involved in each project, including undergraduate students on both magnesium-focused projects. Only one patent has been sought to date, but respondents expect a number of patents and copyrights stemming from this research to be sought in 2006 or 2007. In most cases, the reaction of the Big Three automakers to the software packages or other deliverables finalized from the project was positive, particularly in the case of the magnesium powertrain cast components projects in their decision-making process for incorporating magnesium into automotive production. From the structural cast magnesium development R&D effort, there is potential for commercialization for the magnesium alloy database; radioscopic standard for magnesium castings; and failure model.

The results of the economic analyses, primarily the benefit-cost ratios for all nine projects (including five projects considered earlier under the polymer composites lightweight materials area), are shown in Table 1.

The benefit-cost analysis takes into account energy, environmental, and security benefits and the row designated as DOE in this table indicates the overall contribution of the U.S. Department Energy R&D programs in a specific lightweight material area. 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 a specific lightweight material in light-duty vehicles using a Delphi technique. In every case, the benefit-cost ratios indicate significant benefits for these projects. The estimated benefit-cost ratios of non-composite projects are significantly higher than for composite projects. The non-composite material areas--particularly the aluminum and high-strength steel areas--are comparatively more mature than the carbon-fiber polymer composite materials area. The selected projects under these two material areas are anticipated to aid in the significant penetration of these materials in light-duty vehicles, having significantly higher benefit-cost ratios than for overall material area. A significantly lower project cost in case of the flexible binder control project results in the most benefit-cost ratio in this case. The estimated benefit-cost ratios of magnesium are similar to carbon-fiber polymer composite projects, both indicating a relatively early stage of the use of these materials in light-duty vehicles. Person-year and cost savings from having access to federal R&D funds were also estimated and found to be quite substantial, in most project cases less than 20 person-years and $12 million, respectively.

Conclusions

There are two perspectives that can be taken from this evaluation. When considering an overwhelming majority of the indicators selected, the responses are outstanding. There remain questions about whether the results will be incorporated or whether a material is a viable option. What this evaluation has highlighted are the ongoing challenges to change in the automobile industry: there may remain a gap between establishing the technical feasibility of a material or process and making a business decisions to move forward with a lightweighting material.

The ALM effort helps to reduce the risks to the OEMs and suppliers by exploring new materials options. The program also facilitates discussion and collaborations among the OEMs and suppliers to help overcome the catch-22s such as when and which party (i.e., OEMs or suppliers) needs to invest in the R&D for lightweighting parts. The program is valuable in helping to identify next steps to developing new lightweighting parts. The ALM effort brings materials expertise found in national laboratories and universities that can get the discussions and R&D moving. It has also been shown that the projects help to build a critical mass of professional expertise needed to move the industry forward in these materials areas. This expertise could then direct future R&D in many new directions, not only in the directions represented by the ALM-funded projects.

Presentations/Publications/Patents

Das, S. Peretz, J. H. Tonn, B. E. (2006). "Automotive Lightweighting Materials Benefit Evaluation," ORNL/TM-2006/545, Oak Ridge National Laboratory, Oak Ridge, TN, November.