Automotive Lightweight Materials Assessment

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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. Priority lightweighting materials

include advanced high-strength steels, aluminum, magnesium, titanium, and composites including metal-matrix materials and glass- and carbon-fiber-reinforced thermosets and thermoplastics. Cost reduction is one of the five research areas that ALM is pursuing. ORNL has been involved in this area by addressing the economic viability of new lightweight materials technologies over the past several years. Numerous process cost models have been developed to estimate the cost of lightweight materials technologies.

Process Cost Modeling

A spreadsheet-based cost modeling framework is used for the cost estimation of advanced lightweight materials technologies utilizing the process-cost approach. A manufacturing technology is represented as a sequence of individual process steps under this approach, where the output of the first process step – in terms of total cost and the costs of individual inputs – becomes an input to the second production step, and so forth. For each production step, the total cost of the product at that step, the contribution of that production step to the total cost of the product at that point in production, and the contribution of each input to the total cost and to the cost of a particular production step can be estimated. This methodology thereby allows to identify not only the particular production step but also the input parameter of a production step detrimental to the economic viability of an advanced lightweight materials technology.

Figure 1 shows the cost distribution of a carbon fiber reinforced polymer composite body side inner part for light-duty vehicle applications obtained using the process-cost modeling approach.

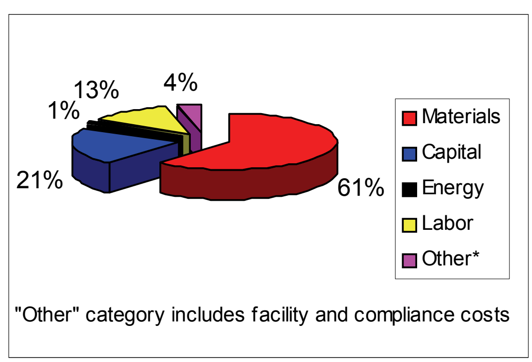

Figure 1. The cost distribution of a carbon fiber reinforced polymer composite body part.

Material cost contributes a major share of total part cost, mainly due to the higher carbon fiber cost limited to military applications today. DOE is currently focusing its carbon fiber R&D activities towards the development of cost-effective carbon fiber production technologies for a widespread use of it in light-duty vehicles in the near future.

Life Cycle Analysis

Life cycle analysis is another methodology frequently used to determine the viability of lightweight materials in light-duty vehicle applications. Most lightweight materials such as aluminum, magnesium, and polymer composites are either expensive and/or energy intensive to manufacture today. Lightweighting benefits include improved fuel economy which compensates for the increased initial vehicle cost and manufacturing energy by lower energy use and cost during the vehicle operation life cycle stage. It is estimated that fuel economy improves by 6.6% per 10% vehicle weight reduction. Life cycle analysis considers all stages from “cradle-to-gate” thereby allowing more accurate and complete assessment of cost, energy, and emission impacts associated with the adoption of any new lightweight materials technologies.

Several life cycle assessments of lightweight automotive materials have been completed to date and they all indicate energy used during vehicle operation dominates the overall life cycle energy use. Figure 2 indicates the life cycle energy impacts of stamped steel versus cast aluminum liftgate inner for light-duty vehicle applications. Although aluminum poses energy penalty at the manufacturing life cycle stage, but benefits in subsequent life cycle stages (i.e., use and recycling) cause a net savings of 1.8 GJ/vehicle compared to steel.

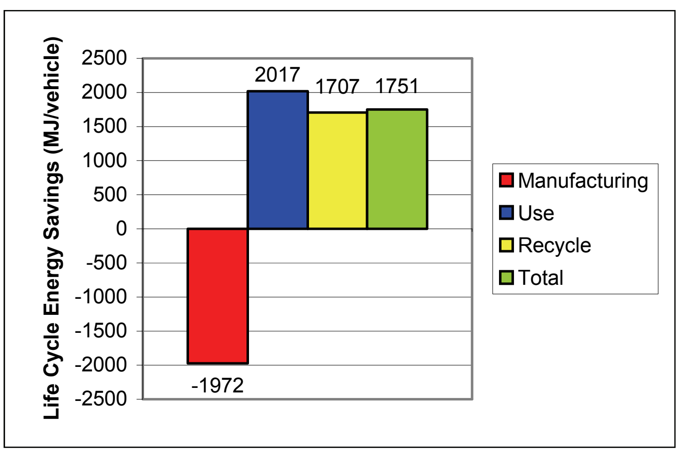

Figure 2. Life cycle energy impacts of stamped steel versus cast liftgate inner for light-duty vehicle applications.

A recent ORNL study looking at the rolled products for body-in-white applications (in which aluminum provides the greatest weight saving potential compared to steel and ultra-light steel autobody) found that it would take about 4 and 10 years, respectively, for aluminum vehicles to achieve a life cycle energy equivalence with steel and ultra-light steel autobody on a single-vehicle basis. A multinational study on the comparative life cycle assessment of magnesium and steel front end automotive parts is currently underway, and a similar assessment for carbon fiber polymer composites has also been planned during the fiscal year 2008.

Research & Development Program Evaluation

An evaluation framework has been developed with the goal of evaluating both short-run outputs and long-run outcomes of the R&D projects supported by the DOE ALM activity. 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 materials in light-duty vehicles using a Delphi technique. 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. This framework has been applied successfully in the benefit evaluation of Phase II ALM projects with a total funding level of about $60 million.

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