

The Budd Company, Design Center

Composite Materials Promise Increased Fuel Efficiency

In the early 1990s, with fuel prices on the rise and conservation of national concern, both consumers and Congress began to push for stricter vehicle fuel economy requirements. However, the advent of sport utility vehicles dramatically increased the sale of light trucks. And though the fuel economy of light trucks had increased twofold since the 1978 Iranian oil embargo, it still did not approach that of passenger cars. To meet fuel-efficiency demands, many auto parts makers wanted to use composite materials (such as plastics), because of their high strength-to-weight and stiffness-to-weight ratios and superior corrosion resistance. The Budd Company sought funding from the Advanced Technology Program (ATP) to accelerate technically risky research and development (R&D) to produce composite vehicle frames by using an innovative high-volume, cost-effective process. At the close of this ATP project in 1998, the Budd Company had successfully completed a pilot manufacture of structural impact bumpers using its structural reaction injection method (SRIM). However, with cycle times of 3 to 6 minutes instead of the desired 60 to 90 seconds, Budd determined that its SRIM technology was still unsuitable for most automotive applications. The company continues to invest in R&D to further reduce cycle times.

COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

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Research and data for Status Report 94-02-0040 were collected during October - December 2001.

Light Trucks Generate Heavy U.S. Economic Activity

As U.S. automotive manufacturers recovered from a sharp downturn in sales resulting from the 1990 recession, light trucks played a salient role in the industry's resurgence. By 1994, light trucks, particularly sport utility vehicles (SUVs), accounted for almost 40 percent of all U.S. motor vehicle sales, with manufacturers pushing the limits of their production capacity in order to meet the overwhelming demand for these popular vehicles. Moreover, light trucks represented a U.S. manufacturing stronghold—domestic manufacturers supplied 90 percent of the light trucks sold in the United States in 1994.

However, Congress and consumers were concerned about the poor fuel economy of light trucks and the resultant depletion of natural resources, the increase in American dependence on imported oil, and the financial strain of high fuel costs on light truck owners.

Composites Begin To Lighten the Load of Light Trucks

Vehicle weight is a primary determinant of fuel economy—75 percent of a vehicle's energy consumption directly relates to factors associated with its weight. To improve the fuel economy of light trucks, therefore, manufacturers focused on reducing their weight, primarily through manufacturing methods that use raw materials offering the strength of steel without its heft.

With the highest strength-to-weight ratio of any known material, composites provide the advantages of steel at 25 percent less its weight. Vehicles with composite frames weighing 225 pounds (25 percent less than the conventional 300-pound steel frame), would consume 1.6 percent less fuel than the standard, greatly reducing overall fuel usage over the life of the vehicle.

Other Benefits Enhance the Outlook for Composites

In addition to improved fuel economy, composites offer many other benefits, such as durability, practicality, and affordable redesign. The durability of composites provides superior dent and corrosion resistance. Because several plastic parts can be molded together in one operation, manufacturers can consolidate composite parts for easy assembly. A reduction in noise, vibration, and harshness also makes composites a preferable alternative to steel.

Market trends before this ATP-funded project indicated that manufacturers should place a higher premium on a vehicle's visual appeal than on its fuel efficiency. Fuel-efficient frames had not fared well in the market due to aesthetic reasons. The molding properties of composite frames, however, could allow fuel efficiency and aesthetics to co-exist by giving parts makers the freedom to enhance visual appeal by adding compound curves and parabolic shapes to a vehicle's design. Moreover, these aggressive styling treatments would come at an affordable tooling price, allowing manufacturers to refresh a model's appearance on a year-to-year basis and keep up with the booming market for vehicles. This is impossible with steel, because exorbitant tooling costs prohibit updating steel-based vehicles as frequently as the market demands. On average, the development of tooling for a composite part is twice as fast and four times less expensive than the development of steel tooling, allowing for the rapid production of limited-edition models with low retooling costs.

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With the advantages of low retooling costs, practicality, and high fuel efficiency, composites seemed to meet all of the demands of the automotive market. Increasing the use of composites in U.S. automotive manufacturing processes promised to strengthen the U.S. position in the lucrative vehicle market, increase the aesthetic and practical appeal of domestic vehicles, save consumers close to \$1 billion annually in fuel costs, and make a positive impact on the environment.

Composites Manufacturing Methods Require Further Development

Composites were first used in the body of the 1954 Chevrolet Corvette; however, relatively high material and manufacturing costs have limited their full use. To convince the industry of the value of composites, parts makers focused on improving manufacturing techniques to reduce scrap costs and accelerate cycle times. Whereas steel proves more cost effective for high-volume applications, composites, because of the relatively low tooling investment costs, were beginning to prove their value for lower volume production. Therefore, parts makers sought to optimize manufacturing methods aimed at producing 100,000 to 150,000 parts annually.

To optimize manufacturing methods, however, parts makers had to overcome significant manufacturing method inertia. For decades, researchers had concentrated on developing methods for manufacturing sheet-molded compound (SMC) as the way to introduce composites into vehicles. However, because of serious drawbacks, such as high scrap waste, low impact resistance of SMC parts, costly refrigeration storage requirements, and low material shelf life, manufacturers sought alternative methods. In the 1980s, structural reaction injection molding (SRIM) presented a possible alternative, providing the following advantages over SMC: better structural control of the amount and orientation of fiberglass (which provides early identification of the quality and strength of the part), lower tooling costs, and reduced scrap waste.

However, SRIM had inadequacies that the Budd Company thought it could address through two innovative improvements. Convinced of the potential benefits of implementing these modifications, the company sought ATP funding in 1995 to accelerate the advancement of SRIM techniques so that the technology for a composite vehicle frame would be available for vehicles manufactured in 2000.

Speed-to-Market Is Critical in the Automotive Industry

Composites promised to speed up product development, which had been a U.S. industry weakness. In the automotive industry, the United States

requires 60 months and 3.2 million labor hours for product development, whereas Japan boasts a development time of 46 months, using only 1.7 million labor hours. Because composites require less extensive tooling, on average 39 weeks for tooling design and manufacture compared to 50 weeks for steel tooling, they could offer quicker product development once the basic composite technology was in place.

Prior to the ATP award, the pace of SRIM R&D lagged behind the goal to develop the basic technology for a full-frame composite vehicle by 2000. The Budd Company's R&D allocation was \$250,000 annually, a rate that translated into a development time of 12 years. ATP's contribution of \$2 million reduced the expected development time to just four years, giving U.S. manufacturers a competitive edge in the composites market.

Innovative Use of New Process Advances SRIM Technology

In its submission to ATP, the Budd Company proposed to develop SRIM manufacturing methodologies for a one-piece hollow closed-section light truck frame. By creatively applying a 70-year-old technology known as the slurry process to the production of preforms and by using a disposable film bladder in the molding stage, the company hoped to use SRIM manufacturing to make the process an economical option for parts production. The ultimate output goal was approximately 50,000 to 100,000 units annually. Before the ATP project, which began in 1995, the Budd Company did not have the capability to produce even a limited number of prototypes; the technical risk was simply too high for internal funding. The potential business impact of lighter frames on the automotive industry and the environmental impact of more fuel-efficient automobiles, however, were too significant to ignore. ATP awarded the Budd Company \$2 million in cost-shared funds to pursue research and prototype development.

Adapted Slurry Process Proves Cost Effective

The Budd Company's first innovation was to adapt the slurry concept to develop a preform manufacturing process. The slurry process is less expensive than the

labor-intensive hand-cut preforms and high-scrap thermoformed preforms. The process involves a tank of water with a hydraulic cylinder mounted beneath it. A cradle is attached to the hydraulic cylinder, upon which a platen rests, covering the surface area of the tank. A perforated screen, shaped to the geometry of the desired vehicle part, is fixed at a cutout in the platen and positioned at the bottom of the tank. Chopped reinforcing fibers and thermoplastic binding fibers are introduced into the water, creating a slurry, which is agitated to produce uniform dispersion. Once uniform dispersion is achieved, the hydraulic cylinder moves the screen rapidly to the surface, capturing fibers as the water passes through, in the fashion of a sieve. The resulting structural preform, now shaped to the geometry of the desired vehicle part, is removed from the screen and placed into an oven to dry.

The next step of the SRIM process, injection molding, uses the Budd Company's second innovation: a low-cost disposable film bladder that acts as a vacuum to hollow out the part. First, two preforms are fit together and clamped. A disposable film bladder, roughly shaped to the geometry of the part, is inserted between the upper and lower preforms and is inflated, thereby defining the hollow surface of the part during the molding process. Catalyzed resins are injected into the mold through flow channels, which pour through the mold cavity to fill the space between the bladder and the preforms. The bladder, a balloon-like vacuum that penetrates the walls of the preforms, withdraws all excess air from the mold cavity, thereby pressing the resins against the pockets and grooves of the two preforms, as in-mold polymerization and curing of the resins occur.

SRIM Process Achieves Technological Advancements

Significant technological advances that Budd achieved during the ATP project include:

- Identification of a durable material to manufacture film bladders strong enough to withstand high heat and pressure and development of a successful nozzle design for the vacuum function of the bladders

- Improvement of the aerial density of finished parts by enhancing the slurry preform process, including modified bubblers for better agitation control, control of the length of time for glass dispersion and the speed for pulling the screen through the slurry, and the patented use of an improved capture method
- Validation of the slurry and molding processes by two successful trial runs that produced prototype SRIM storage boxes and structural impact bumpers

A cost-benefit comparison of the Budd Company's new method compared with the older method revealed a cost savings of 42 percent on a per-unit basis. Moreover, the new slurry process produced lighter parts that exhibited a glass variation of only 10 percent (as opposed to 40 percent associated with other processes) and generated less than 5 percent mold scrap (compared to a scrap rate of 20 percent with other processes).

ATP's contribution reduced the expected development time to just four years, giving U.S. manufacturers a competitive edge in the composites market.

Despite these advances, technical challenges persisted. The Budd Company still needed to address the limitations of bladder technology, as leakage remained a problem and bladders exhibited inferior performance for complex vehicle parts with difficult-to-duplicate preform surfaces. Fine-tuning of slurry process control and molding injection techniques presented other opportunities for SRIM advancement. The Budd Company continued to fund R&D for the SRIM process after the ATP project ended, including its work with the Automotive Composites Consortium to enhance preform technology by focusing on the production of tailgates.

SRIM R&D Intrigues Automotive Industry

During the ATP project, the Budd Company conducted several tours of its plants to generate interest in the

potential of SRIM processes, particularly bumper and chassis applications. Participants included Ford Scientific Laboratory and the Carrier Transicold Division of United Technologies. The Budd Company developed a cost model of its SRIM process to illustrate to several low-volume liquid molding companies the advantages of the slurry process as an alternative to labor-intensive hand-cut preforms and high-scrap thermoformed preforms. Budd validated the SRIM method by successfully producing 200 SRIM structural impact bumpers. Samples of SRIM preforms were supplied to one of the molding companies for testing to determine moldability. Additionally, the Budd Company transferred the 200 structural impact bumpers produced from the successful trial run to ETM Enterprises, Inc., a company that had previously limited its efforts to manufacturing SRIM components from only sheet and thermoformed glass preforms. ETM compared Budd's SRIM-processed components with its sheet and thermoformed glass preforms.

In 1999, the Budd Company's parent company, Thyssen AG, merged with Krupp AG. As a result of that merger, the Budd Company remains a U.S.-owned subsidiary, but is now part of Thyssen Krupp Automotive AG, a company that ranks among the largest automotive suppliers.

Conclusion

During its ATP project, the Budd Company reached average cycle times of three to six minutes for the production of prototype structural reaction injection method structural impact beams. However, it did not achieve desired cycle times of under 60 to 90 seconds, which would make SRIM comparable to sheet-molded compound. Because of the high cycle times associated with SRIM, the Budd Company now focuses primarily on SMC components. However, the business benefits of these composite materials remain attractive for manufacturers, and the promise of a manufacturing breakthrough continues to drive investment in composite materials. The Budd Company continues to invest in research and development to further develop the methods that emerge in the ATP project. Moreover, the SRIM technology that was developed during this ATP project will contribute to the industry's efforts to optimize manufacturing methods for composites.

PROJECT HIGHLIGHTS

Budd Company, Design Center

Project Title: Composite Materials Promise Increased Fuel Efficiency (Development of Manufacturing Methodologies for Vehicle Composite Frames)

Project: To develop and implement a cost-effective method for manufacturing composite frames for light trucks that are 75 pounds lighter than conventional steel frames, thereby increasing vehicle fuel efficiency.

Duration: 2/1/1995-1/31/1998

ATP Number: 94-02-0040

Funding** (in thousands):

| | | |
|------------------------|--------------|-----|
| ATP Final Cost | \$ 2,000 | 60% |
| Participant Final Cost | <u>1,312</u> | 40% |
| Total | \$ 3,312 | |

Accomplishments: The Budd Company validated the structural reaction injection method (SRIM), which incorporates the slurry process and bladder technology, by successfully producing 200 SRIM structural impact prototype bumpers. Budd has written several publications and received the following patents for technologies related to the ATP project:

- o "Apparatus for controlling fiber depositions in slurry preforms"
(No. 5,795,443: filed March 13, 1997, granted August 18, 1998)
- o "Slurry preform system"
(No. 5,972,169: filed January 15, 1998, granted October 26, 1999)

Commercialization Status: At the conclusion of the ATP project in 1998, the Budd Company demonstrated the capability to produce SRIM structural impact bumpers in approximately three minutes per unit. With this relatively high cycle time, commercialization of the SRIM technology developed during this project was impractical, even for vehicle parts with annual volumes of less than 100,000. However, the successful demonstration of this SRIM process opens up possibilities for commercial applications in industries with low-volume output, such as heavy truck, recreational vehicle, and watercraft industries.

Since the ATP project ended, the Budd Company has focused primarily on sheet-molded compound (SMC) components, having determined that its SRIM technology is currently unsuitable for most automotive applications due to high cycle times. However, the company continues to invest about \$40,000 annually in research and development to further develop the methods that emerged in this ATP project. According to The Budd Company's Plastics Division, "the day when a vehicle is all or mostly made of plastics is a long, long way off. But plastics are here to stay in the automotive industry. The characteristics of plastics have become integral to the way stylists think about vehicles of the future and production engineers envision assembly." The Budd Company remains a leader in the growth of composites.

Outlook: The outlook for this technology is uncertain. As high emissions plague various open-molding processes and the industry becomes more environmentally savvy, the Budd Company foresees a possible upswing in the importance of closed-molding processes, including SRIM, that require structural preforms. This shift would make the SRIM technology developed during this ATP project especially valuable, because the unique slurry process has produced more reliable and less expensive preforms than previous methods.

Composite Performance Score: *

Focused Program: Manufacturing Composite Structures, 1994

Company:

The Budd Company
1850 Research Drive
Troy, MI 48083-2167

Contact: Jack Ritchie

Phone: (248) 619-2338

** As of December 9, 1997, large single applicant firms are required to pay 60% of all ATP project costs. Prior to this date, single applicant firms, regardless of size, were required to pay indirect costs.