Bosch Corporation (formerly AlliedSignal Braking Division)

Casting Process Innovations to Lower Cost of Aluminum Automotive Parts

In the early to mid-1990s, the U.S. Government set a far-reaching goal for fuel efficiency at 80 miles per gallon by 2010. At that time, however, most automobiles achieved about 20 miles per gallon. In order to close the fuel-efficiency gap and also to meet the growing demand for reductions in emissions, automobile parts manufacturers began to examine using aluminum more extensively in the manufacturing process. Individual parts producers were examining methods to rid aluminum of porosity and oxide-related defects, but there was no concerted effort across the industry to fix the problem quickly.

To address this problem, the Advanced Technology Program (ATP) created a focused program, " Materials Processing for Heavy Manufacturing." The program would foster innovation in materials-processing technologies that could result in more cost efficient and more reliable products affording U.S. companies a competitive advantage in the marketplace. AlliedSignal Braking Division (now Bosch Corporation) joined with two suppliers, Stahl Specialty Company (now ThyssenKrupp Stahl Company) and The Top Die Casting Company, to form a joint venture to reduce the cost of aluminum automotive parts and to speed their use for braking systems on automobiles and trucks.

The joint venture received an ATP award in 1995 to develop more efficient techniques to produce defect-free aluminum automotive parts. Unfortunately, the technical challenges were too numerous and too difficult to overcome, and the outlook for the technology is uncertain. However, the ATP-funded project eliminated the porosity problems, decreased the overall number of defects in aluminum, and enabled research into aluminum casting to advance two years ahead of where it would have been without ATP support.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 95-07-0020 were completed during October - December 2001.

Inefficient Casting Techniques Increase Costs for Aluminum Parts

In the early to mid-1990s, the preferred methods of fabricating aluminum framework components for automobiles and trucks were die casting and permanent-mold casting. While these processes were expected to grow in importance as the demand for lighter vehicles increased, both processes imposed excess costs on the use of aluminum because they created significant amounts of pores and defects in the castings. Castings with exposed surface pores and defects are typically detected at the foundry and discarded before they are used. However, those castings with defects under the surface can only be detected after machining and, sometimes, after assembly. The cost of discarding a machined casting includes the total cost of both the aluminum casting and the prior investment in machining. Moreover, the cost of discarding a fully assembled component is far higher. These costs could be dramatically decreased if the amount of pores and defects produced by the original casting operations could be reduced.

Increased Use of Aluminum Would Improve Vehicle Fuel Efficiency

By the mid-1990s, the national objectives of increased fuel efficiency and reduced vehicle emissions were forcing manufacturers to adopt lighter weight materials in the fabrication of vehicle components and structures. Components such as wheels and brakes were specific

targets for weight reduction, because a reduction in the mass of these components has a multiplicative effect in improving the vehicle's noise, vibration, and harshness performance, while reducing its fuel consumption. If the persistent, costly problems of impure aluminum could be solved, the metal, with its low density and high mechanical integrity, was expected to displace cast iron in the fabrication of numerous mechanical, hydraulic, and pneumatic components of passenger cars, light trucks, and heavy trucks. If the industry succeeded in creating a method for manufacturing aluminum that reduced the imperfections to just one small defect per part, the cost of using aluminum would decline dramatically, increasing its use in automobile and truck parts. The overall result would be lighter, more fuel-efficient vehicles.

AlliedSignal Partnered to Reduce Aluminum Defects

In 1995, AlliedSignal, a producer of parts for all types of automotive transportation, decided that parts manufacturers could reduce the cost of aluminum significantly faster through a concerted team effort. Therefore, AlliedSignal recruited two companies to form a joint venture project to correct the flaws in the aluminum-casting process. The first company, Stahl Specialty Company (now ThyssenKrupp Stahl Company), is a large firm that uses permanent-mold casting for aluminum. The second company, The Top Die Casting Company, is a small, privately held firm that uses die casting for aluminum. Both of these participants manufacture a variety of near net-shape aluminum castings for the U.S. car and truck industries. AlliedSignal used many of these parts to manufacture truck brakes, turbochargers, and automotive braking systems.

Die casting and permanent-mold casting imposed excess costs on the use of aluminum.

The impetus behind this joint venture was the ATP's focused program, "Materials Processing for Heavy Manufacturing." The primary technical goal of this focused program was to develop and demonstrate innovative materials-processing technologies that will help U.S. companies in the heavy manufacturing sector make longer lasting, more reliable, and more efficient products, features that will give their products a competitive advantage in the marketplace. Another key technical goal was to significantly reduce manufacturing costs, a factor that will enable U.S. manufacturers to offer passenger cars, light trucks, and heavy equipment at prices that will make them especially attractive in the rapidly growing and highly competitive markets of developing countries.

The joint venture's proposed development project identified two tasks that were designed to reduce the concentration of pores and defects per part from an average of one large and three small defects to one small defect. AlliedSignal estimated that achieving this lower defect level would reduce the cost of aluminum manufacturing by 10 percent. The joint venture also proposed to create computational models of the die and permanent-mold casting processes to establish the "intelligent process" conditions and die designs that would minimize the porosity and defect concentration in a wide range of cast component shapes. These models would also generate improvements in the melting, holding, and casting practices in order to prevent defects from forming during the cooling process.

ATP Support Necessary for Joint Venture to Proceed

Without support from ATP, the three companies would not have been able to pool their resources and work together as a team. Internal business processes and priorities would have prevented a focused effort of parallel, complementary research that was designed to double the existing rate for achieving weight reductions in automobiles and trucks. The proposed joint venture met the criteria of the ATP focused program and addressed an extremely important challenge facing the suppliers of the U.S. automotive industry: to reduce the cost of cast aluminum components. The joint venture's proposal claimed that maintaining this cost improvement with the introduction of shorter production runs and new component designs would require developing and maintaining a synergy between the design and casting processes. In 1995, ATP awarded the joint venture $0.9 million in cost-shared funds to establish this materials processing synergy and to work to reduce the overall cost of aluminum for automobile and truck parts.

Some Technical Risks Are Overcome, but Aluminum Not Yet Pure Enough

The technical challenges in reducing waste in die casting and permanent-mold casting are similar.

Establishing intelligent processes for casting, as well as devising improved techniques to prevent defects during cooling, had been unsuccessfully attempted at individual foundries. However, this joint venture hoped to succeed where others had failed by leveraging each entity's specific knowledge. Together, the joint venture participants generated robust, finite element models of each casting process in order to develop new die designs. These models related the controllable casting parameters to the microstructure, expected oxide inclusions, and residual stresses of cast aluminum to attempt to reduce pores that formed during the post-casting cooling process. As a result of these process improvements, oxide particulates and absorbed gasses were reduced significantly in the melting process (zero rejects for porosity).

Achieving this lower defect level would reduce the cost of aluminum manufacturing by 10 percent.

At the end of the ATP-funded project in 1997, the new processes had reduced the defects in cast aluminum from one large and three small defects per part to two small defects per part. Though this was a significant improvement in purity, the aluminum defects were still too prevalent to generate the cost savings needed to use aluminum in AlliedSignal's braking systems. The company was able to eliminate up to 85 percent of the defects from valve body designs using the new processes. While that reduction in defects and scrap was promising, other structures could not be produced as cost efficiently. Therefore, all products still required continuous testing and screening, and the new process did not result in cost reductions.

While the AlliedSignal joint venture was unable to produce multiple-part braking system products, there were some individual successes. The Top Die Casting Company reported that they used the new casting process to manufacture air brake valves, brackets, and other component parts, resulting in reduced scrap and reduced cost to the customer. They reported being one to two years ahead of where they would otherwise have been in aluminum-casting techniques. The company committed several hundred thousand dollars to research this process between 1997 and 2001, when they hoped to learn to cast aluminum in their cold chamber machines. The Top Die Casting Company would not have undertaken this research without the base of knowledge acquired during the ATP-funded research. Additionally, Stahl Specialty Company reported using the ATP-funded tooling design on a separate product line that it began selling in late 1997.

Participants Shared Their Project Knowledge

Throughout the duration of the ATP-funded project, the participants shared their experiences and knowledge with others in the industry. The Top Die Casting Company published an article in *Modern Metals* magazine and attended several annual National Institute of Standards and Technology-sponsored meetings for the industry, where the company's representatives spoke with attendees about its findings. Stahl Specialty Company shared its knowledge through consulting and touring arrangements with other foundries, as well as through presentations at three conferences, including the American Foundry Society and the Aluminum Casting Research Laboratory.

All products still required continuous testing and screening, and the new process did not result in cost reductions.

In 1996, the AlliedSignal Braking Division was sold to a German company, Bosch Corporation, and in 1997 it became a subcontractor rather than a joint venture partner. Although the company participated fully as a subcontractor and performed to expectations, it was not in a position to share its findings.

Conclusion

Although the AlliedSignal joint venture sought to create improved braking systems for automobiles and light trucks by decreasing the total cost of aluminum production, the project did not reach its overall goals. Aluminum production costs were not reduced by 10 percent, because the new process could not achieve the target reduction in defects that would eliminate the costly inspection and rejection processes that follow machining. Research into processes to reduce aluminum defects did continue after the close of the ATP-funded project, although no new product lines resulted.

PROJECT HIGHLIGHTS
Bosch Corporation (formerly AlliedSignal Braking Division)

Project Title: Casting Process Innovations to Lower Cost of Aluminum Automotive Parts (Low-Cost, Near Net-Shape Aluminum Casting Processes for Automotive and Truck Components)

Project: To develop design and process innovations in die casting and permanent-mold casting to minimize microstructural defects, thereby improving the quality and lowering the cost of cast aluminum components for cars and trucks.

Duration: 9/30/95-12/30/97
ATP Number: 95-07-0020

Funding (in thousands):

ATP Final Cost	$ 898	50%
Participant Final Cost	898	50%
Total	$ 1,796	

Accomplishments: Participants in this joint venture were unable to reach their goal of a 10-percent reduction in the cost of aluminum manufacturing as a step toward increasing overall fuel efficiency in automobiles and trucks. However, they were able to create a synergy between design and casting processes that resulted in the following accomplishments:

- Elimination of porosity problem (zero rejects for porosity)
- Reduction from one large and three small defects per part to two small defects per part
- Acceleration of research by two years ahead of where it otherwise would have been through parallel research efforts
- Reduction of defects in a specific type of valve body design by up to 85 percent
- Commitment of hundreds of thousands of research dollars by The Top Die Casting Company to continue the ATP-funded research between 1997 and 2001; they reported being one to two years ahead of where they would otherwise have been in aluminum-casting techniques
- Manufacture of air brake valves, brackets, and other component parts by The Top Die Casting Company, resulting in reduced scrap and reduced cost to the customer
- Small process improvement at Stahl Specialty Company

In addition, the Top Die Casting Company published an article in *Modern Metals* magazine and attended several annual National Institute of Standards and Technology-sponsored meetings. The Stahl Specialty Company made presentations at three conferences, including the American Foundry Society and the Aluminum Casting Research Laboratory.

Commercialization Status: The technical challenges of this project were too numerous and difficult to overcome. As a result, AlliedSignal created no new products for brakes using the technology developed under the ATP-funded project. The Top Die Casting Company produced some components using the new processes, such as air brake valves and brackets. Stahl Specialty Company used one step of the aluminum manufacturing process to assist in aluminum filtration. That process had a small impact on several of the company's product lines.

Individual joint venture participants used the technology and process improvements developed through this ATP-funded project to create new castings with a reduced number of defects. However, the number of defects was not low enough for commercial acceptance. After additional research and development, the individual participants hope to be able to commercialize aluminum automobile parts that meet the 10-percent cost-reduction goal. As of December 2001, however, major research initiatives had ended in favor of other industry priorities, though improved aluminum purity remains a priority for the future of the industry.

Outlook: Due to continuing technical challenges in producing purer aluminum through the casting process, the outlook for this technology is uncertain. Improvements in purity did occur, and Stahl Specialty Company's manufacturing process did improve somewhat. However, it is unclear whether the industry will continue to build upon these innovations.

PROJECT HIGHLIGHTS
Bosch Corporation (formerly AlliedSignal Braking Division)

Composite Performance Score: * *

Focused Program: Materials Processing for Heavy Manufacturing, 1995

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