

Dana Corporation

## Magnetic Pulse Welding Process To Decrease Vehicle Weight and Increase Fuel Efficiency

*Looking forward in 1995, automobile manufacturers identified a potential shift in customer preferences to lighter weight, fuel-efficient automobiles; fuel-cell powered cars; and hybrid gas/electric vehicles. To make existing cars more fuel efficient and to meet the coming needs of alternatively powered vehicles, automobile original equipment manufacturers (OEMs) needed lighter components. These same OEMs, however, recognized that the 1995 generation of automobile components was manufactured as light as they could be using the existing technology. Therefore, improved efficiency could only be gained by using new, lighter weight materials, such as aluminum, and new manufacturing processes that reduced the use (and therefore the weight) of steel in welding. The Advanced Technology Program's (ATP) Focused Program, Motor Vehicle Manufacturing Technology, provided Dana Corporation with the necessary funding to develop technology to bond aluminum to steel without depositing additional metal at the weld site. Dana Corporation developed a functional magnetic pulse welding machine prototype to manufacture automobile parts that are two-thirds lighter. Once installed into vehicles, these lighter parts would result in increased fuel efficiency of 8 to 10 percent. Since the project ended in 1998, automakers have contacted Dana Corporation about using magnetic pulse welded materials in their vehicles.*

### COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

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Research and data for Status Report 95-02-0055 were collected during October - December 2001.

### Current Welding Technology Increases Component Weight

The challenge that the industry faced was how to join different metals together so that the assembled components had the desired stiffness, strength, and dimensional quality. Current manufacturing technologies that provided multi-metallic joints, such as the use of fasteners or adhesives, require additional implementation expense, such as processes and special design features, and may not achieve acceptable levels of strength and dimensional quality. Attachment processes are critical to performance in weight-reduction initiatives involving rotating assemblies, such as driveshafts. Minimizing forcing functions related to both the shaft's mass and dimensional quality necessitated a new assembly approach, especially when using large-diameter, thin-walled tubular components.

The welding method commonly used before this ATP-funded project deposited substantial amounts of additional metal onto the joint. This additional metal was critical to the integrity of the weld because it flowed into the materials to be joined, hardened, and formed into an intermolecular bond. While this bond was extremely strong, the added metal from each weld could increase the part's weight by up to 10 percent, thereby decreasing fuel efficiency.

### ATP Funds Development of Magnetic Pulse Welding Process

In 1995, Dana Corporation submitted a proposal to ATP's Focused Program, Motor Vehicle Manufacturing Technology, to develop a novel technology for bonding aluminum to steel without depositing additional metal at the weld site. ATP awarded the company \$2.0 million for a three-year research program. The company's

proposed magnetic pulse welding process begins by subjecting preshaped aluminum and steel tubular stock to high pressure within precision die cavities machined directly from computer-aided design files. This process, called hydroforming, leads to more precisely fitting structural components, which require little overlap or fill material for the subsequent welding steps.



Frames, side rails, cradles, stampings, space frames, and bumper reinforcements are a few examples of automobile products produced more efficiently due to the magnetic pulse welding process.

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These hydroformed parts are then fitted loosely together. An inductor is utilized either internally or externally to create a rapidly switching magnetic field that causes one of the metallic components to form quickly and finally impact the other "stationary" metallic part with sufficient velocity and force to create a metallurgical bond. Implementation of this process would require new machinery capable of generating proper welds in complex geometric arrangements. Because of these project risks, automobile parts manufacturers had only studied the technology, but had not taken steps to develop it.

### **New Welding Process Promises Wide-Ranging Benefits**

Dana Corporation envisioned that its new process would enhance manufacturing productivity through a simplified welding process that offered a reduction in manufacturing steps, materials, equipment, and personnel expenses. One predicted benefit to the original equipment manufacturers (OEMs) and automobile purchasers was a vehicle frame that was two-thirds lighter, which would result in an 8- to 10-percent improvement in vehicle fuel efficiency. Increased fuel efficiency, in turn, would reduce air pollution. Moreover, Dana Corporation's process could potentially reduce the energy consumed in joining components and eliminate the shielding gases associated with conventional welding, benefits that would further decrease air pollution.

If U.S.-manufactured vehicles became less expensive to manufacture, operate, and recycle, U.S. competitiveness could be enhanced, and domestic

automobile companies would realize a higher market share. Moreover, the new technology could benefit other industries that need to efficiently join dissimilar metals. Combining hydroforming with magnetic pulse welding could result in nearly limitless possibilities to improve any industry that requires machined metal or welding. New lighter, stronger, and potentially more efficient structures could be created, and costs could be reduced. The strong potential for economic spillover made the project more attractive to ATP.

### **Dana Corporation Overcomes Project Roadblocks**

During the project, Dana Corporation's team faced daunting technical roadblocks that threatened to derail the project. The prototype magnetic pulse welder, as originally designed, forged a new path for shop floor assembly power distribution and required a substantial risk assessment that took many months of the initial installation. The welding process utilized a rapidly changing magnetic field derived from the rapid release of high-voltage and high-current electricity through the welding circuitry. Concerns and design revisions addressed changes to the power distribution and insulation of the elements to prevent the potential of electrical arc-off that could compromise components of the equipment. The Dana Corporation team took nearly a year to resolve these safety problems, and, by October 1996, the machine was operating safely and more efficiently.

A second technical challenge was to determine the proper geometric relationship between the mating components to be welded. The weld angle, for example, ultimately determines a shape configuration that

influences the design for hydroformed tube ends. The shape factor is important because precisely formed tubes allow strong, smooth bonds without the need to deposit additional metal on top of deformities. A challenge throughout the project was to understand the relationship between weld angle, part size, and power distributed to the weld surface. After much effort, Dana Corporation determined the appropriate parameters for particular tubes, created prototypes, and sent the prototypes to automobile OEMs for testing. A third technical challenge was to develop consistent metallurgical bonds.

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The goal was to create bonds strong enough that, even under extreme torque, the tube warped before the bond failed. The team achieved this goal; moreover, there was virtually no gross distortion associated with this welding process once the company refined the process. It could be used to join combinations of low-carbon steel, aluminum, and stainless steel in a variety of geometries.

### **ATP-Funded Technique Applies to Other Industrial Applications**

Despite delays, Dana Corporation's advanced welding method has the potential to change entire industries. Dana Corporation engineers continue to work on production technology transfer in this post-project phase and, as of mid-2001, imminent commercialization was anticipated with a machine expected on the production floor by fourth quarter of 2002. Technical issues have been solved, a proof of concept has been developed, and automobile OEMs now recognize the value of magnetic pulse welding. When commercialization is achieved, the new welding process promises to deliver driveshafts that are straighter and lighter, experience less vibration, and enable new geometries that could change the configuration of automobile transmissions and undercarriages.

Dana Corporation's process is the most advanced of its kind in the industry. Automotive industry news indicates

that BMW attempted to use friction welding to accomplish a similar result, but could not forge strong enough bonds in their bimetallic driveshafts. According to Dana Corporation executives, because of ATP's funding and the company's innovation, major automobile manufacturers are conducting studies on how to incorporate magnetic pulse welding into their production. Since the ATP project disproved the old paradigm that dissimilar metals could not be structurally welded, OEMs are rethinking their automobiles' structures and powertrains to find cost savings and fuel efficiencies that were not thought possible before this project.

While clearly important to the automobile industry, magnetic pulse welding has wider applicability. Bimetallic welding enables lighter structures in new shapes and allows for cost savings in a way that could revolutionize the design and manufacture of many kinds of metal-based products.

### **Conclusion**

ATP funded the development of a new welding method to join dissimilar metals (something never before accomplished for productive structural shapes). Dana Corporation developed magnetic pulse welding and is poised to begin selling components into automotive production. Moreover, the company received four patents as a result of the ATP-funded project. The company had also filed several other patents that had not yet been granted when this project case study was compiled. Magnetic pulse welding has the potential to change the way many kinds of metal items are manufactured by making them lighter, assembled with greater dimensional accuracy, less expensive, and easier to assemble.



## PROJECT HIGHLIGHTS

### Dana Corporation

**Project Title:** Magnetic Pulse Welding Process To Decrease Vehicle Weight and Increase Fuel Efficiency (Advanced Welding Technology-A Phase Shift for Metallurgical Manufacturing)

**Project:** To develop a versatile manufacturing process (implemented by a new machine that combines a precision metal-forming step with an unconventional welding method that is capable of joining dissimilar metals) to build lower cost, lower weight aluminum and steel load-bearing structures, such as car and truck frames. The process requires precisely crafted and machined tubes of metal bonded by heat generated by a rapidly shifting magnetic field.

**Duration:** 9/10/95-9/98

**ATP Number:** 95-02-0055

#### Funding\*\* (in thousands):

ATP Final Cost	\$2,000	47%
Participant Final Cost	<u>2,221</u>	53%
Total	\$4,221	

**Accomplishments:** Through ATP funding of this technology, Dana Corporation created a process for welding tubular steel to aluminum without depositing additional metal, overcame technical barriers to join dissimilar metals, enabled new geometries for automobile undercarriages, and maintained the potential to increase fuel efficiency and create a phase shift in automobile manufacturing.

Dana Corporation holds four U.S. patents as a result of this ATP-funded technology and has filed for several others still in the approval process. The patents granted are:

- o "Molecular bonding of vehicle frame components using magnetic impulse welding techniques" (No. 6,104,012: filed June 14, 1996, granted August 15, 2000)
- o "Method of magnetic pulse welding an end fitting to a driveshaft tube of a vehicular driveshaft" (No. 5,981,921: filed June 20, 1997, granted November 9, 1999)

- o "Method for joining vehicular frame components" (No. 5,966,813: filed December 13, 1997, granted October 19, 1999)
- o "Molecular bonding of vehicle frame components using magnetic impulse welding techniques" (No. 6,234,375: filed August 22, 1998, granted May 22, 2001)

**Commercialization Status:** Despite delays, Dana Corporation views commercialization of the technology as imminent. The only remaining barrier is to complete extensive durability testing at original equipment manufacturer (OEM) sites, something Dana Corporation expects will occur by the end of 2002. The big U.S. automakers, as well as European companies, have contacted Dana Corporation about using magnetic pulse welded materials in their vehicles. Moreover, the company is ready to provide component parts for fuel-cell or hybrid-electric cars, if and when they are produced in larger volume.

**Outlook:** The outlook for this technology is good. Safety-related concerns and other manufacturing difficulties delayed commercialization of this manufacturing process, but Dana Corporation has overcome these difficulties. If commercialization occurs as planned, the benefits to automobile manufacturers, automobile purchasers, other industries requiring metal components, and the U.S. economy as a whole could be substantial.

**Composite Performance Score:** \* \* \*

**Focused Program:** Motor Vehicle Manufacturing Technology, 1995

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\*\* 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.

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