Quick Plastic Forming of Aluminum Sheet Metal

Background

Aluminum automotive components made using a hot blow forming process are reducing vehicle weight and increasing the fuel efficiency of today's cars. However, before General Motors (GM) and the U.S. Department of Energy (DOE) sponsored research in this technology, blow forming of aluminum was not a viable process for automakers. The prior blow forming process, called superplastic forming (SPF), was not suitable for the industry's high-production-rate demands, and the materials required for SPF were too expensive (three times the cost of standard, non-SPF, aluminum sheet metal). Therefore, bringing SPF to the automotive industry required developing low-cost SPF alloys and faster forming cycles. Reducing the cost of SPF alloys also required demonstrating the viability of SPF to both the automotive and aluminum industries. DOE initiated a program of jointly-funded research between GM and Kaiser Aluminum, with the Pacific Northwest National Laboratory (PNNL) providing a catalyst to encourage GM to develop aluminum blow forming processes. Based on early research, GM, in collaboration with Alcoa, recognized the inherent limitations of SPF and moved forward with the commercialization of an advanced blow forming process, called quick plastic forming (QPF), which takes place at even higher forming rates. The result is a cost-effective, higher-volume manufacturing technology that is producing lightweight components for today's automobiles.

General Motors' President North America, Gary Cowger, reviews the 2004 Chevy Malibu Maxx after introducing it to the media at the New York Auto Show. (photo courtesy of General Motors)

The Technology

Superplasticity in metals is defined by very high tensile elongations, ranging from two hundred to several thousand percent. The process, conducted under controlled temperature and strain rates, dramatically increases the formability of certain aluminum alloys and allows production of highly integrated, net-shape components that often consolidate many parts into one. This reduces the number of parts, fasteners, and assembly operations required for complex automotive and aerospace applications and enables the use of aluminum in place of steel at competitive costs.

However, conventional SPF can require cycle times of 20 minutes or more. The joint research between DOE and GM confirmed the limitations of conventional superplasticity, but it opened up the idea of decreasing cost through the introduction of additional blow forming developments. After the close of the joint GM-PNNL program, GM went on to develop a new process with an order-of-magnitude reduction in cycle time.

GM and PNNL researchers developed accurate SPF testing methods, including an improved specimen design based on finite element analysis and testing of various specimen geometries. The research also developed accurate and efficient SPF models, providing a valuable tool for optimizing SPF forming. Modeling was utilized in conjunction with testing of new alloy compositions in an attempt to reduce forming time. In a simplified test case, an apparent reduction in forming time was found for the modified alloys compared with a commercial SPF-grade aluminum alloy 5083.

The DOE-funded team also included research collaborators at Boeing, Washington State University, and the University of Michigan. In addition, DOE sponsored a technology feasibility demonstration with GM through a contract with Oak Ridge National Laboratory.

The research results catalyzed thinking within GM to actively pursue hot blow forming of aluminum as a mainstream metal working technique; and following additional development work, GM successfully used hot blow forming to produce aluminum closure components. For the DOE/GM work completed in March 1997, the DOE/GM team earned a Federal Laboratory Consortium Award for Excellence in Technology Transfer in 2000.

Commercialization

The QPF process made its commercial debut on GM's 2004 Chevy Malibu Maxx. GM utilized the technology to make the entire outer panel for the Malibu Maxx's liftgate as one piece instead of two pieces. In the March/April 2004 edition of *Aluminum Now*, GM's VP of Research and Development is quoted as saying, "QPF provides GM greater flexibility to create body panels with eye-catching shapes and adds to our stable of technologies [to] improve fuel economy." GM's development of a cost-effective process and cost-effective sheet materials has made blow forming aluminum viable for higher and higher volume vehicles, and will ensure that future vehicles are lighter and more fuel-efficient.

Benefits

- Weight savings of 40% on a typical mid-sized automobile, which reduces greenhouse gas emissions and increases fuel economy
- No color and fit issues on the auto assembly line where two piece construction has become one piece
- Simplification of auto assembly process
- A competitive advantage for U.S. industry in manufacturing lightweight automotive components
- For domestic aluminum industry, increased demand for higher-value mill products

Contacts

Joseph Carpenter
Office of FreedomCAR and Vehicle Technologies
(202) 586-1022
joseph.carpenter@ee.doe.gov

Mark T. Smith
Pacific Northwest National Laboratory
(509) 375-4478
mark.smith@pnl.gov

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.