SAE TECHNICAL
PAPER SERIES

2001-01-3088

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**Reprinted From: Proceedings of the 2001 SAE International Body Engineering Conference on CD-ROM (IBEC2001CD)**

The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL

**International Body Engineering Conference and Exhibition
Detroit, Michigan
October 16-18, 2001**

**400 Commonwealth Drive, Warrendale, PA 15096-0001 U.S.A. Tel: (724) 776-4841 Fax: (724) 776-5760**

**ISSN 0148-7191**




**Printed in USA**

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## ABSTRACT

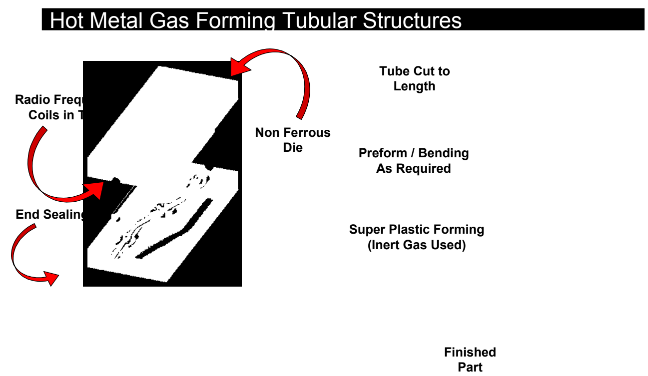
Hot Metal Gas Forming is an innovative metal forming technique with the potential to leapfrog conventional metal forming techniques of structural steel components for automotive and aerospace industry. HMGF is an outgrowth of superplastic forming (SPF) and hot blow forming (HBF) techniques that the aerospace industry developed to form aluminum and titanium structures. The goal of this program is to develop the HMGF process and prove its production readiness for wide spread use in the Automotive and Aerospace industries

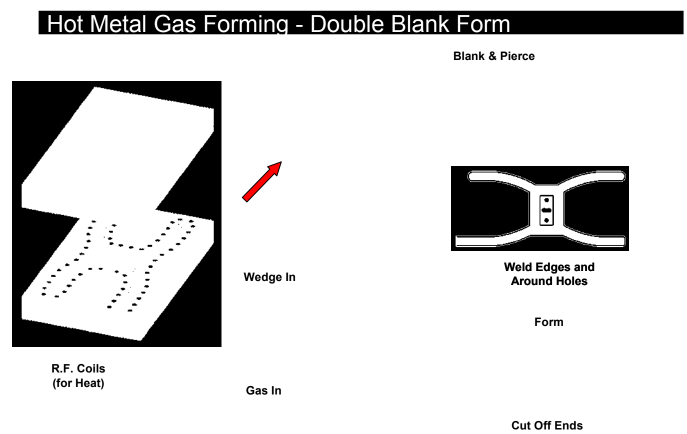

## INTRODUCTION

THE TEAM - The Technology is being developed by team formally known as the Hot Metal Gas Forming Consortium. This Consortium (or team) is made up of individual companies. Each of these companies were asked to participate, because of their expertise in a field of technology which in-urn provided the team with the building blocks to develop this technology.

| | |
|---|---|
| Autodesk | Design and Tooling Software |
| Alcoa | Material Expertise – Aluminum |
| Atlas Technologies | Material Transfer Technology |
| Battelle | Research Institution |
| Boeing Aircarft | OEM - SPF Technology |
| Daimler/Chrysler | OEM - Product Requirements |
| LTV / Copperweld | Material Expertise – Steel |
| Erie Press | Special Press Technology |
| Ford Motor Company | OEM - Product Requirements |
| Lamb / Modern Proto. | Integration / Tooling Tech. |
| Rockwell / AB | Controls Technology |
| Sekely Industries | Tooling Expertise |
| TOCCO | Induction Heating Technology |
| Tower Automotive | Manufacturing Requirements |
| Troy Design | Product and Tooling Designs |
| Wayne State University | Research Institution |

ORIGIONAL CONCEPTS




<u>Background of the process</u>
A metallic part is placed in a inductive field . Heat through the resistance of the material to the electrical current which then passes through the metal (aluminum or steel) component. Because the yield stress of the component decreases with the increase in temperature, the part can then be formed into a shape using low pressure (gas).

CURRENT POSITION OF THE HMGF PROGRAM - The HMGF program is now in its final year of a three-year research program. Where the team is in relation to its objectives is listed as follows

Deliverables of the program - At the beginning of the HMGF program three distinct goals were established that once met would establish the process as a production ready process.

Goal 1 - (Completed)
Verify feasibility of the process (To prove out HMGF techniques using simple laboratory tooling)

Goal 2 - (Target completion Dec 2001 – 6 mo after PPFS system is running)
To build a prototype production system using tooling, material and processing techniques learned in this program to prove process robustness and establish production costs (tooling and piece) / 300 piece run.

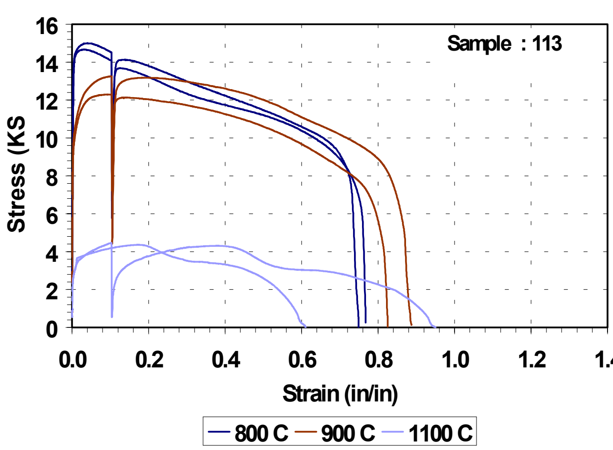
Goal 3 - (Item 1 completed and Item 2 completion for year 3 of program)

1 To prove out low temperature Superplastic techniques and to conduct DOE experiments.
2 In-situ thermal treatment to achieve improved mechanical properties of the parts.

Research and Development Plan - (Initial outline of what work was to be performed in what steps at the start of project)

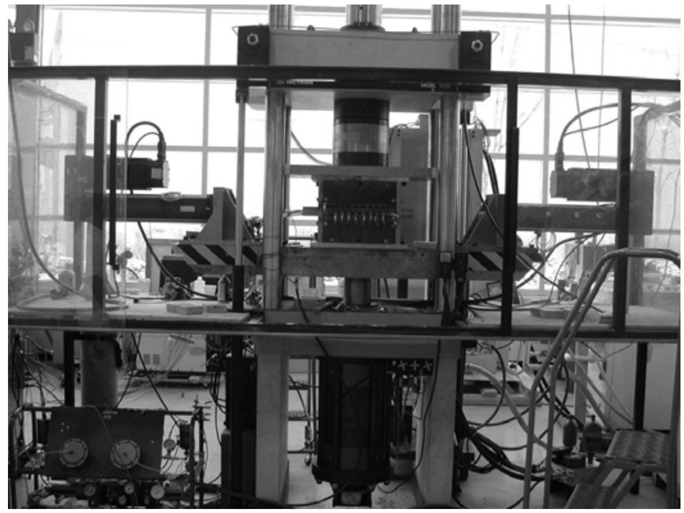
Phase I - (Completed)

1 Utilizing a Tensile System (TS) at WSU, determine forming limits and process parameters of selected materials (Aluminum and Steel)
2 This phase of the program will determine process parameters/equipment capabilities required for phase II



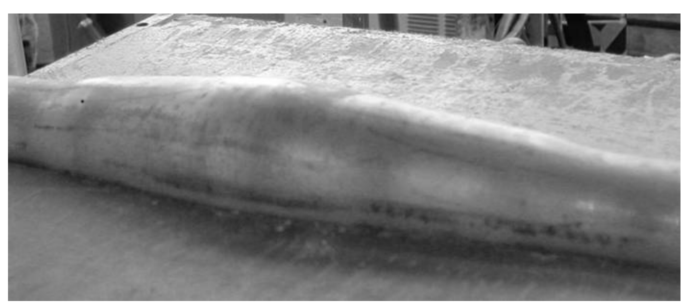

Phase II – (Items 1,2 and 3 are currently completed)

1 Design, build/modify and launch the Laboratory Forming System (LFS).
2 Utilizing the LFS, determine forming limits and process parameters of experimental shapes and/or selected materials (Aluminum and Steel)
3 Determine experimental shapes – build tooling for and tryout lab forming testing tool and determine forming limit parameters for selected materials
4 Determine process parameters/equipment capabilities required for prototype production forming system



Laboratory Forming System at Wayne State University

Steel part formed into a semi-square shape



First part – Al 6061 die formed 2 to 3 diameter

Phase III - (Installation underway, first part targeted for October 1, 01)

1 Design, build and launch the Prototype Production forming System (PPFS) to validate process robustness
2 Design, build and tryout forming tooling for the (PPFS)
3 Determine process parameters for various materials (Aluminum and Steel), process-forming capability, post processing capability and production process validation


Year 3 overview - In the last year of the program we should be able to accomplish the following tasks

1 Prove that the process is capable of producing parts in a production mode (completion of Goal 2)
2 Develop and tryout 2 to 3 different forming tools for the purpose of proving product design flexibility and process parameters (completion of Phase II and Phase III)

Raising the Bar - The ultimate goal of the program is to have the HMGF process widely accepted by US automotive and aerospace industry as a normal manufacturing process (like stamping, forging, superplastic forming or hydroforming). To achieve this goal we need to prove that the process is Implementation Ready (IR). This means that there is very low risk associated with components used in designing vehicles (air or ground) around the process of HMGF.

Manufacturing Questions

1 Determine what the cost of processing parts using the HMGF process will be.
2 Determine mean time between failures of the equipment (cost and timing of repairs)
3 Determine tool life cycle costs (cost of tool, number of parts per tool, cost of repair ect)
4 Determine what repeatability of the process will be of the parts (Dimensional, material structure)
5 Determine what the Join-ability of selected material will be after forming (Grain structure, Strength)

OEM questions

1 Determine if or how the fatigue life of the material has changed, and what the effect of the service life of the product produced by the HMGF process will be
2 FEA simulation
    - Development of math models of what the material behaviors will be after the parts have been formed
    - Development of math models of selected (al and steel) materials to predict forming behavior of the material under the HMGF process parameters
    - Development of FEA tools to accurately predict electro mechanical coupling of inductive coil fields to parts being developed

The HMGF team will be able to answer some of these questions during this 3-year program but not all. With the resources we have available we will be able to accomplish the following in our Commercialization Plan

Commercialization Plan - Many companies have developed technology in the past (OEM’s and Suppliers) that has never been used in an actual vehicle. This is generally due to one of the two following factors

First - Program management at the OEM’s weigh the Benefits of using the technology (cost, weight, timing, safety) vs. it’s the Risk of using the technology (pour quality, risk of not meeting vehicle launch dates)

Second - The “not invented here”, syndrome

Both of these issues we are trying to cover in our commercialization plan (short term and long term). First is in the introduction of the process to the world OEM and Manufacturing base(s) - Timing and organization here is the key to getting the most "bang for the buck". We need to develop and release of information in a way that best introduces and that enables the OEM's to "want" the technology. The "want", of the technology is clear to us "the HMGF team", (low cost, high formability and heavy potentional for Intelligent structures). However the "Enablers", to the technology will be difficult to achieve. Think about it, when someone runs into your office and try's to sell some thing too good to be true, you become immediately cautious. The "Enablers", can be different groups or individual persons. Each of these groups of enablers has different missions, and therefore different reasons why they would or would not embrace HMGF. For some of these groups we need to be "process neutral to positive", if we are "process negative", implementation of HMGF will be difficult to achieve in a short period of time.

- OEM Purchasing Enabler
  How is it cheaper? Why is a better value from a total vehicle build concept?
- OEM Manufacturing Enabler
  How will it make my life simpler?
- OEM Design Engineering Enabler
  How will it allow me to create more efficient designs?
- OEM Quality Assurance Enabler
  What are process controls? How do these process controls affect the finished product? How does this affect the entire vehicle? Process Robustness?
- OEM Program Manager Enabler
  How will this process make the vehicle program easier? Cost, weight and vehicle program timing are the mission objectives – How does this process improve the objectives?
- OEM Assembly Engineering Enabler
  How do I weld it? How dimensionally reputable of a component are you sending me? How does it effect my Vehicle build points?
- OEM Durability Enabler
  How will the process work under loading / fatigue conditions? / Material Life?

Supply base – Enabler's
Same question's - How will it make my life simpler? Low Capitol investment requirement's needs, ease of operation, through put, product flexibility, equipment uptime, tool maintance, ect.

Why the development of this technology?

An evaluation of the make-up of cars and trucks reveals that the body structure is made out of tubular sections. Some of these tubular sections may not be recognizable at first, because their shapes are not uniform in size or shape or their true function is hidden. Up to the last few years the only approved material processing method that was allowed to make these sections were conventional stampings combined with spot welding (used primarily for body shells, BIW), or stampings and MIG welding (used primarily for engine cradles and frame assemblies).

Currently a more popular manufacturing process called tubular Hydroforming has been introduced and accepted by the automotive industry to make these tubular sections. We have found many cases where the value of the new (tubular) design (hydroformed) is greater than the value of the old (conventional stamp and weld) design, however we have also found cases where it was the other way around. Which process is capable of producing the more "value", component is primarily dependent on a variety of items. First of which is how well does the new (hydroformed), designed component replace the function of the currently designed component. Second how well does the new component tie in or assemble to "the rest of the structure". Third is its weight to performance Raito and finally the total cost picture. All of these four items have to be evaluated when determining the value or efficiency of a component or assembly.

Hydroforming is a process is that uses water and pressure to form material (aluminum or steel), into a shape determined by the shape of a die cavity. This process has been demonstrated to be very reliable and dimensionally accurate for both tubular sections (primary high volume application so far) and single sheet Hydroforming. It should also be noted here that extensive research work has been done around the world in duel sheet Hydroforming. This process uses duel blanks that have been laser welded together around the outside to create a fill cavity and using either oil or water mixture as the fill / pressure forming mechanism to form the duel sheet blanks to fill the die cavity.

Hydroforming in general (tubular, single sheet and multi sheet) are generally slow (22 to 50 sec/[part), has high capitol costs associated with it (in both the hydraulic press, intensifier equipment and tooling), and can place undesirable strain in the material at uncontrolled locations and is shape or design constrictive.
Even with these restrictions the automotive vehicle OEM's have found many, many applications for these hydroformed tubular sections and have designed in components using Hydroforming as a tubular manufacturing shaping process.

The process of Hot Metal Gas Forming was not designed to replace Hydroforming, but was originally conceived as a low cost alternative to Hydroforming and to complement tubular structural manufacturing technologies. As the vision was developed the focus areas were expanded to process speeds, capitol equipment costs, and improving the product strength to weight Raito through heat-treating.

ACKNOWLEDGMENTS

Again, this program would not be possible without the combined efforts of the entire Hot Metal Gas Forming Team, under the leadership of Ernie Vahala and the Auto Body Consortium

CONTACT INFORMATION

For additional information contact the Auto Body Consortium directly at 734 741 5905 or visit www.autobody.org and link to Hot Metal Gas Forming. At this location detailed contact information is listed on the Team members and published papers for reference.