Hot Metal Gas Forming

Production prove-out tool (simulated midsize pickup cross member) and large aluminum front frame rail for simulated full size pickup
The Prototype Production Forming System

This portion of the presentation will concentrate on “Equipment Requirements”
Prototype Production Forming System Overview

Hydraulic Pressure supply

Ajax/Tocco Induction Heating Power supply

End feed / end seal system

Atlas transfer system

Control Panel

Gas pressure and supply

Erie Press 60 Ton Ram 5 ton Ram

Water Quenching system
Press and hydraulic pressure supply control panel

Hydraulic pump drives press and transfer system

Duel Ram Press
60 ton forming station
5 ton quenching station

Transfer system
Part Holders

Walking Beam Transfer system
End Sealing / End feeding Units

Seckely Industries

Proprietary to Hot Metal Gas Forming, Inc. and its Members
Gas Pressure System (by Lamb) & End Sealing (by Lamb / Sekely)

Gas pressure Nitrogen bottles

End feeding cylinder

Gas pressure regulation system

End Seal for compression
Part Quenching System
(By Atlas, TOCCO & Lamb)

Pump

Quenching die in press

Individually controlled quenching Zones
Thermal history for one process cycle:

- Heating (20 sec)
- Material forming Gas pressure and end feeding (5 sec)
- Dwell Uniform temperature (3 sec)
- Pressure holding (2 sec)
- Dwell Gas pressure release, end seals retract, Transfer grips part, press opens (currently 8 sec)
- Parts transferring air cooling to part (4 sec)
- Quench station close (3 sec)
- Actual part quench (7 sec)
PPES Results

Generic Steel Crossmember

Background
- Steel 65W HSS
- Different Thermal/Pressure Profile Curves
- June 6th part had a 48 sec cycle time
- July 30th part had a 58 Sec cycle time

Figure 1 Photograph of Pre bend tube sample showing the location of sectioned tensile coupon specimens.

Figure 2 Photograph of Formed Part June 6th sample showing the location of sectioned tensile coupon specimens.

Figure 3 Photograph of Formed Part July 30th sample showing the location of sectioned tensile coupon specimens.
Conclusions

- Prebend grain size = 12.5
- HMGF processing resulted in a full martensitic structure in the June 6 sample
- HMGF processing resulted in a bimodel metallurgical structure – 60% ferrite and 40% lath martensite in the July 30 sample
- HMGF resulted in a change in grain size in the July 30 sample; 12.5 → 11/7
- HMGF processing resulted in an increase of yield strength, tensile strength and hardness in the June 6 sample and a decrease in elongation
Preformed tube

Examination of metal thinning at regular 1 in intervals

Sections

Formed tube
Strain at Thickness (Engineering Scale)

\[
\varepsilon = \frac{t - t_0}{t_0} \quad t_0 - \text{Original thickness} \\
\dot{t} - \text{Current thickness}
\]

- FRONT
- TOP
- BACK
- BOTTOM

- Inspection Sections (Inch)
Steps involved to make a HMGF Die’s (forming and quenching)

- HMGF is a more complex process than room temperature metal forming
  
  - Stamping is basically a one dimensional metal forming process
    - Pressure (pressure and stroke)
  
  - Hydroforming is basically a two dimensional process
    - Pressure and time
  
  - HMGF is three dimensional
    - Pressure, time and temperature

- Because HMGF is a more complex process, it requires a higher degree of planning
Steps involved to make a HMGF Die’s
(forming and quenching)

Material Evaluation
- Material characteristics required from formed product (tailored along length?)
- Type of material (Steel, Aluminum, Other)
- Material Grade / Material forming properties at elevated temperatures
- Quenching method (Water, Mist, Forced air, etc)

Productivity Evaluation
- Thru Put required (Influences quenching design, part transfer requirements)

Product Evaluation
- % expansion (how much as important as where it is required)
- Tubular Pre-Form (Die shaped, mandrel bender) “what it looks like before heating”

HMGF Die Evaluation
- Thermal profiles required (influences coil design)
- Annual Production volume required (influences die design)
- Coil Design, Die forming shell design, and construction method
• Patent #1 – filed Sept 99 (initial intellectual property 6 mo into program)
• Originally filed as ABC-12518 Provisional #60/155,969 (Die Shell Concept)
  • Claims allowed became Patent 6,322,645 – patent status - Granted
  • Initial claims not allowed were resubmitted as a continuation of patent number 1 ABCE2 12581-1
US patent tracking #09/944,769 patent pending
• Foreign filings was under PCT/US00/21405 and was granted almost entirely as written

Brazil  BZ #PL 0014286-7
Canada  C #2,384,771
Mexico  M #02/03061
France  EP #00953 845.5
Germany  EP #00953 845.5
United Kingdom  EP #00953 845.5
The design of the part (pre-form) to be formed influences the coil shape by:

- Location of part relative to coil

An evaluation of the thermal profile that would result then drives the choice of coil design:

- Square
- Round
These factors determine what the thermal profile will look like.

Fig. 12 Tube to Square Forming: Deformation Geometry Change Effects if Using Circular Coil
Forming die - design and construction

Material / Tool tryout considerations

Temperature

107 Mild Steels (similar to C1008)
108 Low C - HSLA
109 Low C, Nb - HSLA
110 Low C, Nb - HSLA
112 High C,Nb - HSLA (C>0.1%)
113 High C,Nb, Mn – HSLA

Internal Pressure Chart

- 2axis forming
- 3axis forming

Thermal Profile
Die Forming Shell was constructed of a ceramic Oxide/Oxide composite using a “lay-up” process. It is then fixed to a fixture. The fixture is fixed to the parting line of the die. Die casting complete. Turn over.

Ceramic fill material
Thermal Shock Resistance of Common Ceramic Materials

- SiC/SiC Composites
- Estimated HGMF Heating Rate
- Estimated Max HGMF Delta T.
- Non-Oxides Fall Between Blue Lines
- Only Fused Silica and SiC/SiC have the thermal shock resistance to withstand the quench rate which occurs when 1150°C metal comes in contact with HGMF tool. Fused Silica has 1/10 the strain capability of SiC/SiC. It does well in thermal shock because it has a low expansion coefficient.

Fig. 16.3. Variation in quench temperature causing fracture for different materials under different conditions of heat transfer, assuming that failure occurs when the thermal stress reaches the fracture stress. Curves are calculated from material properties at 400°C. Dashed curves for Al₂O₃ are calculated from material properties at 100°C and 1000°C, as an indication of temperature effects.

Source: Kingery
Large Die construction and tryout

This portion of the presentation will concentrate on “tooling requirements”
Construction and assembly of HMGF forming die

View of die at Sekely Industries
Die box – coils in box and die shell

Bottom die half

End view of photos
On next page
Large HMGF forming die in simple clamping fixture prior to testing