Forming aluminum alloys at elevated temperatures, Part II

Case studies

BY LONG JU AND TAYLAN ALTAN

Elevated-temperature (ET) forming of aluminum can be accomplished isothermally or nonisothermally. In isothermal warm forming, the die, blank holder, and punch are heated. In nonisothermal deep drawing, the die and blank holder are heated, and the punch may or may not be cooled. The die and punch are kept at different temperatures, which means the temperature of the sheet is not constant during forming.

Modeling of nonisothermal warm forming is a complex process which requires accurate constitutive material models and heat transfer calculations, and simulation of deformation.

Finite Element Simulation of ET Forming

The finite element method (FEM) is used widely in industry for sheet metal forming simulation. Conducting successful FE simulation of aluminum ET forming requires a comprehensive understanding of the process details.

Robust and reliable FE simulation is essential for the optimum design of ET-stamped components from aluminum alloys, especially 7xxx alloys, and requires the knowledge of:

- Material properties (in function of strain and strain rate) at various temperatures.
- Thermal properties (in function of temperature) of the sheet/die materials.
- Heat transfer coefficient and coefficient of friction (in function of sheet/die interface pressure and temperature).
- Microstructural variations in the sheet material during deformation.
- Optimum design of cooling or heating channels in the dies.
- Optimization of press/ram speed to reduce cycle time.
- Forming and quenching of tailor-welded and tailor-rolled sheet to obtain tailored properties in the warm- or hot-stamped parts.

Nonisothermal Deep Drawing of Round Cups

The Center for Precision Forming (CPF), in cooperation with AIDA-America, conducted a laboratory study on ET forming of round cups from 5754-O aluminum alloys (see **Figure 1**). To achieve the nonisothermal conditions in the experiment, the die and blank holder were heated to 300 degrees C with cartridge heaters, and the punch was cooled by water circulation. A PTFE-based lubricant provided excellent lubrication at ET conditions.

The AIDA servo-driven press enabled maximum flexibility in the ram speed control (see **Figure 2**). Formability experiments showed that for Al 5754-O, ET forming helped reduce thinning at the punch corner. FE simulations using DEFORM 2-D software indicated that the heat transfer coefficient had a significant effect on the thickness distribution of the cups.

Heated Sheet and Cold Die Drawing Process

To develop a robust and cost-effective ET forming process, CPF conducted studies

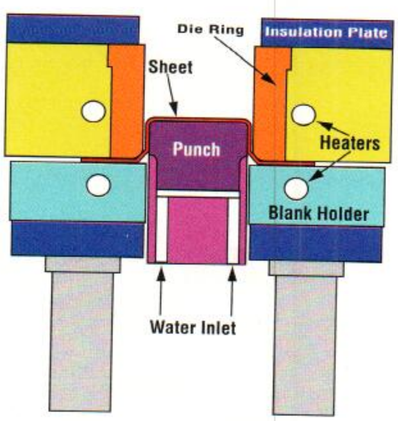
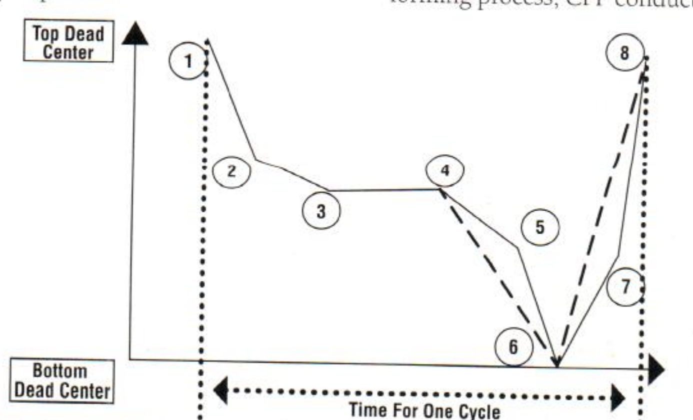


Figure 1

CPF used this nonisothermal drawing tool in its laboratory study of ET forming of round cups from 5754-O aluminum alloys. From "Warm Forming of Magnesium and Aluminum Alloys."



1-2	Fast Approach
2-3	Slower approach reduces impact and vibrations. Both tools are in contact at 3.
3-4	Dwell (heating of blank).
4-5	Slower punch velocity for forming sharp corner radii.
5-6	Higher velocity for faster forming.
6-7	Slower exit from the tool.
7-8	Faster return to TDC.

Figure 2

This is the slide motion of the servo press used in nonisothermal forming of round cups. From "Warm Forming of Magnesium and Aluminum Alloys."

using a heated sheet and cold die (see **Figure 3**). The sheet was heated to a selected temperature and transferred to the room-temperature dies. Compared to normal warm/hot forming processes, this operation required less energy because only the sheet was heated; tooling costs were lower as well. Although it was a relatively simple nonisothermal process, researchers needed to determine the material behavior under certain temperatures and strain rates, heat transfer, and friction.

In a recent study conducted by USCAR, aluminum alloys were warm-formed using relatively low-cost tooling. In the process, the aluminum sheets were preheated to about 200 to 300 degrees C and formed in room-temperature dies. Tests showed that the aluminum panels could be formed successfully at 250 degrees C, ±10 degrees C. However, additional studies are required to evaluate the effects of the increasing die temperature on the formability at high production rates.

ET Forming of B-pillar With High-strength Aluminum Alloy

A number of companies including Benteler, Aleris, Ford, and Hydro-Aluminum are conducting R&D with the objective to produce structural chassis parts (such as B-pillars and roof rails) to replace hot-stamped boron steel parts using 1,600-MPa UTS. These studies already developed preliminary techniques for material modeling, lubrication, analysis of metal flow and fracture behavior, postheat treatment, and e-coating (paint baking) techniques. However, the material and processing costs must be addressed before this technology can be introduced to production.

A case study conducted at CPF focused on FE simulation of ET forming of a B-pillar with Al 7075-T6 using PAMSTAMP®. The 2-mm-thick 7075-T6 Al blank with an initial temperature of 220 degrees C was formed virtually in room-temperature dies.

The surface heat transfer coefficient (HTC) is a function of interface pressure if two interfaces are in contact. HTC increases with the increasing pressure until the pressure exceeds a threshold value. Based on the experimental research conducted by Ilinich and Luckey, the HTC under different contact pressures was determined using a ring-shaped 7075 blank.

Figure 4 shows the predicted thinning values at selected locations in the B-pillar in the simulated warm forming of Al 7075. The maximum thinning in the current case is 35.7 percent at location 1. As shown in **Figure 5**, the temperature distribution in the deformed part also was predicted using PAMSTAMP. Compared to the initial blank temperature, the temperature reduction in the deformed B-pillar was about 50 degrees C, with a forming time of about 1.6 seconds.

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Resources

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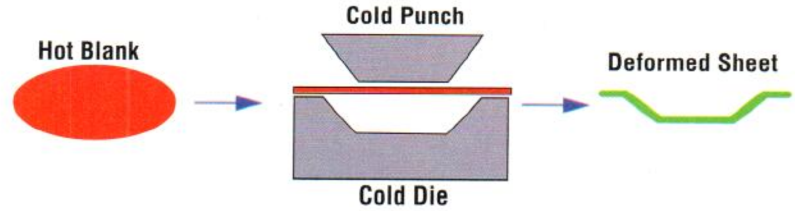
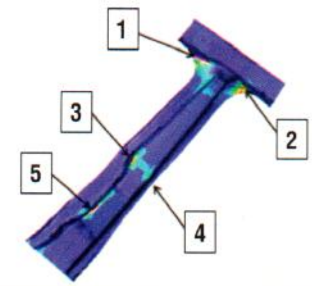


Figure 3

To develop a robust and cost-effective ET forming process, CPF conducted studies using a heated sheet and cold die. From "Optimization of High-Volume Warm Forming for Lightweight Sheet."



Location	Thinning Value (%)
1	35.7
2	19.5
3	21.3
4	13.2
5	25.8

Figure 4

Shown here are the predicted thinning values at selected locations in the B-pillar in the simulated warm forming of Al 7075. Initial blank temperature was 220 degrees C, and initial die temperature was 25 degrees C.

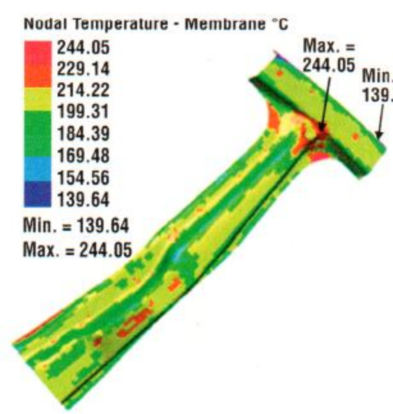


Figure 5

The temperature distribution in the Al 7075 B-pillar after ET forming was predicted using PAMSTAMP. The initial blank temperature was 220 degrees C, and the initial die temperature was 25 degrees C.