Warm-forming aluminum and magnesium

Part II: Determining magnesium sheet properties at elevated temperatures

Editor's Note: This is Part II of a two-part series on warm forming. Part I, which appeared in the December 2005 issue, covered the elevated-temperature deep drawing of aluminum- and magnesium-alloy sheets.

This column was prepared by Serhat Kaya, a staff member of the Engineering Research Center for Net Shape Manufacturing (ERC/NSM), The Ohio State University, Taylan Altan, professor and director.

Tensile testing is used to determine material properties and the quality of incoming sheet. Despite the fact that it obtains properties only uniaxially, this test has been widely adopted by the industry.

Stress conditions in stamping, however, are not uniaxial. Because of the tensile test's limited representation of the actual state of stress in a real industrial part, it is necessary to obtain material properties under biaxial deformation conditions (see Figure 1).

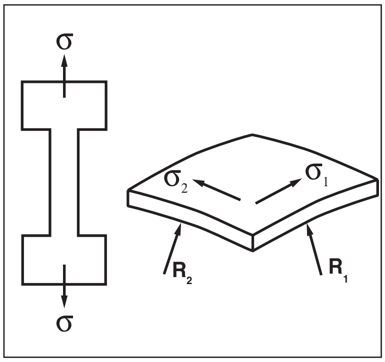

Figure 1

Because of the tensile test's limited representation of the actual state of stress in a real industrial part, it is necessary to obtain material properties under biaxial deformation conditions.

Hydraulic Bulge Test

One option for obtaining sheet metal properties biaxially is the room-temperature hydraulic bulge test. This test produces higher strains before necking compared with the tensile test.

The Engineering Research Center for Net Shape Manufacturing (ERC/NSM) of The Ohio State University has been using this test for industrial sponsors to determine material properties (stress-strain curves), as well as incoming sheet quality.

In the hydraulic bulge test (see Figure 2), the sheet is clamped between the lower and upper dies. When the fluid in the lower chamber is pressurized, the sheet is bulged into the cavity of the upper die. The clamping force between the lower and upper dies has to be high enough to prevent the sheet from sliding between the dies.

Often a lock bead is used to prevent the sheet from moving in the clamped region. In this manner, the sheet is only stretched, and no draw-in occurs.

When the deformation of the material exceeds its formability limit, the bulged sheet will fracture. In this test, the deformation is not affected by friction, so the reproducibility of the test results is good.

Because magnesium alloy has little formability at room temperature, it must be formed at elevated temperatures. Therefore, the stress-strain properties also must be determined at warm temperatures, in the range of 150 to 300 degrees C.

Testing on Magnesium Alloy

The properties of magnesium alloys at elevated temperatures have been determined by various researchers around the world. However, information on properties obtained at elevated temperatures under a biaxial state of stress using hydraulic bulge testing is limited.

For this reason, the ERC/NSM conducted elevated-temperature hydraulic bulge tests using the tooling available from the Institute for Production Engineering and Forming Machines (PtU) of the University of Darmstadt, Germany. Tests on magnesium sheets from a German manufacturer demonstrated the significant formability increase and the property variations that exist in the incoming sheet.[1]

The specific objectives in conducting these tests were to:

•Gain experience and observe the difficulties and advantages of using hydraulic bulge test tooling submerged in a heated pressure medium.

•Obtain the flow stress and approx-

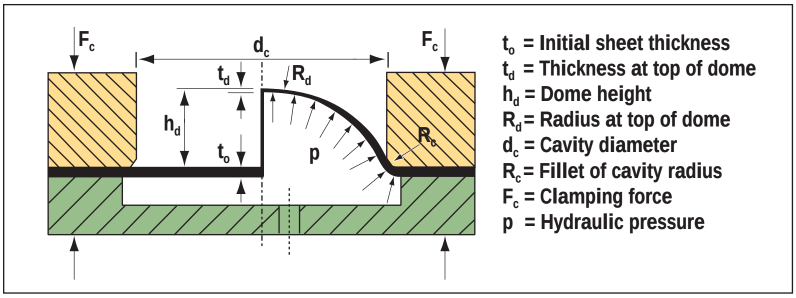

Figure 2

In the hydraulic bulge test, the sheet is clamped between the lower and upper dies.

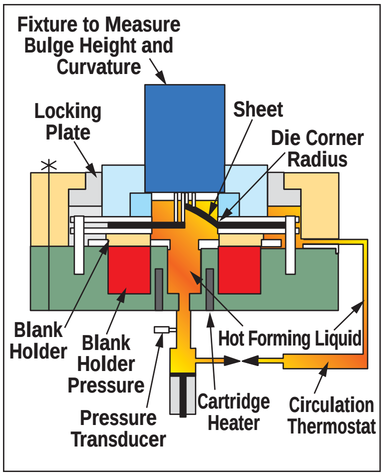

Figure 3

In this hydraulic bulge test, pressure medium was heated via cartridge heaters located at the bottom of the tool, cartridge heaters in an outside tank, and a circulation pump equipped with heaters.

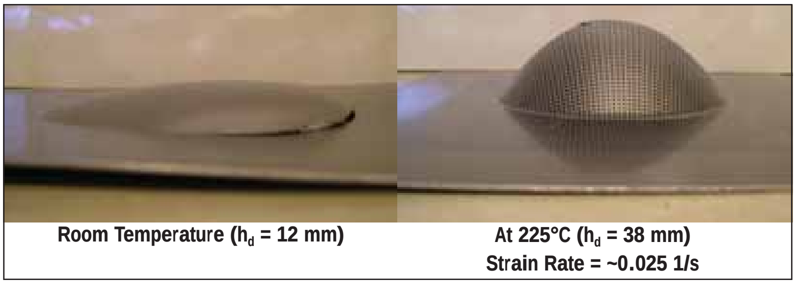

Figure 4

Elevated temperatures improve the formability of magnesium.[1]

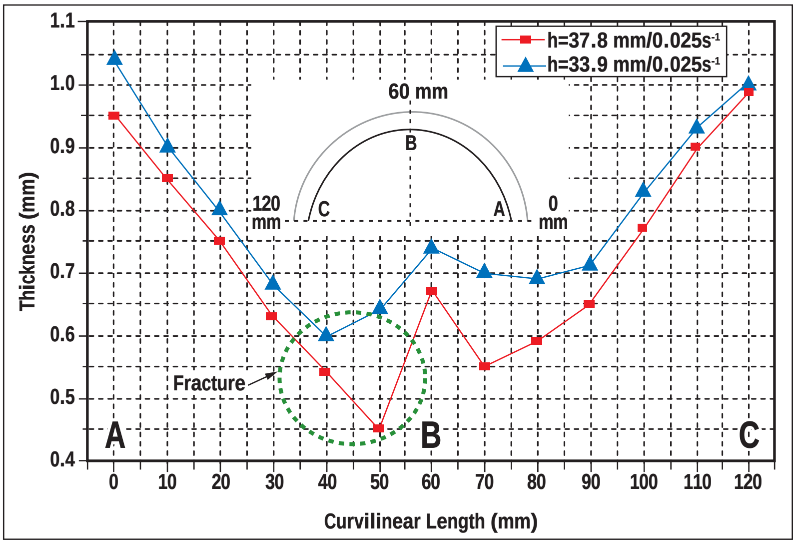

Figure 5

Tests found that up to 50 percent thinning is possible at elevated temperatures.[1]

imate strain rates of magnesium AZ31-O alloy at various temperatures.

Figure 3 shows the elevated-temperature hydraulic bulge tooling used in the experiments. In this setup the die, the blank holder, and the sheet were submerged in the heated pressure medium. Thus, the temperature variations in the tool and the sheet were reduced.

The pressure medium was heated via cartridge heaters located at the bottom of the tool (see Figure 3), cartridge heaters in an outside tank, and a circulation pump equipped with heaters. A displacement sensor was used to record the bulge height while the medium pressure was measured with a pressure transducer. A constant blank holder pressure was applied to lock the sheet to prevent its draw-in into the die cavity.

Experiments were conducted up to 225 degrees C. Figure 4 shows the bulged samples at room temperature and at 225 degrees C. As the figure demonstrates, the deformation before fracture, obtained at room temperature, is very limited compared with that obtained at 225 degrees C.

Figure 5 shows the thickness distributions of magnesium AZ31 alloy bulged samples formed at 214 degrees C (33.9-millimeter bulge height) and 225 degrees C (37.8-mm bulge height) along the curvilinear length of the bulged sample. At around 50-mm curvilinear length, both sheets fractured. As shown, up to 50 percent thinning of the sheet was obtained by forming at elevated temperatures.

Maximum strain values of 0.45 and 0.7 were reached at strain rates of 0.25s^{-1} and 0.025s^{-1}, respectively, while the achievable strains using the tensile test were about 0.3 at the same strain rate values. These results demonstrate the benefit of using the elevated-temperature hydraulic bulge test.

Taylan Altan is a professor and director, and Serhat Kaya is a staff member, of the Engineering Research Center for Net Shape Manufacturing, 339 Baker Systems, 1971 Neil Ave., Columbus, OH 43210-1271, 614-292-9267, fax 614-292-7219, www.ercnsm.org. The ERC/NSM conducts research and development; educates students; and organizes workshops, tutorials, and conferences for the industry in stamping, tube hydroforming, forging, and machining.

Note

1. S. Kaya and T. Altan, “Determination of the Properties of AZ31-O Magnesium Alloy Sheet at Elevated Temperatures Using the Hydraulic Bulge Test,” ERC/NSM Report ERC/NSM-04-R-35, ERC/NSM, The Ohio State University, Columbus, Ohio, 2005.