Experimental Test for Benchmark 1--Deck Lid Inner Panel

Siguang Xu, Terry Lanker, Jimmy Zhang and Chuan-Tao Wang

General Motors Corp., Manufacturing Engineering, Die Center
2000 Centerpoint, Pontiac, MI 48341

Abstract. The Benchmark 1 deck lid inner is designed for both aluminum and steel based on a General Motor Corporation’s current vehicle product. The die is constructed with a soft tool material. The die successfully produced aluminum and steel panels without splits and wrinkles. Detailed surface strains and thickness measurement were made at selected sections to include a wide range of deformation patterns from uniaxial tension mode to bi-axial tension mode. The springback measurements were done by using CMM machine along the part’s hem edge which is critical to correct dimensional accuracy. It is expected that the data obtained will provide a useful source for forming and springback study on future automotive panels.

INTRODUCTION

To meet increasing demand of vehicle fuel efficiency and safety requirement, more and more aluminum and high strength steel parts are being used in automotive industry. However, the relative large springback, due to the low Young’s modulus of aluminum and high yield strength of HSS, often causes large springback after parts are formed, resulting in dimensional deviation of the formed part from the designed shape. To address the springback issue, the first thing is to predict the springback accurately. Therefore, improving the springback prediction accuracy has been the focus of recent sheet metal forming research and software development. It is believed that numerical technologies, material modeling, and software enhancements and development have reached a new level since the last conference (Numisheet2003). The Benchmark Problem 1 (the deck lid inner) is designed to evaluate the springback prediction of an automotive part with the current technology. The part is selected directly from a GM vehicle product. However, the part geometry has been modified so that the part can be made with both steel and aluminum.

DIE SETUP

The forming process is a 3-piece die draw process. The upper die is a solid piece. The punch is stationary. The binder is supported by cylinders. The FEM model is shown in Fig. 1 and a photo of the binder and punch with the pre-bent blank sitting on it is shown in Fig. 2. The upper is driven down by the main ram. The binder is closed first and then pushed down to form the part. The binder travel is 65mm and the binder tonnage is 1344KN. The restraining force is provided by the drawbead around punch opening. The die was built with the kirksite material (soft die material) at Troy Design and Manufacturing Co., Redford, Michigan. The binder was hand-spotted so that the load bearing was evenly distributed on the binder surface. The initial bead geometries were determined by the restraining force obtained from formability finite element analysis. The tryout was primarily carried out based on aluminum sheet. The bead geometry was adjusted during the tryout so that the specified draw-in amount was achieved to meet the formability requirements of no splits and wrinkles. The final drawbead configuration and geometry are listed in details in the Benchmark 1 Instruction [1].
EXPERIMENTAL MATERIALS

Two materials were selected for this benchmark. The 0.9 mm AL 6111-T4P aluminum alloy was provided by Alcan and the 0.8 mm BH 180 bake-hardenable steel was provided by US Steel. The material properties were tested by the two companies respectively and they are documented in details in the Excel files at the conference website. The average material data are listed in Table 1.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Coating</th>
<th>0.2 % YS (MPa)</th>
<th>UTS (MPa)</th>
<th>UE (%)</th>
<th>TE (%)</th>
<th>n Ave (1-UE%)</th>
<th>R Bar (19%)</th>
<th>Friction Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL 6111-T4P</td>
<td>None</td>
<td>126.7</td>
<td>288.7</td>
<td>21.5</td>
<td>26.0</td>
<td>0.265</td>
<td>0.672</td>
<td>0.090</td>
</tr>
<tr>
<td>BH180</td>
<td>EG</td>
<td>201.3</td>
<td>334.4</td>
<td>21.6</td>
<td>39.2</td>
<td>0.195</td>
<td>1.593</td>
<td>0.120</td>
</tr>
</tbody>
</table>

EXPERIMENTAL PROCEDURE

The flat blank was laser-cut to the required shape and de-burred. The aluminum blanks were cleaned with dry cloth and MP-404 lubricant was applied. Steel blanks came with mill oil and no additional lubricant was applied. The blanks were slightly bent by hand before loaded into the die. The tests for steel and aluminum were carried out separately. The aluminum test was conducted first. After the aluminum test was finished completely, the die was cleaned up and the kiss-blocks or equalizers were changed to 0.8mm so that the binder gap was kept same as the blank thickness. Other than the above change, the steel test was carried out under the same die condition as the aluminum test. Fig. 3 shows a trimmed steel panel on the punch and a trimmed aluminum panel on the floor.

STRAIN MEASUREMENT

In order to insure identical measurement locations for each panel, grid lines were developed along the selected die surface locations A to D [1]. These grid lines were laser-marked on the drawn panel as shown in Fig. 3. The detail locations of the lines are shown in the Fig. 6 of the BM1 Instruction [1] and given in the associated math files at the conference website. A uniform network of circles of 2.5 mm diameter was etched on blanks before forming. The strains were measured with FMTI computer assisted optical grid analyzer system at the US Steel lab in Troy, Michigan. The upper surface major and minor strains are measured on the circle closest to the intersection point of the laser grid lines. The thickness is measured right at the laser grid points using a micrometer. Panels were laser-cut along the specified lines after forming.
to allow access for cone point micrometer. Fig. 4 shows a typical thickness measurement taking place.

For aluminum, ten circle grid panels were measured for the top surface major and minor strains and ten additional panels were used for the thickness measurement. Since the circle grid quality of steel is better than aluminum, five steel panels were used for circle grid major and minor strain measurements, and five for thickness measurement. The average of the measurement results for the major, minor and thickness strains are shown in Figs. 6-9. There are many factors that affect the accuracy of the circle grid measurement. The accuracy of the circle grid reading itself is about 2 % on flat surface due to the optical method. The deformation of the stencil in the etching process can introduce additional 2 % strain in the roller rolling direction. The grid line width and clearness also vary from circle to circle. The readings on the curved surface of radii are different from the readings from flat surface even though the surface strain might be same. In the test, it is found that circle grid measurement data varies considerably from panel to panel. While most measurement variations fall in the range of +/- 5 %, some of the measurement at same location varies beyond this range.

The thickness measurement with cone point micrometers was found to be more consistent than circle grid strain measurement. The thickness measurement was double checked at various locations of panels by a second person using a second micrometer. The measurement error was found to be from 0.007 to 0.010 mm or about 1%. The total thickness measurement variations from panel to panel were found to be within 2 % for most locations.

**SPRINGBACK MEASUREMENT**

The main purpose of the BM1 is for springback correlation. The part is laser-trimmed after draw forming and then put on the checking fixture for CMM checking at the specified points as shown Fig. 4 of the BM1 Instruction [1]. The springback amount is measured in the direction perpendicular to the part. The measured springback is assigned negative value when the springback vector (measured from nominal shape to the sprung shape) points to the inside of punch (inboard). Otherwise, the springback amount is positive if the vector points away from the punch (outboard). Ten trimmed panels were measured for aluminum and five panels were measured for steel part. Fig. 10 shows the averages of the springback measurement for both aluminum and steel. It is seen that the springback trend for both aluminum and steel is similar from points 1 to 7. However, from points 10 to 19 the steel panel springs inboard while aluminum panel springs outboard.

**DRAW-IN MEASUREMENT**

The draw-in measurement starts from the binder closure and bead set. It is defined as the three dimensional distance along the binder surface between the blank edge at the binder closure and the blank edge when forming is complete. The blank draw-in is determined by the combinations of all the factors that affect the forming process, which include draw bead restraining force, lubrication, binder travel, binder gap, binder force, material properties, etc. Draw-in distributions determine strain and stress distributions inside the panel and springback measurement. Draw-in measurement locations around panel is shown in Fig. 5 of the BM 1 Instruction [1]. To measure draw-in, the upper die was first moved down to just contact the binder and set the beads while the binder remains at its initial position (called binder wrap). Then the die is retracted and the blank edge of the wrapped blank is marked along the binder surface. A new blank is loaded into the die and formed into the final shape. The draw-in measurement was taken between the final drawn panel blank edge to the initial marked binder wrap blank edge. Draw-ins of five panels were measured for both aluminum and steel. The part was designed symmetrical along the symmetrical plane of the car. However, the draw-ins are not exactly symmetrical in the die although great efforts had been given to balance the draw-in on the both sides of the panel. Fig. 11 shows the average draw-ins of left and right sides for five panels. It is shown that the steel panels have larger draw-ins than aluminum panels.

**CONCLUSIONS**

Numisheet 2005 Benchmark 1, GM deck lid inner, experimental measurement was carried out for both aluminum and steel materials. Although special attention has been paid to the circle grid strain measurement, the variation range of the measurement results is still larger than expected. However, the accuracy of the thickness and springback measurement is tightly controlled within the industrial acceptable range. Every details of the measuring process have been checked carefully. It is found out that the springback trend at the waterfall of the deck lid is different for steel and aluminum for this part.
ACKNOWLEDGEMENTS

Troy Design and Manufacturing Co. (TDM) is gratefully acknowledged for its support in die construction, tryout, panel preparation and springback measurement. Special thanks go to Mr. Guy Roberts of TDM for his great efforts in supporting us through the project. Thanks are also due to Dr. Min Shi of US Steel for his support in providing steel material and conducting the circle grid and thickness measurement of all the panels. Finally, we would like to thank GM Manufacturing Engineering Die Center for supporting us in carrying out this project from beginning to end.

REFERENCE


A) Aluminum panel

B) Steel panel

FIGURE 3 Trimmed draw panels.

FIGURE 4 Grid marking for circle grid strain measurement

FIGURE 5 Thickness measurement using a micrometer
FIGURE 6  Strain measurements on Section A-A

FIGURE 7  Strain measurement on Section B-B
FIGURE 8 Strain measurement on Section C-C

FIGURE 9 Strain measurement on Section D-D
FIGURE 10  Springback Measurement relative to nominal

FIGURE 11  Draw-in measurement