Evaluation of Press Work on Sheet Metal
— Obtaining Accurate Design Data Usable for Simulation —
Evaluation of Press Work on Sheet Metal

Pressed parts made of lightweight materials with poor workability, such as high tensile steel, aluminum alloys, and magnesium alloys, are essential for reducing the weight of transportation equipment. Repeatedly modifying the die to achieve a target shape not only increases costs, but also lengthens the development period. One solution currently being tried is to reduce the number of actual samples evaluated by using simulation to predict forming problems in advance. As simulation technology continues to evolve, the use of methods such as the Yoshida-Uemori Model 1), which considers a greater number of factors than previous methods, including plastic strain dependence of elasticity based on the r-value and the Bauschinger effect, has increased. Due to improvements in simulation techniques, this catalog describes various testing and evaluation methods, including new evaluation methods, considered necessary for improving simulation accuracy.

1) Vol.54 (2013) No.4 SOKKEZAI 16–19
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**Evaluation of Press Work on Sheet Metal**

This provides evaluations that result in more accurate simulations.

- Plastic Strain Dependence of Elasticity Evaluation
- Bauschinger Effect Evaluation
- Yield Surface Evaluation by Biaxial Tensile Testing
- r-Value Evaluation

Using an Autograph Machine Allows You to Comprehensively Evaluate Properties with Respect to Press Forming.

This provides evaluations that result in more accurate simulations.
The r-value is used to evaluate press workability. It is expressed as a logarithmic strain ratio of deformation in the width and thickness directions. A material with a high r-value, for example, does not deform much in the thickness direction, but deforms readily in the width direction. That means the material is easy to press form into a three-dimensional shape with minimal change in thickness.

Testing precision can vary significantly depending on how strain gauges are affixed or extensometers are attached.

Autograph AG-X plus machines feature an automatic extensometer that automates the extensometer attachment process and a digital non-contact extensometer, which enable highly reproducible test results.

Springback is inversely proportional to the elastic modulus. The elastic modulus of sheet materials varies due to the tensile bending-unbending process during press forming. Therefore, more accurate results can be obtained by incorporating these elastic modulus variations in simulations.

TRAPEZIUM X control software allows specifying complicated cyclic loading parameters and changing the elastic modulus calculation range with ease. As a result, data can be obtained in a timely manner based on parameters required for simulation.

For specifications, refer to the Trapezium X product catalog.

For specifications, see page 6.

See page 7 for details.
Press forming generates a Bauschinger effect, a situation in which yield stress decreases in sheet materials due to the bending-unbending process. Conventional press forming simulations did not account for the Bauschinger effect, which prevented fully reproducing the material behavior. Evaluating Bauschinger effects in a material allows identifying input parameters and results in more accurate simulations.

Determining the press forming workability requires evaluating the Bauschinger effect in that material. However, compression testing of a sheet material to large deformation levels without buckling the material is quite difficult, so it is rarely done. By installing a special jig, though, this difficult evaluation can be performed using an Autograph machine.

A comb-shaped guide is included to prevent buckling. This allows performing tests involving large-deformation tensile-compression in-plane reversing loads within a range not previously possible. Due to the difficulty of tensile-compression in-plane reversing load testing of micro specimens, Shimadzu also offers a jig that allows evaluating the Bauschinger effects using cantilever bending tests.

During actual press forming, materials are exposed to forces other than from uniaxial deformation behavior. Therefore, due to the different loading status, uniaxial evaluations alone can result in predicted behavior that does not match reality. Evaluations can be performed with the actual loading status more closely approximated by measuring samples with loads applied in two axis directions, which should improve the accuracy of simulations.

Efforts to perform biaxial tensile testing are often abandoned due to the complicated equipment and sample setup required, high cost, and difficulty determining an appropriate specimen shape.

To address these issues, Shimadzu developed a special jig that allows biaxial tensile testing by simply attaching it to an Autograph testing machine. This means biaxial testing equipment can be obtained for a minimal cost. The jig is also compliant with ISO 16842 standards, so it can be used to test small cruciform specimens much more easily than in the past.
Automatic Extensometers Capable of Measuring r-Value

Changes in both elongation and width over time can be evaluated. Select the optimal system from a wide variety of available models, such as contact, non-contact, and manual models.

Automatic Extensometer Specifications

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable Testing Machine</td>
<td>Autograph series</td>
</tr>
<tr>
<td>Elongation Measurement</td>
<td></td>
</tr>
<tr>
<td>Contact Type</td>
<td>Non-Contact Type</td>
</tr>
<tr>
<td>Measurement Precision</td>
<td>ISO 9513 class 1 (JIS B 7741 class 1) Either ±0.5 % of indicated value or ±2.5 μm, whichever is larger</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>(560 - initial gauge length) mm</td>
</tr>
<tr>
<td>Applicable Gauge Length</td>
<td>10 to 550 mm</td>
</tr>
<tr>
<td>Width Measurement</td>
<td></td>
</tr>
<tr>
<td>Contact Type</td>
<td>Non-Contact Type</td>
</tr>
<tr>
<td>Measurement Precision</td>
<td>ISO 9513 class 0.2 (JIS B 7741 class 0.2) Either ±0.2 % of indicated value or ±0.6 μm, whichever is larger</td>
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<tr>
<td>Measurement Range</td>
<td>4 mm</td>
</tr>
<tr>
<td>Applicable Gauge Length</td>
<td>0.2 to 10 mm thick by 12.5, 20, 25, or 30 mm wide</td>
</tr>
</tbody>
</table>
TRAPEZIUM X: Capable of Evaluating Plastic Strain Dependence of Elasticity

In addition to stress-strain curves, test force and displacement as a function of time can be displayed in real time.

TRAPEZIUM X supports evaluating the plastic strain dependence of elasticity via user-friendly graphs.

The control software allows you to specify even complicated test parameters in an easy-to-understand manner for more efficient testing.
Bauschinger Effect Measurement Jig

Measuring the Bauschinger effect is extremely useful in simulations for evaluating press workability.

The features of this testing jig, which includes a mechanism to prevent buckling, are listed below.

**Using the Bauschinger Effect Measurement Jig**

- Reduces press die development cost and time by reducing the number of required die modifications.
- Allows acquiring basic data used for simulations.
- Improves accuracy of press die simulations.
- Allows evaluating unknown materials.
- Allows performing tensile-compression reversing load tests with the actual sheet material to be used.
- Allows providing actual material characteristics as feedback to simulation.

**Key Points of Shimadzu Jig**

- Allow performing tests not previously possible at a reasonable cost.
- Easy to maintain
- Enable more efficient testing by removing the jig from the Autograph machine and laying it on its side for assembly.
- Grips with no slippage allow performing large-deformation reversing load tests.

Simply attach the jig to an Autograph machine to measure Bauschinger effects.

The anti-buckling guide uses comb-type teeth to allow applying large-deformation tensile-compression in-plane reversing loads.
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AG-100kN

100 kN tensile and 100 kN compression

Manual hydraulic pump

Max. 40 kN

Gauges

Type: Strain gauge type

Gauge Length: 50 mm

Measurement Range: +50 % / -10 %

Measurement Precision: JIS B 7741 Class 1

Room temperature

Specifications

<table>
<thead>
<tr>
<th>Applicable Model</th>
<th>AG-100kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading Capacity</td>
<td>100 kN tensile and 100 kN compression</td>
</tr>
<tr>
<td>Anti-Buckling Unit</td>
<td></td>
</tr>
<tr>
<td>Hydraulic Source</td>
<td>Manual hydraulic pump</td>
</tr>
<tr>
<td>Straightening Pressure</td>
<td>Max. 40 kN</td>
</tr>
<tr>
<td>Elongation Measurement Device</td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Strain gauge type</td>
</tr>
<tr>
<td>Gauge Length</td>
<td>50 mm</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>+50 % / -10 %</td>
</tr>
<tr>
<td>Measurement Precision</td>
<td>JIS B 7741 Class 1</td>
</tr>
<tr>
<td>Applicable Test Specimens</td>
<td></td>
</tr>
<tr>
<td>JIS No. 5</td>
<td>200 mm total length by 40 mm wide</td>
</tr>
<tr>
<td></td>
<td>60 mm long and 25 mm wide area with parallel sides</td>
</tr>
<tr>
<td></td>
<td>1 mm to 3 mm thick</td>
</tr>
<tr>
<td>JIS Special No. 5</td>
<td>200 mm total length by 45 mm wide</td>
</tr>
<tr>
<td>(wider specimen width)</td>
<td>60 mm long and 35 mm wide area with parallel sides</td>
</tr>
<tr>
<td></td>
<td>1 mm to 3 mm thick</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>Room temperature</td>
</tr>
</tbody>
</table>
Biaxial Tensile Test Jig

Biaxial tensile testing helps improve the accuracy of press forming simulations by more closely approximating actual loading conditions. Previously, there was no unified standard and no commonly used evaluation method. However, with the release of ISO 16842, biaxial tensile testing methods have now been standardized globally. Standardization has provided reliable testing methods by taking into consideration the use of sample shapes that are less likely to cause interference with other axes and by specifying the location to affix strain gauges so that they reliably measure biaxial strain. The testing jig is compliant with ISO 16842 standards, enabling tests to be performed easily by simply attaching the jig to the Autograph machine.

1 Includes various convenient features.

- Enables axial tensile testing by simply setting up the jig on the Autograph machine.
- A detachable arm allows changing the tensile ratio to 1:1, 1:1.5, or 1:2.
- Tensile, compression, and bending jigs can be attached with the biaxial tensile test jig installed.

2 Compliant with ISO 16842 test standard

- Pre-tension can be adjusted using the adjustment screw.
- The pre-tension adjustment screw allows applying an initial load with good reproducibility and simplifies the setup process.

3 Benefits compared to a dedicated machine

- Machine can be acquired for a reasonable cost.
- Lack of hydraulics provides easy maintenance.
- Other tests can be performed on the same machine.
The following example shows results from using different tensile stress ratios to test high tensile steel. It shows how results change as the tensile stress ratio changes.

### Biaxial Tensile Test Jig Specifications

<table>
<thead>
<tr>
<th></th>
<th>For AG-250/300kN</th>
<th>For AG-100kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Test Force</td>
<td>50 kN</td>
<td>20 kN</td>
</tr>
<tr>
<td>Test Force Precision</td>
<td>Class 1</td>
<td></td>
</tr>
<tr>
<td>Test Force Measurement Range</td>
<td>1/1 to 1/50</td>
<td></td>
</tr>
<tr>
<td>Applicable Test Standards</td>
<td>Compliant with ISO 16842 Metallic materials - Sheet and strip - Biaxial tensile testing method using a cruciform test piece</td>
<td></td>
</tr>
<tr>
<td>Applicable Specimen Shapes</td>
<td>30 mm wide cruciform with 150, 180, or 210 mm sides (180 and 210 mm sizes are optional)</td>
<td></td>
</tr>
<tr>
<td>Applicable Specimen Thicknesses</td>
<td>0.6 to 3.2 mm</td>
<td></td>
</tr>
<tr>
<td>Biaxial Tensile Stress Ratio</td>
<td>1:1, 1:1.5, or 1:2</td>
<td></td>
</tr>
<tr>
<td>Stroke (pulsating)</td>
<td>7.5 mm</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>30 kg upper and 160 kg lower</td>
<td></td>
</tr>
</tbody>
</table>

Note: The drop in test force at the end of the X-axis for 1:1 is due to sample failure.
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- Obtaining Accurate Design Data Usable for Simulation -

**Evaluation of Die Slipperiness**
- Drawbead Testing System

**Evaluation of Drawability**
- Plane Deep Drawability Test

**Evaluation of Work Hardening**
- HMV-G
  - Micro Vickers Hardness Tester

**Related Testing and Evaluation Instruments**
- Autograph Precision Universal Testing Machine
  - AG-X plus Series
- Material Testing Operation Software
  - TRAPEZIUM X
- Automatic Extensometer
  - SIE-560/560S