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Application News

Autograph™ AGX™ -V2

ISO 10113:2020 r-Value Determination

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User Benefits

- Determination of reliable r-values contributes to improved precision of press forming simulation.
- Related standards include ISO 10113, ASTM E517, GB/T 5027, IS 11999, and JIS Z2254.
- The r-Value Measuring Device enables simultaneous determination of other tensile test properties as well as the r-value.

■ Introduction

Thin materials like high-tension steel have been gaining attention for aspects of fuel efficiency improvement by reducing body weight, especially in the transportation equipment industry. However, high-tension steel is prone to shape defects after press forming, posing a significant challenge in terms of time and cost required for the production of press molds. Recent advancements in Computer Aided Engineering (CAE) analysis techniques and computational speed of computers have enhanced high-precision simulation of press forming for high-tension steel. This enables prediction of the ideal shape of press-formed products, leading to substantial reduction of development time and cost for press molds.

The realization of the high-precision press forming simulation requires reliable determination of the Lankford value, in short the r-value, one of the indicators representing the formability of sheet metal. The r-value serves as a quantitative indicator of the ductility of a material in the thickness direction and corresponds to the material's drawability, which contributes significantly to press formability. In ISO 10113, revised in 2020, three different r-value determination methods have been standardized (the manual method, the semi-automatic method, and the automatic method). The manual method does not require the use of extensometers for the gauge length and width, and the semi-automatic method employs only an extensometer for the gauge length. Both methods demand test force release after applying a certain plastic strain to the test piece. The automatic method, on the other hand, uses extensometers for the gauge length and width, enabling the r-value to be determined for any given plastic strain after completion of the standard metal tensile test in accordance with ISO 6892-1. Therefore, this method is very useful for determining other tensile property values (e.g., tensile strength) at the same time (see Appendix).

This article introduces a case study of the r-value determination in accordance with the automatic method in ISO 10113 by using the AGX-V2 and the r Value Measuring Device.

■ Testing System

In this demonstration, The Autograph AGX-V2, a precision universal testing machine, and the r-Value Measuring Device were used. The other instrument configurations are described in Table 1.

Table 2 provides test piece information. The type of the test piece and gauge length are required to satisfy ISO 6892-1: 2019, Annex B. In addition, the parallel length shall be equal to or larger than $L_0 + 2b_0$, where L_0 is original gauge length and b_0 is original gauge width.

The test conditions and a view of the test are shown in Table 3 and Fig. 1, respectively. The test speed complied with ISO 6892-1, which is the standard for metal tensile testing. A total of five tests were conducted for each of three types of test pieces obtained at different orientations (0, 45, and 90 deg.) relative to the rolling direction.

Table 1 Instrument Configuration

Testing Machine:	AGX-100kNV2
Load Cell Capacity:	100 kN
Grips:	100kN Manual Type Non-Shift Wedge Type Grips
Extensometers:	r-Value Measuring Device (uses DT-50-50-25 for length and SW-4 for width)
Software:	TRAPEZIUM™X-V

Table 2 Test Piece Information

Shape:	ISO 6892-1 Annex B: 3
Dimensions of the Parallel Section:	Length 120 mm Width 25 mm Thickness 1 mm
Material Properties:	SUS 304 CP
Orientations Relative to the Rolling Direction:	0, 45, 90 deg.

Table 3 Test Conditions

Test Speed:	ISO 6892-1: Method B
Original Gauge Length:	50 mm
Distance between Grips:	260 mm
Number of Tests per Orientation:	n=5

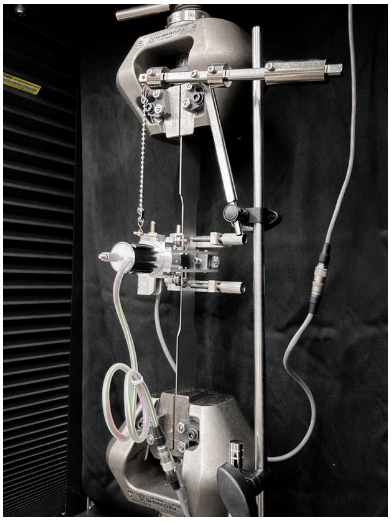

Fig. 1 View of the Test

■ Test Results

Fig. 2 shows examples of stress-strain curves obtained from the demonstration. The test piece was strained until failure. The r-Value Measuring Device was removed after reaching a certain strain (30 %) that is sufficient to determine the r-value. Table 4 shows the averages and standard deviations of the obtained test results, which are automatically calculated by the dedicated software, TRAPEZIUMX-V. Note that the 20 % r-value exhibits anisotropy with respect to the orientation of the test piece relative to the rolling direction. The weighted average r-value was calculated to be 0.961 (see Appendix).

Fig. 3 shows the width strain relative to the length strain measured by r-Value Measuring Device. The well-overlapped curves obtained from five test pieces with 0 deg. orientation to the rolling direction demonstrate the high reproducibility of this demonstration. The curves also imply that the test pieces experienced homogeneous strain in the plastic region. One of the advantages of the automatic method is the prevention of inaccurate r-value determination caused by local strain through observation of the strain behavior throughout the entire test, as represented by the curves.

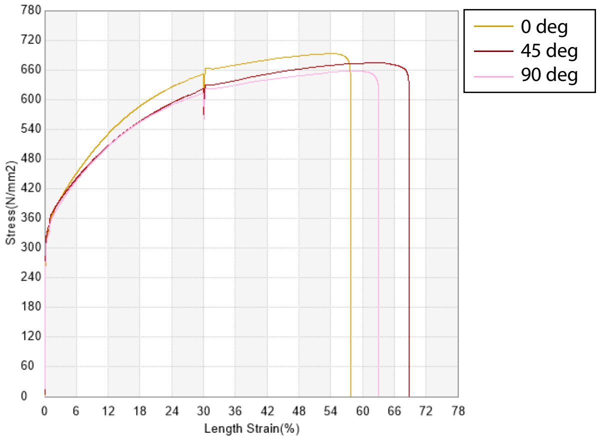

Fig. 2 Examples of the Stress-Strain Curves

Table 4 Averages and Standard Deviations of the Test Results

	20 % r-Value*	0.2 % Proof Stress [MPa]	Ultimate Tensile Strength [MPa]
0 deg.	0.859 ± 0.012	317 ± 2.6	696 ± 2.9
45 deg.	1.08 ± 0.011	311 ± 1.4	654 ± 2.8
90 deg.	0.827 ± 0.0079	326 ± 0.93	674 ± 2.3

*20 % r-value indicates the r-value calculated at the point where 20 % plastic strain is reached.

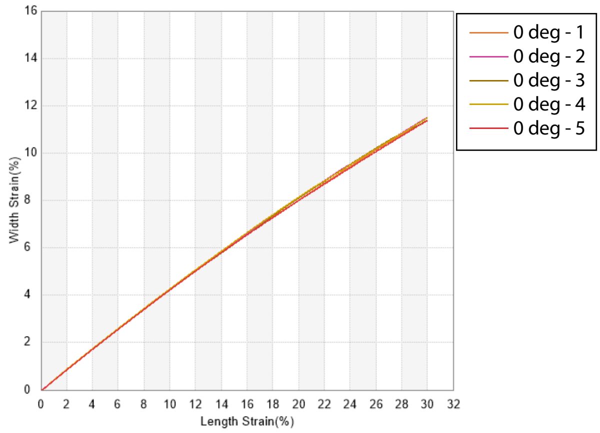

Fig. 3 Width Strain Versus Length Strain Measured by r-Value Measuring Device

■ Conclusion

The Autograph AGX-V2 and r-Value Measuring Device enable the r-value to be determined in accordance with ISO 10113:2020. This article introduces a demonstration of the reproducibility of the automatic method, which employs width and length extensometers. TRAPEZIUMX-V covers all three determination methods, the manual method, the semi-automatic method, and the automatic method. Furthermore, it is possible to compare each calculated r-value and perform subsequent statistical processing such as averaging and calculation of standard deviation.

■ Appendix - Methods for r-Value Determination

The r-value is defined as the ratio of the true plastic width strain to the true plastic thickness strain in a test piece subjected to uniaxial tensile stress. Due to the inherent difficulties in precisely measuring the thickness strain, the r-value is calculated from the true plastic strain in the width direction ($\varepsilon_{\mathrm{p\_b}}$) and the true plastic strain in the tensile direction ($\varepsilon_{\mathrm{p\_L}}$), as shown in Equation (1), using the incompressibility condition.

$$r = -\frac{\varepsilon_{\mathrm{p\_b}}}{\varepsilon_{\mathrm{p\_b}} + \varepsilon_{\mathrm{p\_L}}} \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

There are three types of r-value determination methods standardized in ISO 10113:2020 as shown below.

- Manual method: without using any extensometer
- Semi-automatic method: only with length extensometer
- Automatic method: with width and length extensometer

The manual method and semi-automatic method require the test force to be released after the test piece has been subjected to the desired plastic strain. In contrast, the automatic method enables correction for deformation in the elastic range owing to the use of both extensometers, and to obtain $\varepsilon_{\mathrm{p\_b}}$ and $\varepsilon_{\mathrm{p\_L}}$ without the need to release the test force. The automatic method, therefore, has the advantage that it can be used alongside a standard tensile test method for determining other tensile test properties.

There are two types of method available for the automatic method: the single point method and the regression method. The former method allows a single instantaneous r-value to be obtained for every row of test data, such as force, extension, and instantaneous width reduction value, and was adopted in this demonstration. The latter method applies linear regression to $\varepsilon_{\mathrm{p\_b}}$ vs $\varepsilon_{\mathrm{p\_L}}$ over the entire evaluation range to determine the reliable r-value, and is effective for materials that exhibit inhomogeneous behavior in the plastic region (e.g., materials which display the Portevin-Le Chatelier effect).

It is known that the r-value depends on the orientation of the test piece relative to the rolling direction. The weighted average of r-value ($\bar{r}$) is defined by the following equation,

$$\bar{r} = \frac{r_0 + 2r_{45} + r_{90}}{4} \quad \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

where the subscript of r is the orientation relative to the rolling direction.

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