Excellence in Science

# Application News

**No. i277**

**Precision Universal Testing Machine**

# Tensile Test of Metallic Material by Strain Rate Control Using an Automatic Extensometer

When the international standard for tensile testing of metallic materials, ISO 6892, was revised in 2009 and the corresponding Japanese Industrial Standard, JIS Z 2241, was revised in 2011, a strain rate control method (measurement of strain with an extensometer) was added as a test item in addition to stress rate control as a method for loading materials to their yield point. Accompanying these changes, requests for tensile tests of metallic materials by strain rate control are now increasing.

A highly accurate extensometer is necessary when conducting strain rate control. The Shimadzu SIE-560SA automatic extensometer makes it possible to measure the elongation of hard materials such as metals and soft materials such as plastics with high accuracy over a wide range. Measurements of the elongation can be conducted over the entire region from the start of the tensile test to fracture (rupture), and automatic attachment/detachment of the extensometer arm to the test piece and automatic setting of the gauge length are also possible.

This article introduces an example in which the possibility of conducting ISO 6892-1:2019 compliant strain rate control was verified using a Shimadzu Autograph AGX™-100 kNV precision universal testing machine and an SIE-560SA automatic extensometer.

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## Strain Rate Control

The standards provide three strain rate levels, as shown in Fig. 1, corresponding to the desired property value, and specify the strain rates shown below for the respective levels. So long as there are no other applicable requirements, use of the rates indicated by the * symbol is recommended.

Stain rate until upper yield strength or proof strength is obtained (V1)

Range 1: (0.000 07 ± 0.000 014) $s^{-1}$ or

Range 2: (0.000 25 ± 0.000 05) $s^{-1}$ ( * )

Predicted strain rate of parallel part until lower yield strength is obtained (V2)

Range 2: (0.000 25 ± 0.000 05) $s^{-1}$ ( * ) or

Range 3: (0.002 ± 0.000 4) $s^{-1}$

Predicted strain rate of parallel part until fracture is obtained thereafter (V3)

Range 2: (0.000 25 ± 0.000 05) $s^{-1}$ or

Range 3: (0.002 ± 0.000 4) $s^{-1}$ or

Range 4: (0.006 7 ± 0.001 33) $s^{-1}$ ( * )

The tolerance ranges at these respective strain rates correspond to ±20 % of the numerical values. The V1 and V3 rates are used in the present test, and the V2 rate is not used because the lower yield strength is not required. The ranges used are the two ranges 1 and 2 for V1 and the recommended rate, i.e., range 4, for V3. The strain rate switching point in this test was set at strain of 1 %.

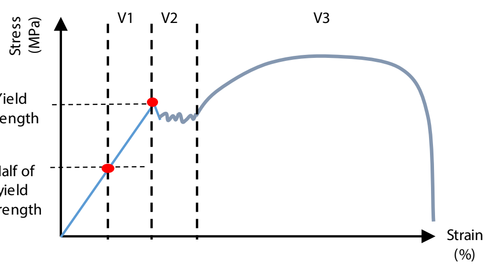


**Fig. 1 Image of Rate Control**

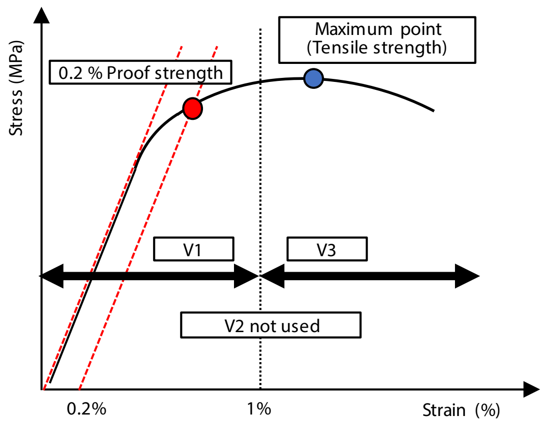


**Fig. 2 Image of Rate Control in Present Test**

**Table 1 Test Rates (Strain Rate Control)**

| Test method | V1<br>Strain rate *1 | V3<br>Predicted strain rate *2 |
|---|---|---|
| ① | 0.000 07 $s^{-1}$ | 0.006 7 $s^{-1}$ |
| ② | 0.000 25 $s^{-1}$ | (40 %/min) |

*1 "Strain rate" is defined as the "increment of strain per unit time" measured from the displacement of the gauge length of the specimen using an extensometer.

*2 "Predicted strain rate" is defined as the "increase of strain per unit time" when the separation of the cross head of the testing machine is regarded as the strain increase of the specimen parallel length.

## Test Specimen and Instrument Composition

Table 2 and Fig. 3 show the instrument composition and the condition of the test, respectively. Table 3 and Fig. 4 show the test specimen and a schematic diagram of the specimen. JIS No. 5 test pieces were used in this measurement test.

**Table 2 Instrument Composition**

| | |
|---|---|
| Testing machine | AGX-100 kNV |
| Load cell capacity | 100 kN |
| Jig | Pneumatic non-shift wedge grip |
| Displacement gauge | SIE-560SA automatic extensometer |
| Software | TRAPEZIUM™X-V (Single) |

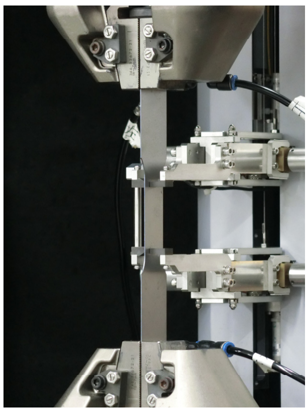

**Fig. 3 Specimen and Jigs for Tensile Testing**

**Table 3 Test Specimen**

| | |
|---|---|
| Material | SPCC |
| Specimen geometry | JIS Z 2241 No. 5 test piece |

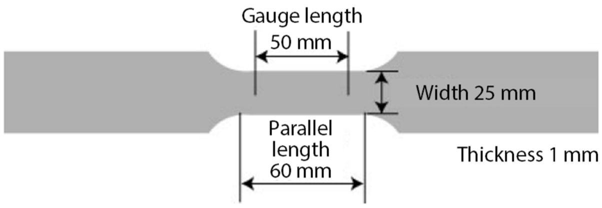


**Fig. 4 Schematic Diagram of Specimen (JIS Z 2241 No.5 Test Piece)**

## Test Results

Table 4 shows the test results, and Fig. 5 shows the stress-strain curves. Close values were obtained in the measurements at the two test rates ① and ②.

Fig. 6 shows the relationship of the strain rates and the stress-strain curves. The tolerance range for strain rate control in ISO 6892 is specified as ±20 %. In Fig. 6, the region of the ±20 % tolerance range for strain rate control specified in ISO6892 is shown in yellow, and the ±10 % region is shown in red as reference. It was possible to conduct tests that amply satisfied the strain rate control tolerance range (±20 %). Moreover, the results trended within ±10 % of the specified value at almost all stain rates, indicating that more accurate strain rate control is possible.

**Table 4 Test Results**

| | | ① | ② |
|---|---|---|---|
| Maximum test force | (N) | 8633.3 | 8600.3 |
| Tensile strength | ($N/mm^2$) | 349.8 | 348.6 |
| Elastic modulus | (GPa) | 189.3 | 185.9 |
| 0.2 % Proof strength | ($N/mm^2$) | 243.5 | 246.4 |

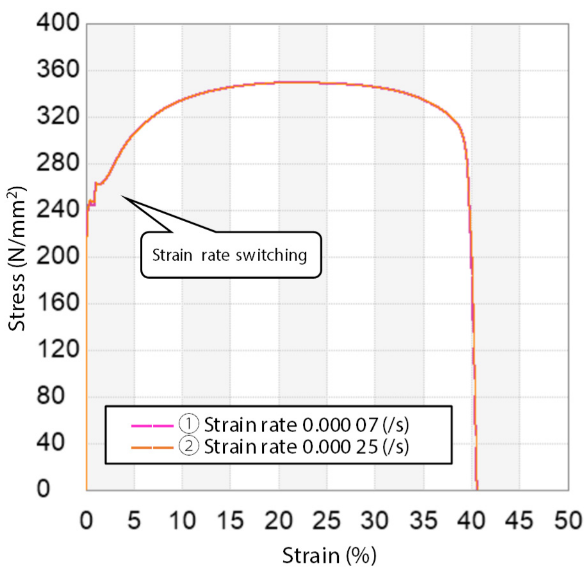


**Fig. 5 Stress-Strain Curve**

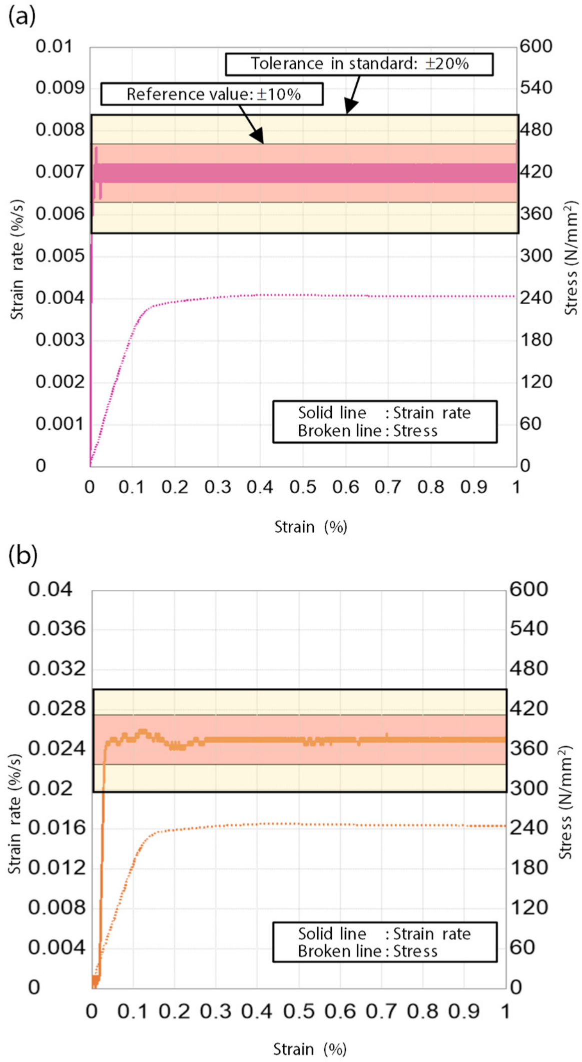


**Fig. 6 Strain Rates and Stress-Strain Curves**
**(a) Test Method ① Strain Rate 0.000 07 (/s)**
**(b) Test Method ② Strain Rate 0.000 25 (/s)**

## Conclusion

Strain rate control in the strain rate tolerance range of ±20 % specified in ISO 6892 is possible if this instrument and the SIE-560SA automatic extensometer are used, enabling testing that amply satisfies the standard.

A function which enables a graphic display of the strain rate, as shown in Fig. 6, has been added to TRAPEZIUM X-V, making it possible to confirm that measurement was conducted in conformance with the standard immediately after the measurement.

In addition, it is possible to measure elongation in the entire region from the start of the tensile test until fracture (rupture) with the SIE-560SA automatic extensometer used in this experiment. Because fracture strength can be measured without the trouble of removing the extensometer, this device is suitable for tensile tests of metallic materials.



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