SHIMADZU

Application News

No.i244

Material Testing System

Tensile Test for Metallic Materials Using Strain Rate Control and Stress Rate Control

Introduction

International standards for tensile testing of metallic materials have been revised as specified in ISO 6892 and JIS Z2241, such that strain rate control, where strain is measured with an extensometer, has recently been added as a test item to the current stress rate control method, in which a load is applied to a material until its yield point is reached. As a result, it can be assumed that there will be situations where both stress rate control and strain rate control tensile testing of metallic materials will be required.

Here, we introduce examples of strain rate control and stress rate control tensile testing of metallic samples, including cold-rolled steel, austenitic stainless steel, aluminium alloy and brass, according to ISO 6892, using the Shimadzu Autograph AG-50kNX Precision Universal Tester, and the SSG50-10H strain gauge type one-touch extensometer (Fig. 1, Fig. 2).

Fig. 1 Overview of Universal Testing System

Fig. 2 Specimen and Jigs for Tensile Testing

Specimens and Test Conditions

Information on the sample specimens are shown in Table 1, and the test conditions are shown in Table 2.

Table 1 Test Specimens

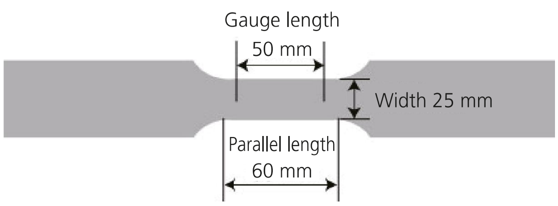
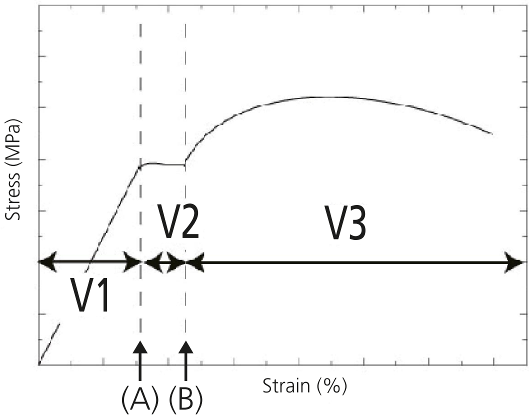
Sample Name	A	B	C	D
Material	Cold-rolled steel	Stainless steel (austenitic)	Aluminium alloy	Brass
Sample size	 Width 25 mm, thickness 1 mm, gauge length 50 mm, parallel length 60 mm (JIS Z 2241 No. 5 test specimen)			

Table 2 Test Conditions

1) Load cell capacity	50 kN
2) Jig	50 kN Non-shift wedge type grips (file teeth for flat specimen)
3) Test speed	See Table 3
4) Test temperature	Ambient temperature
5) Software	TRAPEZIUMX (single)

Fig. 3 shows an image diagram of the test speed, and Table 3 and Table 4 show the applicable test speeds for the strain control and stress control tests, respectively.



(A): Upper yield point (or its corresponding point)
(B): Upper limit of strain measurement (point after proof strength point)

Fig. 3 Image of Test Strain Rate

Table 3 Test Strain Rate (based on strain rate control)

V1: Strain rate	0.00025/s (1.5 %/min)
V2: Strain rate	0.00025/s (1.5 %/min)
V3: Predicted strain rate	0.0067/s (40 %/min)

Table 4 Test Stress Rate (based on stress rate control)

V1: Stress rate	10 MPa/s
V2: Strain rate	0.00083/s (5 %/min)
V3: Predicted strain rate	0.0067/s (40 %/min)

Test Results

Fig. 4 shows a diagram of the stress – stroke displacement for each sample using strain-rate control, and Table 5 shows their characteristic values. In Fig. 4, the point at which the stress becomes discontinuous, as indicated by the jump in the stress-stroke displacement curve, corresponds to the point at which the strain rate is switched.

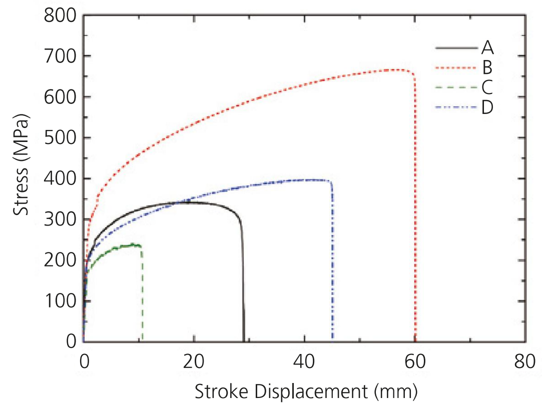


Fig. 4 Test Results for Each Metallic Material (stress-stroke curve based on strain rate control)

Table 5 Test results (Average n = 3)

Sample Name	Elastic Modulus (GPa)	0.2 % Proof Strength (MPa)	Tensile Strength (MPa)	Elongation at Break (%)
A (cold-rolled steel)	194	185.5	341.5	43.3
B (stainless steel)	200	278.5	660.8	55.0
C (aluminum)	71	170.1	236.3	13.0
D (brass)	109	193.1	398.1	49.1

Note 1) Strain rate refers to the amount of increase in strain, obtained using an extensometer to measure the gauge length of a test specimen, per unit time.
Note 2) Predicted strain rate was obtained using the displacement of the testing machine crosshead at each point in time and the test specimen's parallel length. Thus, it is defined as the increase in strain of the specimen's parallel length per unit time.

Fig. 5 (a) – (d) shows the strain rate and predicted strain rate obtained from tensile testing of the respective metallic materials using strain rate control. The red solid lines show the strain rate, the blue solid lines the predicted strain rate, and the black broken lines show the stress. In addition, the green dotted lines represent the permissible value ±20 % relative tolerance in the strain rate control (as specified in ISO 6892). As for the actual load rate, it is clear that the values are well within the permissible strain rate control range, indicating excellent strain rate control. Regarding samples A and B, displacement is measured up to 2 % of the gauge length using an extensometer. In the case of samples C and D, the strain measured using an extensometer was only up to 0.8 %, because of the appearance of serration when strain corresponding to about 1 % was applied.

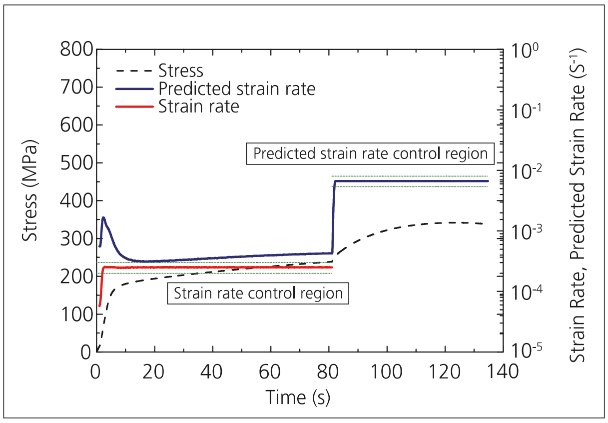


Fig. 5 (a) Test Results (Sample A)

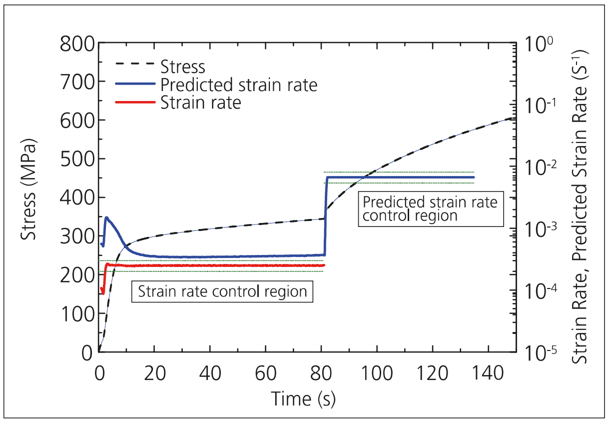


Fig. 5 (b) Test Results (Sample B)

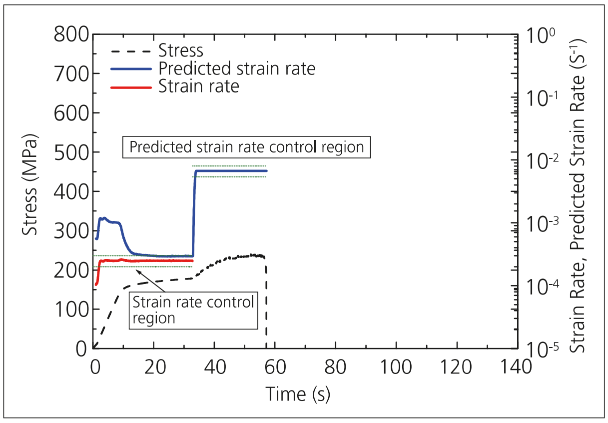


Fig. 5 (c) Test Results (Sample C)

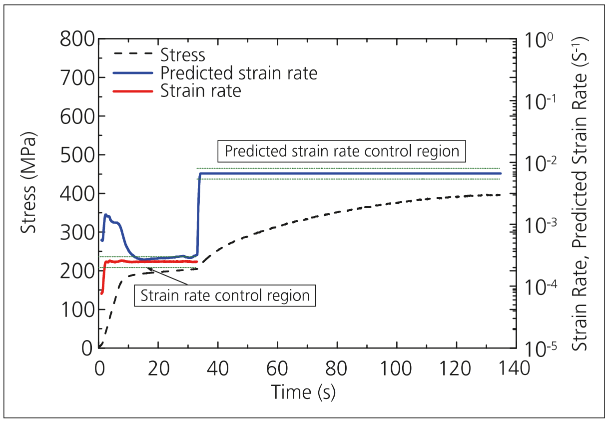


Fig. 5 (d) Test Results (Sample D)

Fig. 6 shows the stress-stroke displacement curve diagram obtained from tensile testing of each of the metallic materials using stress rate control, and the characteristic values are shown in Table 6.

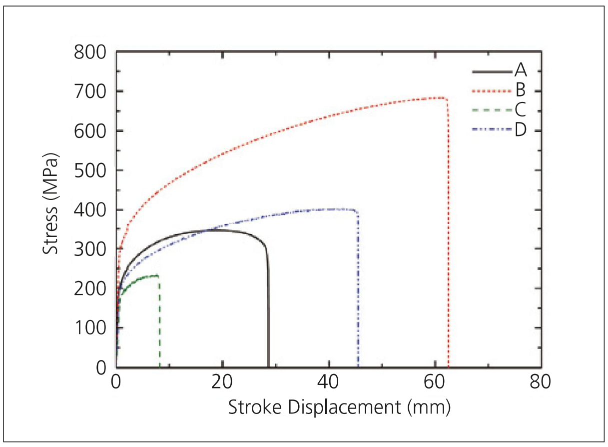


Fig. 6 Test Results (stress-stroke curve based on stress rate control)

Table 6 Test Results (Average n = 3)

Sample Name	Elastic Modulus (GPa)	0.2 % Proof Strength (MPa)	Tensile Strength (MPa)	Elongation at Break (%)
A (cold-rolled steel)	194	193.3	349.3	42.0
B (stainless steel)	205	290.7	687.0	54.8
C (aluminum)	69	177.0	233.5	12.6
D (brass)	112	196.7	405.5	48.8

Fig. 7 (a) – (d) shows the strain rate and predicted strain rate obtained from tensile testing of the respective metallic materials using stress rate control. The pink solid lines show the stress rate, the blue solid lines the predicted strain rate, and the black broken lines show the stress.

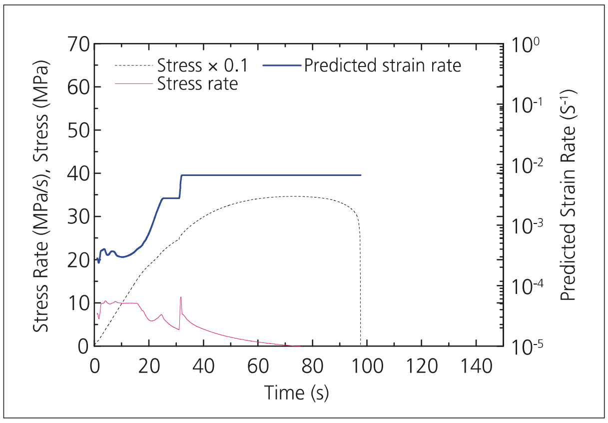


Fig. 7 (a) Test Results (Sample A)

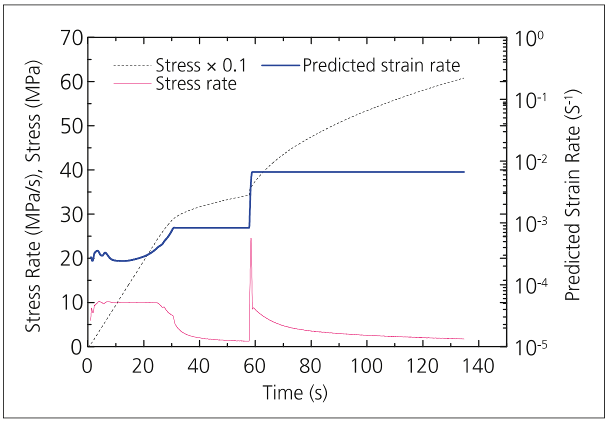


Fig. 7 (b) Test Results (Sample B)

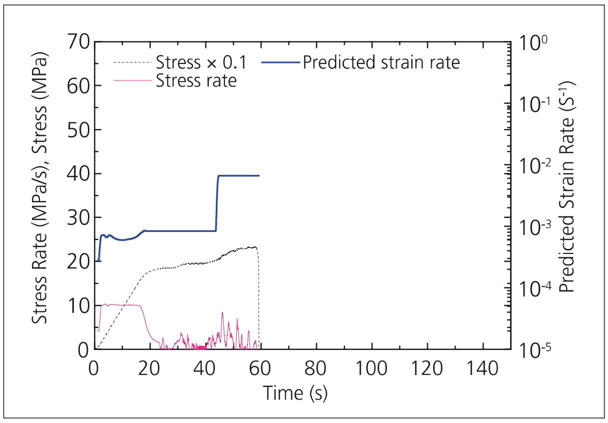


Fig. 7 (c) Test Results (Sample C)

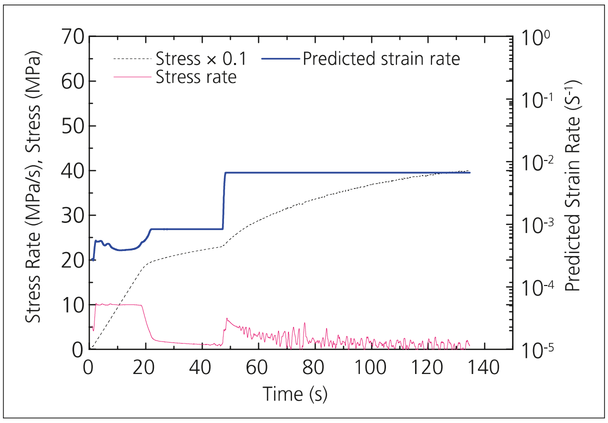


Fig. 7 (d) Test Results (Sample D)

It is clear that at the set rates, suitably stable data could be acquired for both stress rate and predicted strain rate.

The above results demonstrate that in the tensile testing of the various types of metallic materials using the Shimadzu Autograph AG-50kNX Precision Universal Tester, the strain rate control values were well within the range of the permissible values (± 20 %) specified in ISO 6892. Similarly, stable testing using stress rate control was also achieved. When using typical universal testing machines, testing control methods other than the crosshead rate control, e.g. strain rate control and stress rate control, normally require burdensome adjustment of the control gain depending on the material being tested. However, with this instrument, strain rate control and stress rate control in tensile testing of any metallic material are easily conducted because the gain is adjusted automatically (auto-tuning feature).

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