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HYDROGENIUS DATABASE

— SSRT Properties —

No. A105

Database on Slow Strain Rate Test (SSRT) Properties of cold-rolled
JIS-SUS316L (316L Type) Austenitic Stainless Steel
in 115 MPa Hydrogen Gas

Data Provider: Kyushu University
Nippon Steel Corporation
The Japan Research and Development Center for Metals

2022

Edited by
Research Center for Hydrogen Industrial Use and Storage (HYDROGENIUS)
Kyushu University

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1. MATERIALS

Table 1 Production process and related data of SUS316L.

| Heat | Production process | Product form | Dimensions |
|-----------------|--------------------|--------------|---|
| Q ¹⁾ | Hot-rolled | Plate | Length: ~650 mm Width: 90 mm Thickness: 20~70 mm |
| R ¹⁾ | Hot-rolled | Plate | Length: ~650 mm Width: 90 mm Thickness: 20~70 mm |

1) Laboratory-melted steel.

Table 2 Chemical compositions of SUS316L.

| | Heat | Element (mass %) | | | | | | | | | |
|------------------|---------------------------|------------------|-------|------|-------|-------|-------|-------|-------|------|-------|
| | | C | Si | Mn | P | S | Ni | Cr | Mo | Cu | N |
| Product analysis | Q ¹⁾ | 0.020 | 0.36 | 1.39 | 0.035 | 0.001 | 11.98 | 16.33 | 2.11 | 0.15 | 0.011 |
| | R ¹⁾ | 0.020 | 0.37 | 1.72 | 0.035 | 0.001 | 12.65 | 17.58 | 2.55 | 0.15 | 0.011 |
| Ladle analysis | Q ²⁾ | 0.019 | 0.38 | 1.39 | 0.030 | 0.001 | 12.00 | 16.40 | 2.13 | 0.15 | 0.011 |
| | R ²⁾ | 0.019 | 0.37 | 1.71 | 0.031 | 0.001 | 12.39 | 17.51 | 2.57 | 0.15 | 0.011 |
| | Requirement ³⁾ | max | 0.030 | 1.00 | 2.00 | 0.045 | 0.030 | 15.00 | 18.00 | 3.00 | |
| | min | | | | | | 12.00 | 16.00 | 2.00 | | |

1) Performed by HYDROGENIUS.

2) As reported by Nippon Steel Corp.

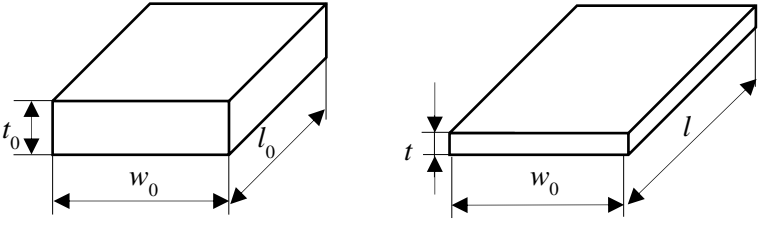
3) As per JIS G 4304 (2021), "Hot-rolled Stainless Steel Plate, Sheet and Strip".

Table 3 Heat treatment conditions of SUS316L.

| Heat | Heat treatment | Condition |
|-----------------|--------------------|--------------------------------|
| Q ¹⁾ | Solution-treatment | 1100°C, 30 min, water quenched |
| R ¹⁾ | Solution-treatment | 1100°C, 30 min, water quenched |

1) As reported by Nippon Steel Corp.

Table 4 Cold-rolling process of SUS316L.

| | | |
|--|---|---|
| <p>Definition of cold-rolling reduction-ratio, CW (%)</p> | $CW = ((t_0 - t) / t_0) \times 100$  <p style="text-align: center;">Before cold-rolling After cold-rolling</p> | |
| <p>True pre-strain, ϵ_{pre}</p> | $\epsilon_{pre} = \ln \frac{A_0}{A} = \ln \frac{1}{1 - (CW / 100)}$ | |
| <p>Heat</p> | <p>Cold-rolling reduction ratio, CW (%)</p> | <p>True pre-strain, ϵ_{pre}</p> |
| <p>Q</p> | <p>0</p> | <p>0</p> |
| | <p>20</p> | <p>0.22</p> |
| | <p>40</p> | <p>0.51</p> |
| | <p>50</p> | <p>0.69</p> |
| | <p>70</p> | <p>1.20</p> |
| <p>R</p> | <p>0</p> | <p>0</p> |
| | <p>20</p> | <p>0.22</p> |
| | <p>40</p> | <p>0.51</p> |
| | <p>50</p> | <p>0.69</p> |
| | <p>70</p> | <p>1.20</p> |

2. MECHANICAL PROPERTIES

Table 5 Mechanical properties of SUS316L.

| Heat | Cold-Drawing Ratio, CW (%) | Tensile Properties | | | | Vickers hardness (HV) |
|---------------------------|------------------------------|--|-----------------------------------|-----------------------------|---------------------------------|---------------------------|
| | | 0.2% proof strength $\sigma_{0.2}$ (MPa) | Tensile strength σ_B (MPa) | Elongation ϵ_f (%) | Reduction of area φ (%) | |
| Q ^{1),2)} | 0 | 201 | 520 | 81 | 85 | |
| | 20 | 534 | 646 | 49 | 81 | |
| | 40 | 784 | 883 | 20 | 76 | |
| | 50 | 829 | 918 | 20 | 75 | |
| | 70 | 911 | 1028 | 16 | 72 | |
| R ^{1),2)} | 0 | 212 | 523 | 80 | 84 | |
| | 20 | 590 | 661 | 43 | 79 | |
| | 40 | 775 | 870 | 19 | 72 | |
| | 50 | 807 | 922 | 18 | 72 | |
| | 70 | 903 | 1031 | 14 | 68 | |
| Requirement ³⁾ | max min | | | | | 200 |
| | | 175 | 480 | 40 | | |

1) As reported by Nippon Steel Corp.

2) Average of 3 times tensile test.

3) As per JIS G 4304 (2021), "Hot-rolled Stainless Steel Plate, Sheet and Strip".

3. SSRT PROPERTIES

Table 6 SSRT conditions.

(a) Kyushu University ($CW = 0\%, 20\%, 40\%$)

| | | |
|--|--|--------------------|
| Type and capacity of testing machine | Servo-hydraulic, 50 kN or 100 kN | Screw type, 100 kN |
| Loading condition | Uniaxial, Monotonic | |
| Environment | In 115 MPa hydrogen gas at RT and 200°C In 106 MPa hydrogen gas at -45°C In 0.1 MPa nitrogen gas at -45°C In air at 200°C | In air at RT |
| Gas purity | Hydrogen gas: 99.999% (5N) | |
| Test speed | $1.5 \times 10^{-3} \text{ mm/s}^2$ ($5.0 \times 10^{-5} \text{ s}^{-1}$) ³⁾ $1.0 \times 10^{-3} \text{ mm/s}^2$ ($5.0 \times 10^{-5} \text{ s}^{-1}$) ³⁾ | |
| Specimen ¹⁾ (dimensions in mm) | <p>(a) Type A</p> <p>(b) Type B</p> | |

1) Specimen surface was finished by longitudinal polishing with 600 grade emery paper (LP) or circumferential buffing with a colloidal SiO₂ (0.04 μm) solution (CP).

2) Test speed was determined by crosshead speed.

3) Estimated from crosshead speed divided by the length of parallel section; 30 mm for Type A and 20 mm for Type B. The value of $5.0 \times 10^{-5} \text{ s}^{-1}$ is given by $1.5 \times 10^{-3} \text{ mm/s} / 30 \text{ mm}$ or $1.0 \times 10^{-3} \text{ mm/s} / 20 \text{ mm}$.

(Table continues on the following page)

Table 6 SSRT conditions. (Continued)

(b) Nippon Steel Corporation ($CW = 0\%, 20\%, 40\%$)

| | |
|--|---|
| Type and capacity of testing machine | Mechanical-Servo, 10 kN |
| Loading condition | Uniaxial, Monotonic |
| Environment | In 90 MPa hydrogen gas at RT In 70 MPa hydrogen gas at -40°C In air at RT In 0.1 MPa nitrogen gas at -40°C |
| Gas purity | Hydrogen gas: 99.99999% (7N) |
| Test speed | $1.0 \times 10^{-3} \text{ mm/s}^2$ ($5.0 \times 10^{-5} \text{ s}^{-1}$) ³⁾ |
| Specimen ¹⁾ (dimensions in mm) | <p style="text-align: center;">(mm)</p> |

1) Specimen surface was finished by longitudinal polishing with 600 grade emery paper.

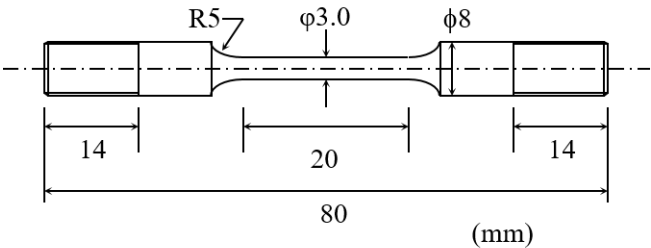
2) Test speed was determined by crosshead speed.

3) As determined based on a 20-mm, parallel-length of a specimen. $5.0 \times 10^{-5} \text{ s}^{-1}$ is given by $(1.0 \times 10^{-3} \text{ mm/s}) / 20 \text{ mm}$.

(Table continues on the following page)

Table 6 SSRT conditions. (Continued)

(c) The Japan Research and Development Center for Metals ($CW = 50\%, 70\%$)

| | |
|--|---|
| Type and capacity of testing machine | Mechanical-Servo, 10 kN |
| Loading condition | Uniaxial, Monotonic |
| Environment | In 90 MPa hydrogen gas at RT In 70 MPa hydrogen gas at -40°C and -50°C In air at RT In 0.1 MPa nitrogen gas at -40°C and -50°C |
| Gas purity | Hydrogen gas: 99.99999% (7N) |
| Test speed | $1.0 \times 10^{-3} \text{ mm/s}^2$ ($5.0 \times 10^{-5} \text{ s}^{-1}$) ³ at RT $1.7 \times 10^{-4} \text{ mm/s}^2$ ($8.3 \times 10^{-6} \text{ s}^{-1}$) ³ at -40°C |
| Specimen ¹⁾ (dimensions in mm) |  <p style="text-align: center;">80 (mm)</p> |

1) Specimen surface was finished by longitudinal polishing with 600 grade emery paper.

2) Test speed was determined by crosshead speed.

3) As determined based on a 20-mm, parallel-length of a specimen. $5.0 \times 10^{-5} \text{ s}^{-1}$ is given by $(1.0 \times 10^{-3} \text{ mm/s}) / 20 \text{ mm}$.