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HYDROGENIUS DATABASE

— Mechanical Properties —

No. B4

Database of Mechanical and Hydrogen Transport Properties of
JIS-SCM435 Low-Alloy Steel for Use in Storage Cylinders in a
35-MPa-Hydrogen Type “A” Station

Year of publication: 2009

Research Center for Hydrogen Industrial Use and Storage (HYDROGENIUS)
Kyushu University - JAPAN

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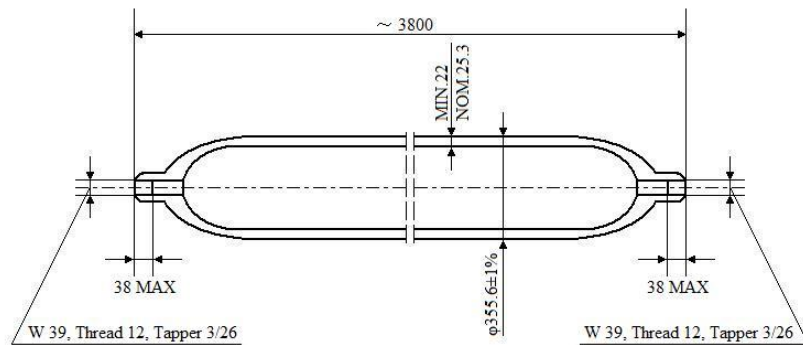
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Database of Mechanical and Hydrogen Transport Properties of JIS-SCM435
Low-Alloy Steel for Use in Storage Cylinders in a 35-MPa-Hydrogen Type "A" Station

1. MATERIAL

Table 1. Processing details and related properties of SCM435.



Cylinder hot-forging → Head and tail cold-forming → Quenching-tempering

→ Hardness measurement → Screw-processing → Shot-blasting

→ Inner and outer surface inspection → Pressure-proof testing → Stamping → Painting

Table 2. Chemical composition of SCM435.

			Element (mass%)						
			C	Si	Mn	P	S	Cr	Mo
Product Analysis	Present Material ¹⁾	Center	0.37	0.22	0.84	0.012	0.005	1.15	0.24
		Interior	0.38	0.22	0.79	0.006	0.004	1.1	0.23
Ladle Analysis	Present Material ²⁾		0.35	0.20	0.77	0.008	0.003	1.05	0.20
	Requirements ³⁾	Max.	0.38	0.35	0.85	0.030	0.030	1.20	0.30
		Min.	0.33	0.15	0.60	-	-	0.90	0.15

¹⁾ As performed at HYDROGENIUS.

²⁾ As reported by the manufacturer.

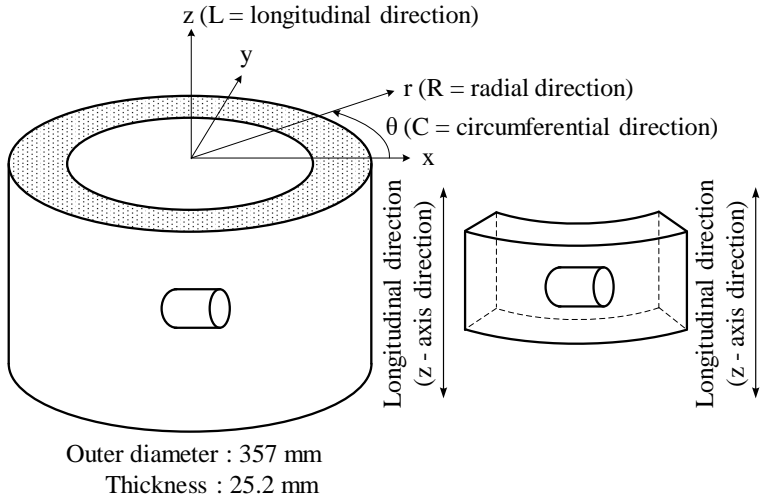
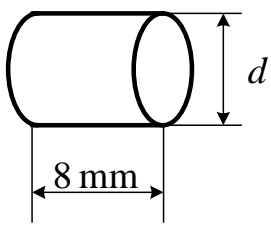
³⁾ As per JIS G 3441:1988, "Alloy Steel Tubes for Machine Purposes".

Table 3. Heat-treatment conditions for SCM435.

Quenching	Tempering
Barrel furnace	Truck furnace
860°C, Water-spraying	630°C, Air-cooling
3.60~3.95 BHD (Target hardness)	

2. HYDROGEN CONTENT

Table 4. Hydrogen-exposure and hydrogen-content measurement conditions.

(a) Hydrogen-exposure conditions	
High-pressure vessel	Gases : Hydrogen, Nitrogen, Argon Maximum pressure : 100 MPa Maximum temperature : 140°C Inner volume : $1.0 \times 10^{-3} \text{ m}^3$
Exposure conditions	100 MPa, 85°C, 200 h
Specimens	 <p style="text-align: center;">Outer diameter : 357 mm Thickness : 25.2 mm</p> <p style="text-align: center;">(a) Sampling of specimens¹⁾</p>  <p style="text-align: center;">$d = 5, 7, 10 \text{ mm}$</p> <p style="text-align: center;">(b) Shape and dimensions of specimens²⁾ (in mm)</p>
¹⁾ Specimens for hydrogen measurement were sampled from a storage cylinder located inside the JHFC Kasumigaseki hydrogen station. ²⁾ Surface-finishing was performed by circumferential polishing with 600-grade silicon-carbide paper.	
(b) Hydrogen-measurement conditions	
Type of spectroscope	TDA (Thermal Desorption Analysis) Hydrogen detection accuracy : 0.3 Vol. ppm Amount of hydrogen molecule detection : $6.1 \times 10^{-10} \text{ mol/min}$
Measurement conditions	20~520°C, 100°C/h

3. MICROSTRUCTURES

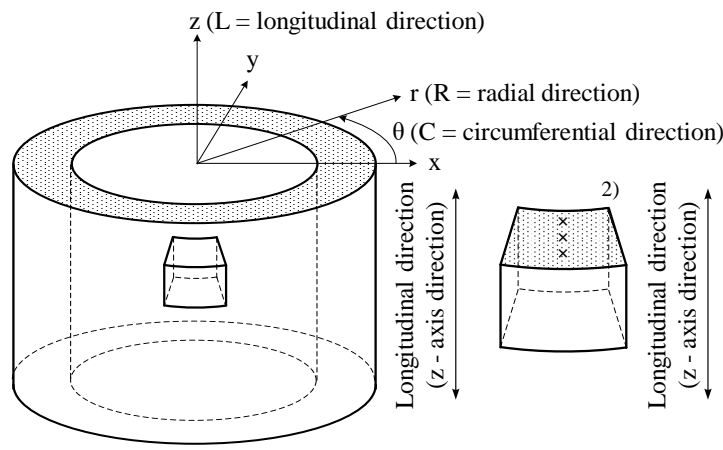
Table 6. Conditions for microstructural observation.

Surface Preparation	Optical microscope →	Nital (Nitric acid : 3%, Ethyl alcohol : 97%)
Surface Preparation	EBSD → (Electron Backscatter Diffraction)	Colloidal silica solution Acceleration voltage : 25 kV
Sampling ¹⁾	<p>z (L = longitudinal direction)</p> <p>y</p> <p>r (R = radial direction)</p> <p>θ (C = circumferential direction)</p> <p>x</p> <p>Longitudinal direction (z - axis direction)</p> <p>L-R plane (θ - axis direction)</p> <p>R-C plane (z - axis direction)</p> <p>L-C plane (r - axis direction)</p> <p>Longitudinal direction (z - axis direction)</p> <p>Outer diameter : 357 mm Thickness : 25.2 mm</p>	

¹⁾ Specimens for microstructural observation were sampled from a storage cylinder located inside the JHFC Kasumigaseki hydrogen station.

4. VICKERS HARDNESS

Table 7. Vickers hardness measurement-conditions.

Type and capacity of testing machine	Micro-Vickers, 0.01 kN~0.50 kN
Loading conditions	0.20 kN, 15 s
Environment	In air, RT
Sampling ¹⁾	 <p>Outer diameter : 357 mm Thickness : 25.2 mm</p>

¹⁾ Specimens used for Vickers hardness measurements were sampled from a storage cylinder located at the JHFC Kasumigaseki hydrogen station. Surface-finish polishing was completed via buffing.

²⁾ Vickers hardness measurements were taken radially from inner-to-outer surfaces, using those perpendicular to the loading direction.

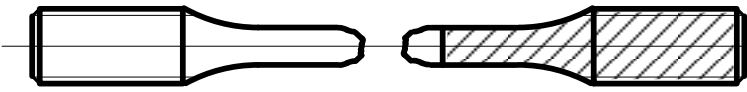
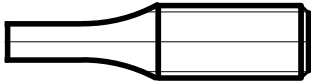
5. TENSILE PROPERTIES AND HYDROGEN CONTENT

Table 9. Tensile-test, hydrogen-exposure and hydrogen-content measurement conditions.

(a) Tensile-test conditions	
Type and capacity of testing machine	Screw-type, 50 kN
Loading conditions	1 mm/min
Environment	In air, RT
Specimens	<p style="text-align: center;">Outer diameter : 357 mm Thickness : 25.2 mm</p> <p style="text-align: center;">(a) Sampling of specimens¹⁾</p>
	<p style="text-align: center;">(b) Shape and dimensions of specimens²⁾ (in mm)</p>
(b) Hydrogen-exposure conditions of tensile specimens	
High-pressure vessel	Gases : Hydrogen, Nitrogen, Argon Maximum pressure : 100 MPa Maximum temperature : 140°C Inner volume : $1.0 \times 10^{-3} \text{ m}^3$
Exposure conditions	100 MPa, 85°C, 200 h

(Table continues on the following page)

Table 9. Tensile-test, hydrogen-exposure and hydrogen-content measurement conditions. (Continued)

(c) Hydrogen-content measurement conditions of specimens fractured by tensile tests	
Type of spectroscope	TDA (Thermal Desorption Analysis) Hydrogen detection accuracy : 0.3 Vol. ppm Amount of hydrogen molecule detection : 6.1×10^{-10} mol/min
Measurement conditions	20~520°C, 100°C/h
Specimens	 <p>(a) Sampling of specimens¹⁾</p>
	 <p>(b) Shape of specimens</p>

¹⁾ Specimens used for hydrogen measurement were fractured by tensile tests.

6. CHARPY IMPACT PROPERTIES AND HYDROGEN CONTENT



Table 11. Charpy impact test, hydrogen-exposure and hydrogen-content measurement conditions.

(a) Charpy impact test conditions	
Capacity of testing machine	Weight : 252 N, Radius : 0.66 m
Loading condition	Raising angle : 141°
Temperatures	-100°C (173 K) ~ 100°C (373 K)
Environment	In air, RT
Specimens	<p style="text-align: center;">(a) Sampling of specimens¹⁾</p>
	<p style="text-align: center;">(b) Shape and dimensions of specimens (in mm)</p>
¹⁾ Charpy impact specimens were sampled from a storage cylinder at the JHFC Kasumigaseki hydrogen station.	
(b) Hydrogen-exposure conditions of Charpy impact specimens	
High-pressure vessel	Gases : Hydrogen, Nitrogen, Argon Maximum pressure : 100 MPa Maximum temperature : 140°C Inner volume : $1.0 \times 10^{-3} \text{ m}^3$
Exposure conditions	100 MPa, 85°C, 200 h

(Table continues on the following page)

Table 11. Charpy impact test, hydrogen-exposure and hydrogen-content measurement conditions.
(Continued)

(c) Hydrogen-content measurement conditions of specimens fractured by Charpy impact tests

Type of spectroscope	TDA (Thermal Desorption Analysis) Hydrogen detection accuracy : 0.3 Vol. ppm Amount of hydrogen molecule detection : 6.1×10^{-10} mol/min
Measurement conditions	20~520°C, 100°C/h
Specimens	 <p>(a) Sampling of specimens¹⁾</p>
	 <p>(b) Shape of specimens</p>

¹⁾ Hydrogen measurement was conducted on specimens fractured by Charpy impact tests.