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HYDROGENIUS DATABASE  
— Fatigue Crack-Growth Properties —

No. A17

Database of Long, Fatigue Crack-Growth Properties of JIS-SNCM439  
Low-Alloy Steel for Use in a Storage Cylinder at a 70-MPa-Hydrogen  
Station

2012

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

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# Database of Long, Fatigue Crack-Growth Properties of JIS-SNCM439 Low-Alloy Steel for Use in a Storage Cylinder at a 70-MPa-Hydrogen Station

## 1. MATERIAL

Table 1. Processing details and related properties of SNCM439.

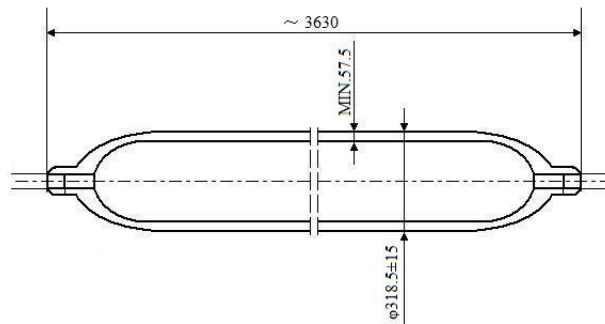


Table 2. Chemical composition of SNCM439.

		Element (mass%, *mass ppm)								
		C	Si	Mn	P	S	Ni	Cr	Mo	H*
Product Analysis <sup>1)</sup>	Inside	0.43	0.28	0.82	0.004	0.002	1.95	0.90	0.23	0.0
	Outside	0.43	0.27	0.82	0.005	0.002	1.95	0.91	0.23	
Ladle Analysis <sup>2)</sup>			0.42	0.26	0.80	0.01	< 0.01	1.91	0.89	0.25
	Requirements <sup>3)</sup>	Max.	0.43	0.35	0.90	0.030	0.030	2.00	1.00	0.30
		Min.	0.36	0.15	0.60			1.60	0.60	0.15

<sup>1)</sup> As performed at HYDROGENIUS.

<sup>2)</sup> After issuance of the inspection certificate.

<sup>3)</sup> According to JIS G 4053:2008, "Low-Alloyed Steels for Machine Structural Use".

Table 3. Heat treatment<sup>1)</sup>.

Quenching	Tempering
Barrel furnace	Barrel furnace
860°C, Water-spraying	620°C, Air-cooling
3.30 ~ 3.50 BHD (Target hardness)	

<sup>1)</sup> As reported by the manufacturer.

It should be noted that the following data are identical to those in HYDROGENIUS DATABASE No.8: Tables 1, 2, 3, 4 and 5 and Image 1.

### 3. MECHANICAL PROPERTIES

Table 4. Tensile properties of SNCM439.

$\sigma_{0.2}$  : 0.2% Proof strength  
 $\sigma_B$  : Tensile strength  
 $\delta$  : Uniform elongation  
 $\varphi$  : Reduction of area

(a) Circumferential direction (Inner)

$\sigma_{0.2}$ (MPa)	$\sigma_B$ (MPa)	$\delta$ (%)	$\varphi$ (%)
772	910	7.1	49.6

(b) Circumferential direction (Outer)

$\sigma_{0.2}$ (MPa)	$\sigma_B$ (MPa)	$\delta$ (%)	$\varphi$ (%)
808	927	8.3	55.3

(c) Longitudinal direction (Inner)

$\sigma_{0.2}$ (MPa)	$\sigma_B$ (MPa)	$\delta$ (%)	$\varphi$ (%)
750	903	8.6	60.1

(d) Longitudinal direction (Outer)

$\sigma_{0.2}$ (MPa)	$\sigma_B$ (MPa)	$\delta$ (%)	$\varphi$ (%)
801	933	8.2	60.4

Table 5. Average Vickers hardness value of SNCM439.

$\overline{HV}$
292

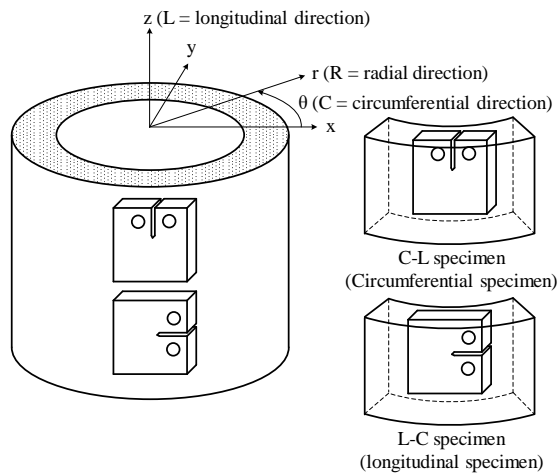
It should be noted that the following data are identical to those in HYDROGENIUS DATABASE No.8: Tables 1, 2, 3, 4 and 5 and Image 1.

#### 4. LONG, FATIGUE CRACK-GROWTH PROPERTIES

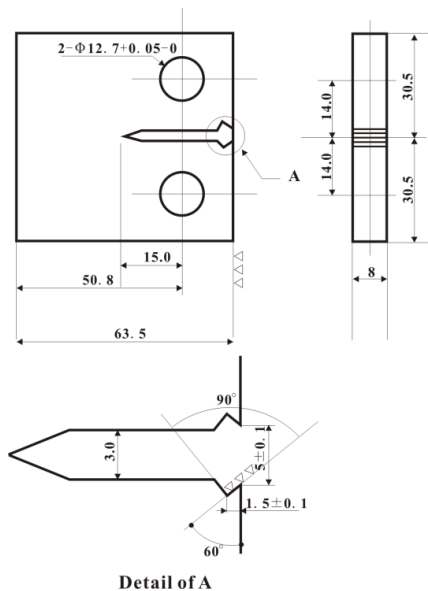
Table 6. Fatigue crack-growth test conditions.

Type and capacity of testing machine	100 kN servo-hydraulic fatigue machine in 120-MPa-hydrogen and 120-MPa-nitrogen gas 50 kN servo-hydraulic fatigue machine in 0.1-MPa-hydrogen and 0.1-MPa-nitrogen gas 30 kN servo-hydraulic fatigue machine in air
Loading conditions	Uniaxial, Sinusoidal
Environment	Room temperature, 0.6 ~ 90-MPa-hydrogen gas (absolute pressure) Room temperature, laboratory air
Frequency	0.01 ~ 20 Hz

Specimens<sup>1)</sup>



(a) Sampling of CT specimens



(b) Shape and dimensions of CT specimens (in mm)

(Table continues on the following page)

Table 6. Fatigue crack-growth test conditions. (Continued)

<p>Loading conditions<sup>2)</sup></p>	<p>① <math>\Delta K</math> - decreasing / <math>\Delta K</math> decreasing rate : <math>d\Delta K/da = -2 \text{ GPa} \cdot \text{m}^{-1/2}</math>                  ② <math>\Delta K</math> - increasing / <math>\Delta K</math> increasing rate : <math>d\Delta K/da = 2 \text{ GPa} \cdot \text{m}^{-1/2}</math>                  ③ <math>\Delta K</math> - constant                  ④ <math>\Delta P</math> - constant / <math>\Delta K</math> - increasing</p> $\Delta K = \frac{\Delta P}{B\sqrt{W}} \frac{(2+\alpha)}{(1-\alpha)^{3/2}} (0.886 + 4.64\alpha - 13.32\alpha^2 + 14.72\alpha^3 - 5.6\alpha^4) \quad (1)$ <p><math>\Delta P</math>: Force range  <math>W</math>: Width  <math>B</math>: Thickness  <math>a</math>: Crack size  <math>\alpha = a/W</math></p>
<p>Crack-length measurement<sup>2)</sup></p>	<p>Compliance method with clip-on gage</p> $a = W(C_0 + C_1u_x + C_2u_x^2 + C_3u_x^3 + C_4u_x^4 + C_5u_x^5) \quad (2)$ $u_x = \left\{ \left[ \frac{EvB}{P} \right]^{1/2} + 1 \right\}^{-1} \quad (3)$ <p><math>W</math>: Width  <math>E</math>: Elastic modulus  <math>v</math>: Displacement between measurement points  <math>B</math>: Thickness  <math>P</math>: Force  <math>C_0 = 1.0010</math>  <math>C_1 = -4.6695</math>  <math>C_2 = 18.460</math>  <math>C_3 = -236.82</math>  <math>C_4 = 1214.9</math>  <math>C_5 = -2143.6</math></p>

<sup>1)</sup> The specimen surface was polished by final buffing using a colloidal SiO<sub>2</sub> (0.04 μm) solution.

<sup>2)</sup> As per ASTM E647 - 08e1, "Standard test method for measurement of fatigue crack growth rates".