HYDROGENIUS
水素材料先端科学研究センター

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HYDROGENIUS DATABASE
― Fatigue Crack-Growth Properties ―

No. B58

Database of Long, Fatigue Crack-Growth Properties of
JIS-SCM435 Chromium Molybdenum Steel in 115-MPa-Hydrogen Gas

2015

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

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Kyushu University
HYDROGENIUS
Fatigue and Fracture Department
MATSUOKA Saburo (Leader)
MATSUNAGA Hisao
YAMABE Junichiro
HAMADA Shigeru
ITOGA Hisatake
AWANE Tohru
YOSHIKAWA Michio

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YOSHINAGA Tomofumi (Nissan Motor Co., Ltd.)

Kyushu University, Research Center for Hydrogen Industrial Use and Storage (HYDROGENIUS)
744 Motooka, Nishi-ku, Fukuoka-city, Fukuoka, 819-0395, JAPAN
Tel.: +81-92-802-3921 Fax: +81-92-802-3928
E-mail: db@hydrogenius.kyushu-u.ac.jp

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1. MATERIALS

Table 1. Details of processing and related data for SCM435.

Heat	Production Process	Product Format	Dimensions (mm)
J[1)]	Hot-rolled	Plate	Length: 280 mm Width: 110 mm Thickness: 25 mm
K[1)]	Hot-forged	Cylinder	Length: 3800 mm Outer diameter: 357 mm Inner diameter: 306.6 mm Thickness: 25.2 mm
T[1)]	Hot-forged	Cylinder	Length: 7530 mm Outer diameter: 270 mm Inner diameter: 210 mm Thickness: 30 mm

1) As reported by the manufacturer.

Table 2. Chemical composition of SCM435.

	Heat		Element (mass%)						
			C	Si	Mn	P	S	Cr	Mo
Product Analysis	J[1)]		0.36	0.18	0.78	0.013	0.005	1.04	0.20
	K[2)]		0.37	0.22	0.84	0.012	0.005	1.15	0.24
	T[2)]		0.37	0.21	0.77	0.012	0.007	1.07	0.28
Ladle Analysis	J[3)]		0.34	0.19	0.76	0.014	0.005	1.06	0.20
	J'[3)]		0.33	0.21	0.74	0.014	0.004	1.05	0.20
	Requirements[4)]	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 recorded by JPEC.
2) As conducted by HYDROGENIUS.
3) As reported by the manufacturer.
4) As per JIS G 3441:2012, *"Alloy steel tubes for machine purposes"* and JIS G 4053:2008, *"Low-alloyed steels for machine structural use"*.

The data on this page are identical to those featured in HYDROGENIUS DATABASE No. A57.

Table 3. Heat-treatment conditions of SCM435.

Material	Heat	Shape	Quenching	Tempering
Large-sized specimen	J[1)]	Plate	900°C/60 min, Oil-quenching	600°C/100 min, Air-cooling
	K[1)]	Cylinder	860°C, Water-spraying	630°C, Air-cooling
	T[1)]	Cylinder	900°C, Oil-quenching	560°C, Air-cooling
Small-sized specimen	K[2)]	Near net shape of specimen[3)]	860°C/60 min, Oil-quenching	650°C/90 min, Water-cooling
	T[2)]	Near net shape of specimen[3)]	855°C/30 min, Oil-quenching	550°C/60 min, Water-cooling
				600°C/60 min, Water-cooling
				650°C/60 min, Water-cooling

1) As reported by the manufacturer.
2) As performed by HYDROGENIUS.
3) See Table 5.

The data on this page are identical to those featured in HYDROGENIUS DATABASE No. A57.

2. MECHANICAL PROPERTIES

Table 4. Mechanical properties of SCM435.

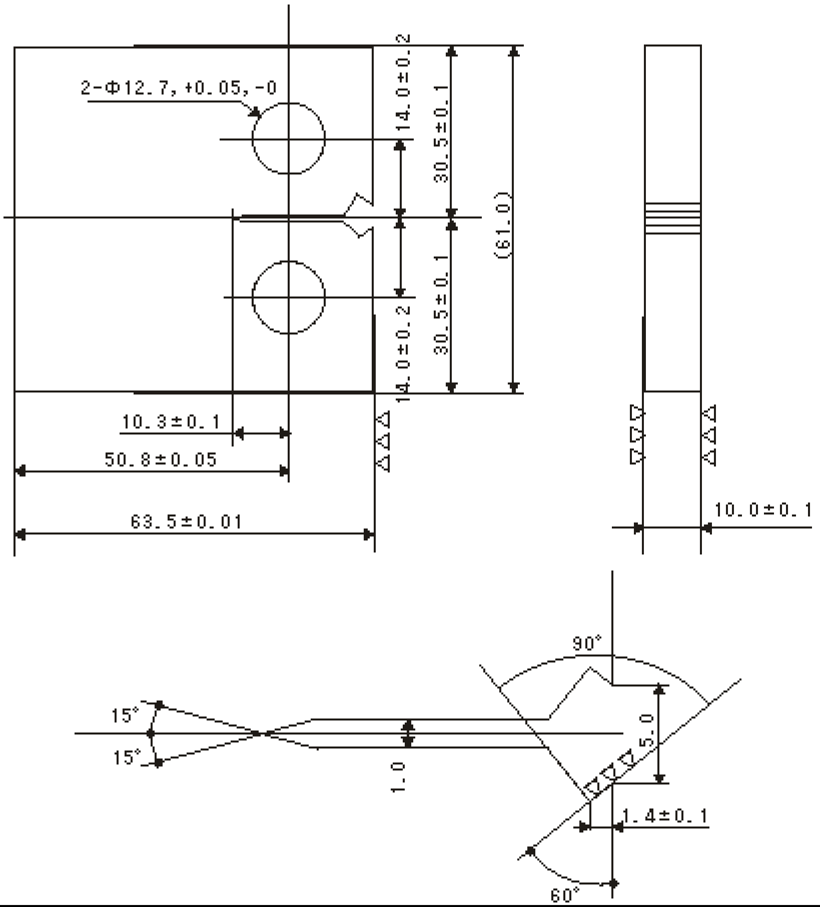
Material	Heat	Shape	Tempering Temperature (°C)	Tensile Properties				Vickers Hardness (*HV*)
				0.2% Proof Stress, $\sigma_{0.2}$ (MPa)	Tensile Strength, σ_B (MPa)	Fracture Elongation, ε_f (%)	Reduction of Area, φ (%)	
Large-sized specimen	J[1]	Plate	600	681[3] (687)[4]	838	23	73	258
	K[1]	Cylinder	630	687[3], [5] (688)[4]	824[5]	20[5]	71[5]	256[5]
				679[3], [5] (678)[4]	815[5]	24[5]	73[5]	
	T[1]	Cylinder	560	785[3], [5] (788)[4]	951[5]	17[5]	65[5]	289[5]
				779[3], [5] (778)[4]	943[5]	17[5]	66[5]	
				777[3], [5] (776)[4]	936[5]	18[5]	65[5]	
Small-sized specimen	K[1]	Near net shape of specimen	650	800[3] (802)[4]	903	20	70	284
	T[1]	Near net shape of specimen	550	1044[3] (1054)[4]	1127	19	64	338
			600	911[3] (918)[4]	1002	21	68	319
			650	772[3] (775)[4]	875	24	72	276
Requirements[2]			Max.					
			Min.	785	930	15	50	

[1] As performed by HYDROGENIUS.
[2] As per JIS G 3441:2012, *"Alloy steel tubes for machine purposes"* and JIS G 4053:2008, *"Low-alloyed steels for machine structural use"*.
[3] As determined by the σ-ε curve.
[4] As determined by the σ-stroke curve. See Fig. A1-6.
[5] As reproduced from HYDROGENIUS DATABASE Nos. 4 and 6 (Table 10, uncharged L-specimen).

The data on this page was reproduced from HYDROGENIUS DATABASE No.A57.

3. FATIGUE CRACK-GROWTH PROPERTIES

Table 5. Fatigue crack-growth test conditions.

Testing machines	• 100 kN, servo-hydraulic fatigue-machine, in gaseous hydrogen and nitrogen up to 120-MPa • 30 kN, servo-hydraulic fatigue-machine, in air
Loading condition	Sinusoidal
Environment	• 10 ~ 115-MPa-hydrogen gas, at RT • Laboratory air, at RT
Gas purity	Hydrogen gas: 99.999% (5 N)
Frequency	0.001 ~ 20 Hz
Specimens[1), 2)] (dimensions in mm)	

(Table continues on the following page)

Table 5. Fatigue crack-growth test conditions. (Continued)

ΔK conditions[2)]	ΔK-constant or ΔP-constant ΔK-increasing $$\Delta K = \frac{\Delta P}{B\sqrt{W}} \frac{(2+\alpha)}{(1-\alpha)^{3/2}}(0.886 + 4.64\alpha - 13.32\alpha^2 + 14.72\alpha^3 - 5.6\alpha^4) \quad (1)$$ ΔP: Force range W: Width B: Thickness a: Crack size $\alpha = a/W$
Crack-length measurement[2)]	Compliance method with clip-on gage $$a = W(C_0 + C_1 u_x + C_2 u_x^2 + C_3 u_x^3 + C_4 u_x^4 + C_5 u_x^5) \quad (2)$$ $$u_x = \left\{ \left[\frac{E v B}{P} \right]^{\frac{1}{2}} + 1 \right\}^{-1} \quad (3)$$ W: Width E: Elastic modulus v: Displacement between measurement points B: Thickness P: Force $C_0 = 1.0010$ $C_1 = -4.6695$ $C_2 = 18.460$ $C_3 = -236.82$ $C_4 = 1214.9$ $C_5 = -2143.6$

[1)] The specimen surface was finished by buffing, using a colloidal SiO_2 (0.04 μm) solution.
[2)] According to ASTM E647 - 08e1, *"Standard test method for measurement of fatigue crack growth rates"*.