

Duplication is prohibited. 複製禁止



DOI: 10.48708/4756000

HYDROGENIUS DATABASE
— Fatigue Crack-Growth Properties —

No. A2

Database of Fatigue Crack-Growth Properties of A6066-T6 Aluminum Alloy Plate for Use in High-Pressure Hydrogen Storage Vessels of Fuel-Cell Vehicles in 115-MPa-Hydrogen Gas

2012

Research Center for Hydrogen Industrial Use and Storage (HYDROGENIUS)
National Institute of Advanced Industrial Science and Technology (AIST)
Kyushu University – JAPAN

HYDROGENIUS DATABASE No. A2

Database of Fatigue Crack-Growth Properties of A6066-T6 Aluminum Alloy Plate for
Use in High-Pressure Hydrogen Storage Vessels of Fuel-Cell Vehicles
in 115-MPa-Hydrogen Gas

Year of publication: 2012

HYDROGENIUS Executive Staff

Yukitaka MURAKAMI (Director)

Hydrogen Fracture and Fatigue Team

Saburo MATSUOKA (Leader; Kyushu University - Professor)

Yoshihiro FUKUSHIMA (Kyushu University - Assistant Professor)

Hisatake ITOGA (AIST - Researcher)

Michio YOSHIKAWA (Technical Staff)

Kazuhisa HATAKEYAMA (Technical Staff)

Kengo MIZUGUCHI (Technical Staff)

Shoichi SHIMIZU (Technical Staff)

Satoko YOSHIDA (Technical Staff)

Users' acceptance of these terms: This HYDROGENIUS DATABASE is available without charge on these express terms that users who view, access, download to use this HYDROGENIUS DATABASE expressly agree to these terms of use indicated herein. If you do not accept these terms, you must not access, view or download to use for any purpose.

Disclaimer: Unless otherwise stated, any products designed and/or fabricated in accordance with this HYDROGENIUS DATABASE are neither endorsed by nor affiliated with HYDROGENIUS. To the extent permitted by laws of Japan, HYDROGENIUS excludes, whether express or implied, all conditions, warranties, representations or other terms which may apply to this HYDROGENIUS DATABASE or any content on it. HYDROGENIUS will not be liable for any direct or indirect losses/damages of any consequence resulting from, whether in contract, tort (including negligence), breach of statutory duty or otherwise whether foreseeable or not, or arising under or in connection with use of or reliance on this HYDROGENIUS DATABASE and any content displayed on this HYDROGENIUS DATABASE, or for inability to use this HYDROGENIUS DATABASE thereon. There are no express or implied warranties of merchantability or fitness for a particular purpose regarding the use of this HYDROGENIUS DATABASE and any content displayed on this HYDROGENIUS DATABASE.

All rights reserved: No part of this HYDROGENIUS DATABASE or any of content displayed on HYDROGENIUS DATABASE may be reproduced or republished in any format, stored in any electronic or alternative retrieval system, or else modified, transferred, distributed, circulated, transmitted or exploited in any manner, without the prior written permission of HYDROGENIUS. All company and product names, design rights and equipment that are featured, used or cited in this HYDROGENIUS DATABASE shall remain any of intellectual property and/or registered trademarks of their respective companies/owners.

Termination: HYDROGENIUS reserves the rights to modify this HYDROGENIUS DATABASE in any way or discontinue providing any or all of this HYDROGENIUS DATABASE without notice. HYDROGENIUS may require the termination of any and all display distribution or other use of any or all of this HYDROGENIUS DATABASE for any reason.

These terms of use, its subject matter and formation are governed by the laws of Japan, and the courts of Japan will have exclusive jurisdiction in case of dispute or claims related to this HYDROGENIUS DATABASE.

Any personal information or data collected from your access to this HYDROGENIUS DATABASE will be handled according to the policy of Kyushu University Institution Repository (QIR) and Privacy Policy of Kyushu University which can be found at <https://www.kyushu-u.ac.jp/en/website/privacypolicy>.

Copyright © 2021

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

744 Motoooka, 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

Database of Fatigue Crack-Growth Properties of A6066-T6 Aluminum Alloy Plate for Use in High-Pressure Hydrogen Storage Vessels of Fuel-Cell Vehicles in 115-MPa-Hydrogen Gas

1. MATERIAL

Table 1. Processing details and related properties of A6066-T6.

Heat	Production Process	Thickness (mm)	Format	Date of Issue
A	Hot-rolled	20	Plate	

Table 2. Chemical composition of A6066-T6.

	Heat	Element (mass%)								
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	
Product Analysis ¹⁾	A	1.35	0.21	1.00	0.78	1.02	0.02	0.01	0.03	
Ladle Analysis ²⁾	A	1.4	0.21	1.0	0.8	1.1	0.020	0.01	0.03	
	Requirements ³⁾	Max.	0.80	0.7	0.40	0.15	1.2	0.35	0.25	0.15
		Min.	0.40		0.15		0.8	0.04		

¹⁾ As performed at HYDROGENIUS.

²⁾ As reported by the manufacturer.

³⁾ As per the Aluminum Association (AA).

Table 3. Heat-treatment conditions for A6066-T6 ^{1), 2)}.

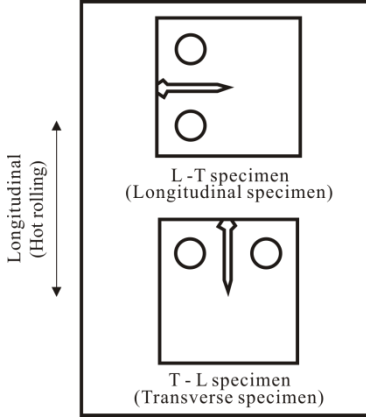
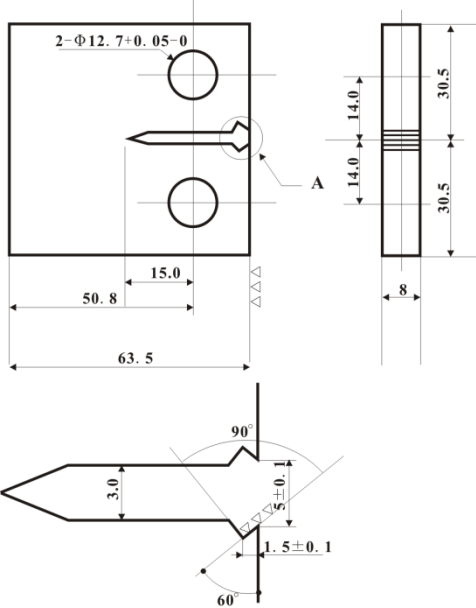
Heat	Conditions
A	550°C, 2h, water-cooled Natural aging, 24h Artificial aging, 175°C, 10h

¹⁾ As per the inspection certificate issued.

²⁾ Based on the heat-treated material received.

4. 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, 115-MPa-hydrogen gas (absolute pressure) Room temperature, 0.1-MPa-nitrogen gas (absolute pressure) Room temperature, laboratory air
Frequency	0.01 - 10 Hz
Specimens ¹⁾	<div style="text-align: center;">  <p>(a) Sampling of CT specimens</p> </div> <div style="text-align: center;">  <p>(b) Shape and dimensions of CT specimens (in mm)</p> </div>

(Table continues on the following page)

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

<p>Loading conditions²⁾</p>	<p>① ΔK - constant ② ΔP - constant / ΔK - 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>ΔP: Force range W: Width B: Thickness a: Crack size $\alpha = a/W$</p>
<p>Crack-length measurement²⁾</p>	<p>Compliance method with clip-on gage</p> $a = W(C_0 + C_1u_x + C_2u_x^2 + C_3u_x^3 + C_4u_x^4 + C_5u_x^5) \quad (2)$ $u_x = \left\{ \left[\frac{EvB}{P} \right]^{\frac{1}{2}} + 1 \right\}^{-1} \quad (3)$ <p>W: Width E: Elastic modulus v: Displacement between measurement points B: Thickness P: Force $C_0 = 1.0010$ $C_1 = -4.6695$ $C_2 = 18.460$ $C_3 = -236.82$ $C_4 = 1214.9$ $C_5 = -2143.6$</p>

¹⁾The specimen surface was polished by final buffing using a colloidal SiO₂ (0.04 μm) solution.

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