Current status and draft plan of round-robin tests

Transmitted by Japan

5th Meeting of the informal working group on GTR No.13 (Phase 2)

5-7 March 2019 @ Powertech Labs, BC, Canada

Participant institutes, material, and remaining bars

Japan

HYDROGENIUS

Sandia National Laboratories — MPA STUTTGART Materialprüfungsanstalt Universität Stuttgart

USA **Germany**

φ25 mm × L500 mm × 12 bars

SUS316L (MPA)

Supplied numbers of bars

SNL	3 bars
MPA	2 bars
HYDROGENIUS	7 bars

Chemical composition and mechanical properties

Chemical composition（mass%）

Heat	C	Si	Mn	P	S	Ni	Cr	Mo	N
MPA	0.019	0.49	1.41	0.029	0.024	12.19	17.13	2.05	—
Require ment[1)]	≤0.03	≤1.00	≤2.00	≤0.045	≤0.030	12.00 ~ 15.00	16.00 ~ 18.00	2.00~ 3.00	—

1) JIS G 4303 (1981), "Stainless steel bars"

$Ni_{eq} = Ni + 12.6C + 0.35Si + 1.05Mn + 0.65Cr + 0.98Mo = 27.2$ mass%

Mechanical properties

Heat	$\sigma_{0.2}$ [MPa]	σ_B [MPa]	Elongation [%]	RA [%]	*HBW*
MPA	245	551	60	78	141
Requirement[1)]	≥175	≥480	≥40	≥60	≤167

1) JIS G 4303 (1981), "Stainless steel bars"

Test procedures of round-robin test

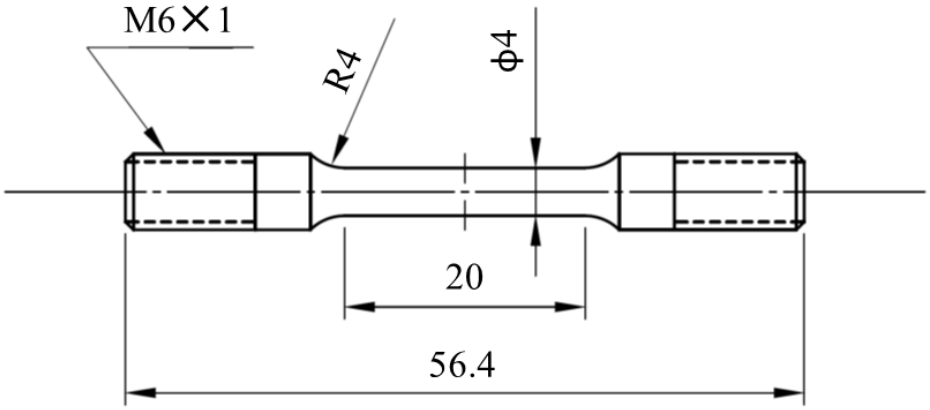
Test condition and required numbers of specimens for each test

Test	Environment	Condition	Number of specimens
SSRT at -40°C	0.1-MPa N_2 gas	5×10^{-5} /s	3
	90-MPa H_2 gas		3
Notch fatigue at R = 0.1 at -40°C	0.1-MPa N_2 gas	1Hz, σ_a=200 MPa σ_{max}=444 MPa, σ_{min}= 44 MPa	3
	90-MPa H_2 gas		3
Smooth fatigue at R = -1 at -40°C	0.1-MPa N_2 gas	1Hz, σ_a=320 MPa σ_{max}=320 MPa, σ_{min}= -320 MPa	3
	90-MPa H_2 gas		3

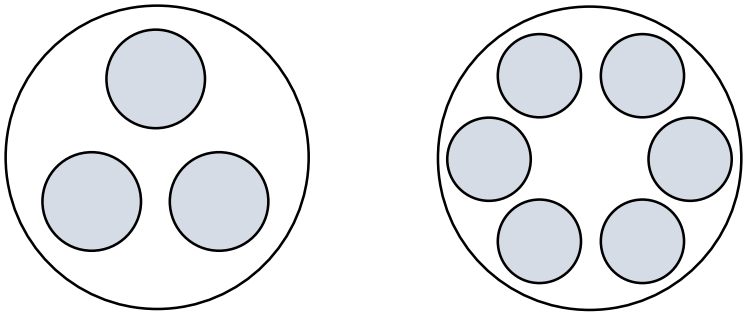
Manufacture of specimens

- The SSRT specimen was manufactured by MPA
- The circumferentially-notched specimen was manufactured by SNL.
- The smooth, round-bar specimen was manufacture by HYDROGENIUS.

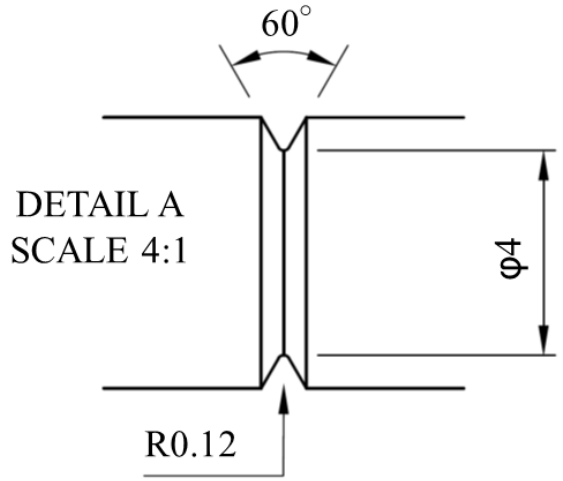
Specimen geometries（SSRT and notched specimens)

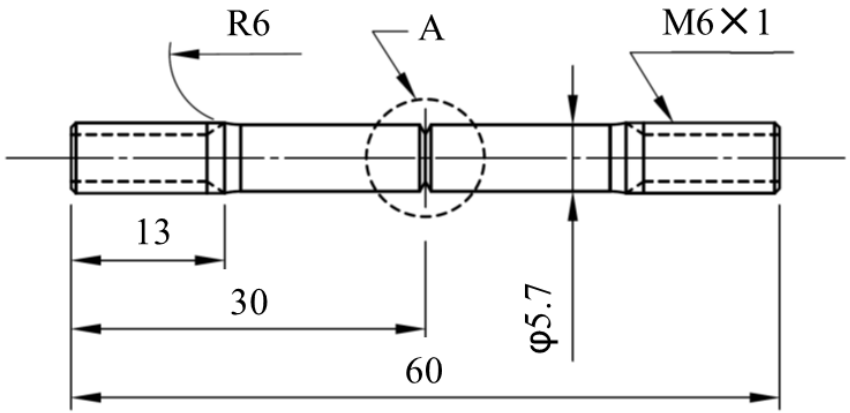


SSRT specimen
(MPA, ASTM E8 Specimen 4)



SSRT specimen　Notched specimen

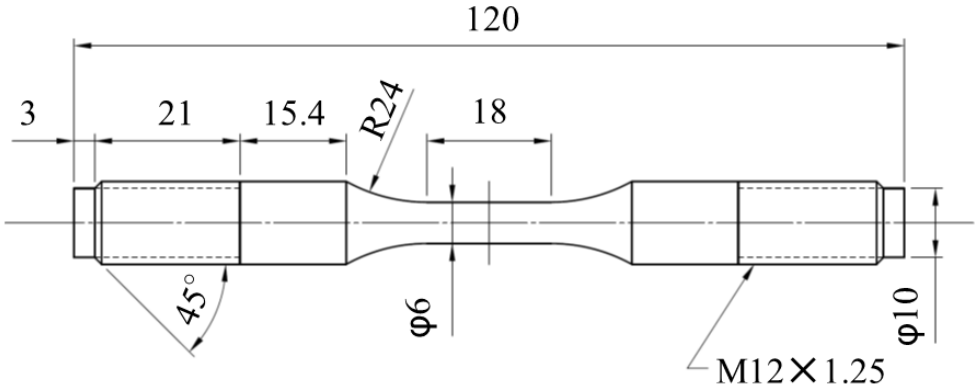




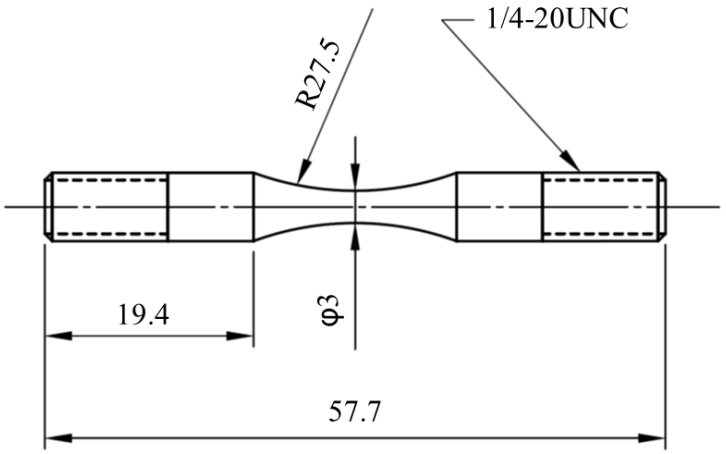
Circumferentially-notched specimen
(SNL, K_t=4.1)

Specimen geometries（smooth, round-bar specimens

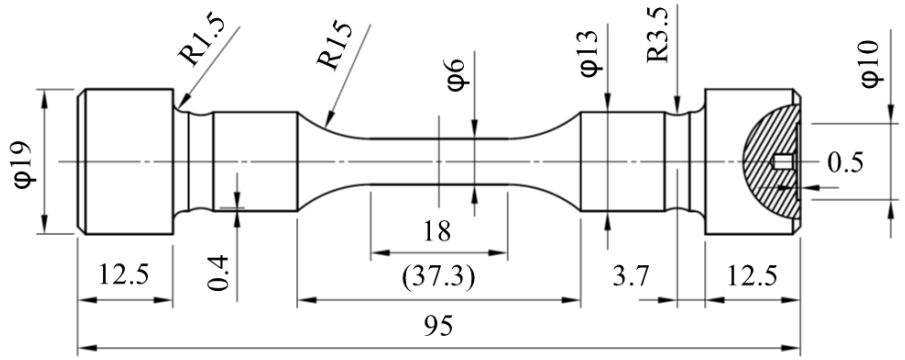
MPA

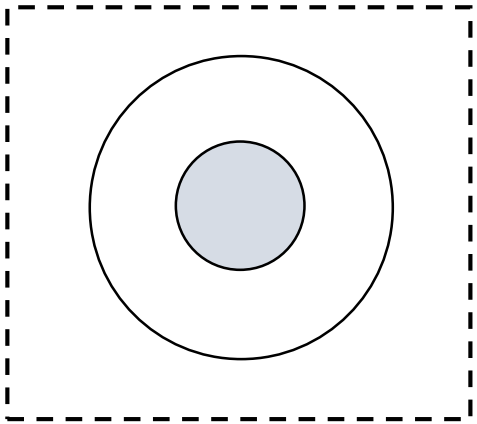


SNL



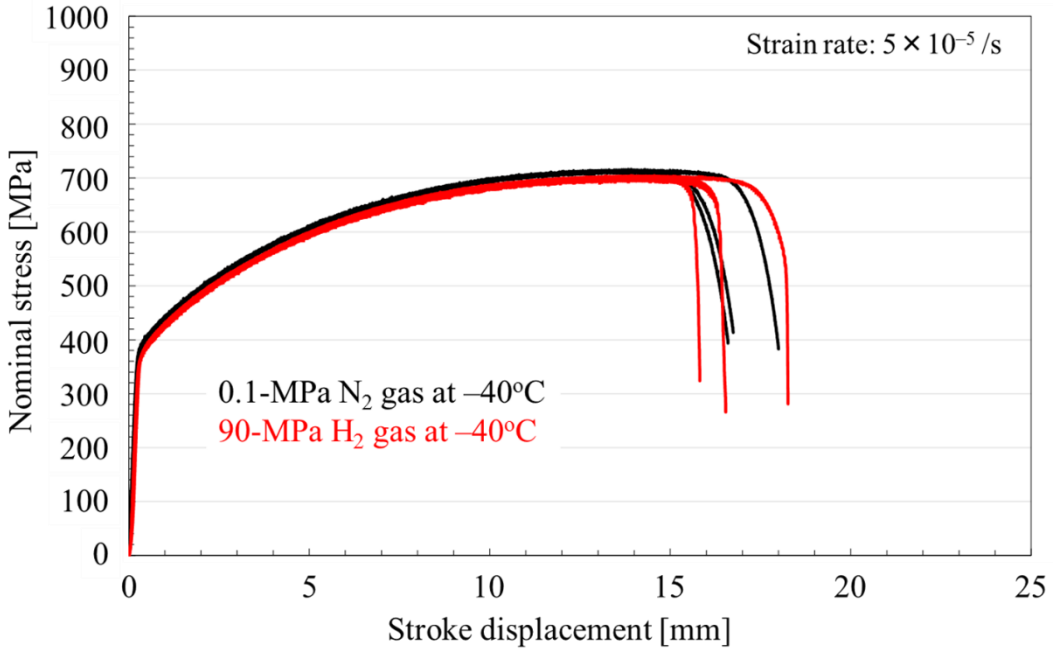
HYDROGENIUS

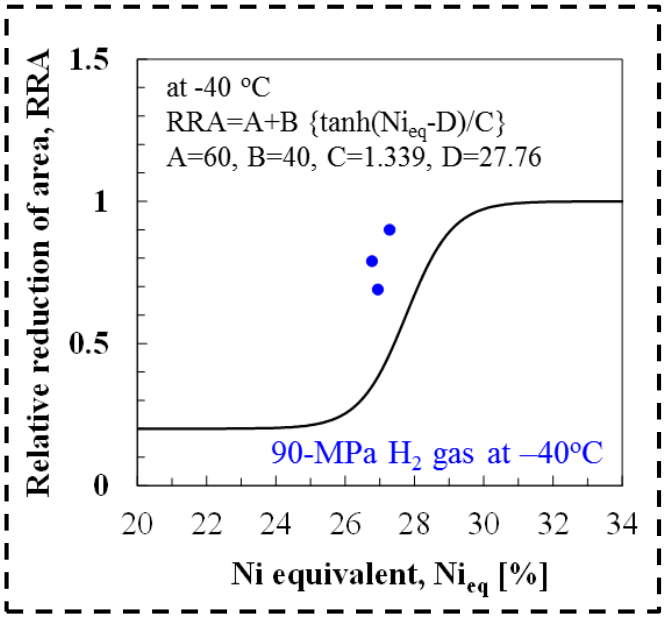




Smooth, round-bar specimens (manufactured by HYDROGENIUS)

Results of SSRT test



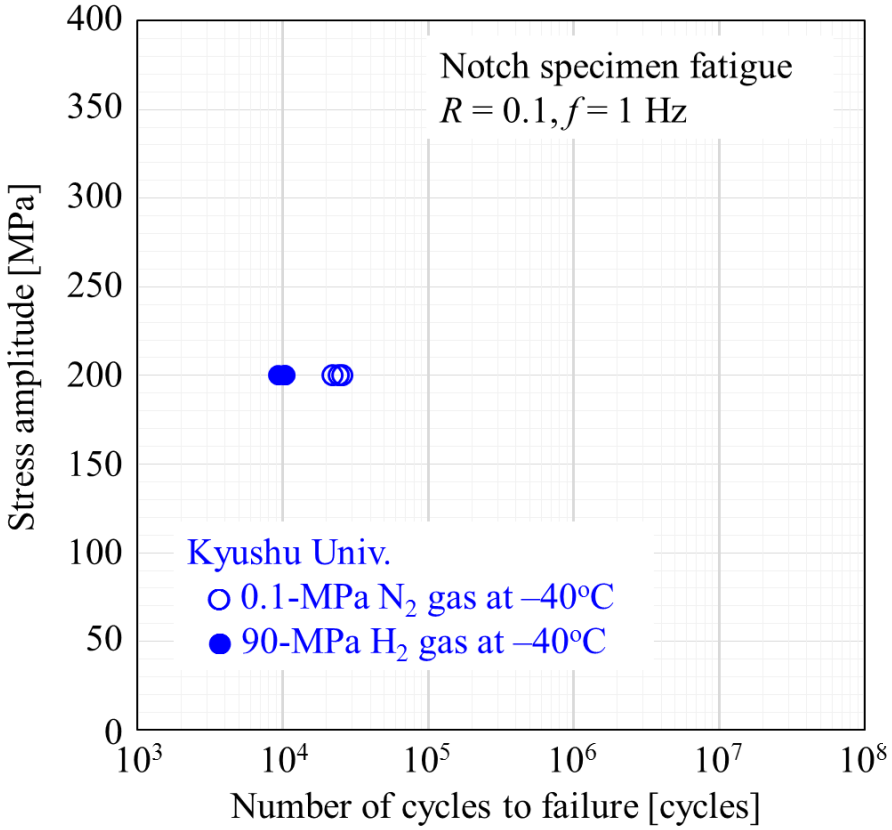


SSRT properties (HYDROGENIUS)

Test data (HYDROGENIUS)

Test environment	SSRT properties under a strain rate of 5×10^{-5} /s			
	Tensile strength [MPa]	Elongation at failure [%]	Reduction in area [%]	
0.1-MPa N_2 gas at –40°C	716	81	84	Average RA: 84%
	716	84	83	
	716	90	85	
90-MPa H_2 gas at –40°C	704	94	76 (RRA = 0.90)	
	703	79	66 (RRA = 0.79)	
	699	75	58 (RRA = 0.69)	

Results of notched specimen fatigue test (HYDROGENIUS)



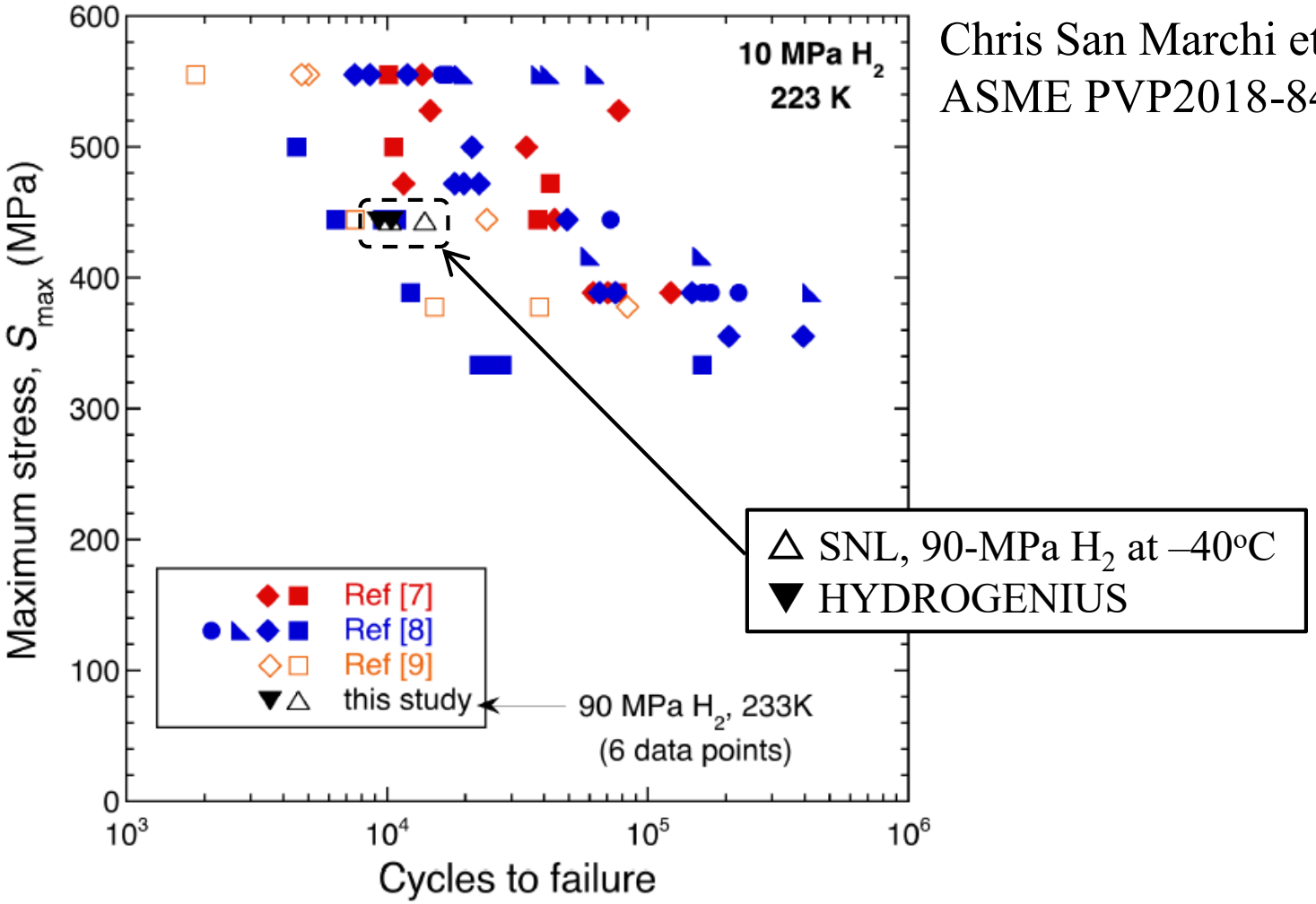
Test data（HYDROGENIUS）

Test environment	Number of cycles to failure [cycles]
	Notch specimen fatigue : σ_a = 200 MPa, R = 0.1, f =1Hz
0.1-MPa N_2 gas at -40°C	2.20×10^4
	2.57×10^4
	2.44×10^4
90-MPa H_2 gas at -40°C	1.03×10^4
	1.04×10^4
	9.25×10^3

Notched specimen fatigue properties (HYDROGENIUS)

- In HYDROGENIS, all the tests (3 tests at each environment) were finished.
- At –40°C, the notch fatigue life was shorter in 90-MPa hydrogen gas than 0.1-MPa nitrogen gas.

Results of notched specimen fatigue test (SNL)

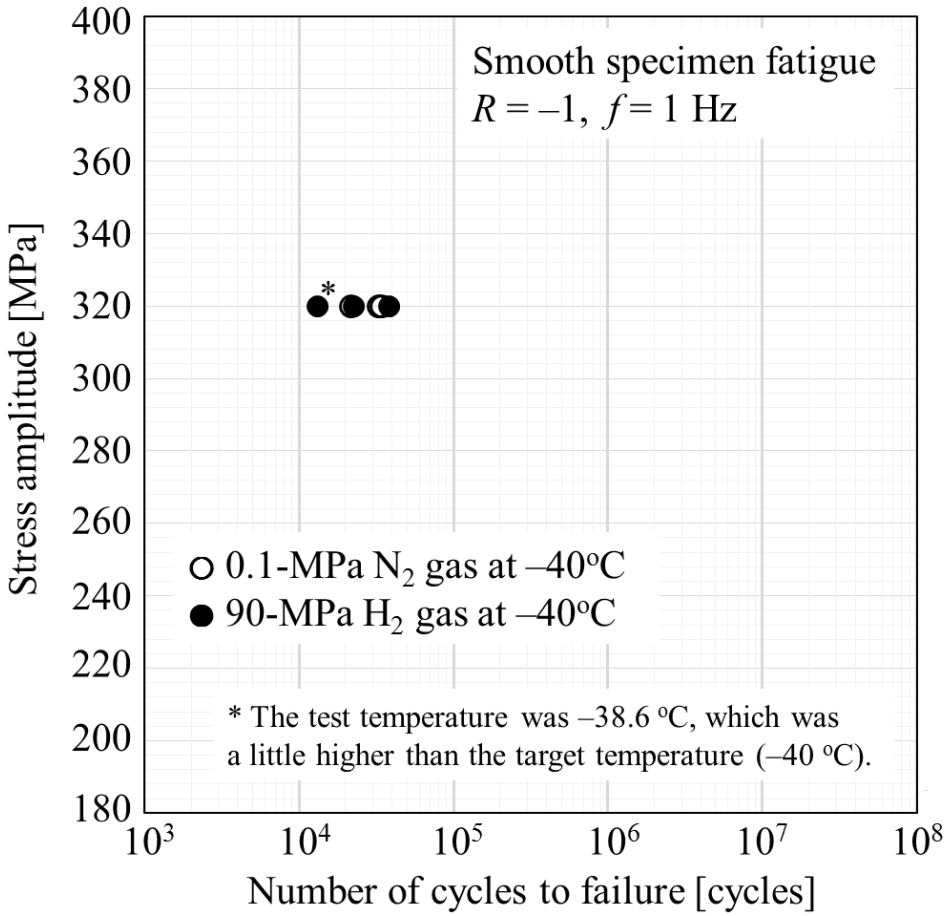


Chris San Marchi et al.,
ASME PVP2018-84898

Notched specimen fatigue properties (SNL and HYDROGENIUS)

- In SNL, 3 tests in 90-MPa hydrogen gas were finished (no reports from MPA).
- The experimental results from SNL and HYDROGENIUS were nicely consistent.

Results of smooth specimen fatigue test (HYDROGENIUS)



Test data (HYDROGENIUS)

Test environment	Number of cycles to failure [cycles]
	Smooth specimen fatigue : σ_a = 320 MPa, R = -1, f =1Hz
0.1-MPa N_2 gas at -40°C	3.29×10^4
	2.17×10^4
	3.41×10^4
90-MPa H_2 gas at -40°C	2.26×10^4
	1.31×10^4 *
	3.83×10^4

Smooth specimen fatigue properties (HYDROEGNIUS)

- In HYDROGENIS, all the tests (3 tests at each environment) were finished.
- There are no reports from SNL and MPA.

Summary of current status of round-robin test

Current status of round-robin test

Institute	Environment	SSRT	Notched specimen fatigue	Smooth specimen fatigue
SNL	H_2	0	3 (finished)	0
	Inert	0	0	0
MPA	H_2	0	0	0
	Inert	0	0	0
KU	H_2	3 (finished)	3 (finished)	3 (finished)
	Inert	3 (finished)	3 (finished)	3 (finished)

Draft plane of round-robin test

- At China and Korea, notched specimen fatigue in H_2 gas (3 specimens) and smooth specimen fatigue in H_2 gas (at maximum, 3 specimens)
- Supply the notched specimen from SNL
- Supply the raw material for the smooth specimen (φ25 × L275mm) from HYDROGENIUS. The specimen geometry of the smooth specimen can be determined at each institute.

Notch fatigue at R = 0.1 at -40°C	0.1-MPa N_2 gas	1Hz, σ_a=200 MPa σ_{max}=444 MPa, σ_{min}= 44 MPa	3
	90-MPa H_2 gas		3
Smooth fatigue at R = -1 at -40°C	0.1-MPa N_2 gas	1Hz, σ_a=320 MPa σ_{max}=320 MPa, σ_{min}= -320 MPa	3
	90-MPa H_2 gas		3

Draft schedule

1. Supply the notched specimen and raw material : April, 2019
2. Finished of fatigue test in H_2 gas : September, 2019

Thank you for your attention