

Progress on HG-SCC test method proposal for aluminum alloys

HG-SCC : **H**umid **G**as **S**tress **C**orrosion **C**racking

Transmitted by Japan

9th Meeting of the informal working group on GTR No.13 (Phase 2)
23,25,26 March 2021

Current status

- Japan has proposed HG-SCC test method based on verification test results **under humid air environment**.
- Japan also conducted the additional reference test **under humid hydrogen environment** which was pointed out at the past IWG meeting.



- ◆ Today's contents
 - ✓ to introduce the test results under humid hydrogen environment.
 - ✓ to clarify the future plan on this proposal.

Summary of HG-SCC test method

■ The test conditions

from the 7th Meeting of IWG, 6-7 November 2019

- Temperature: $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$
- Atmosphere and humidity : 85 % or higher in relative humidity in air
- Test period: 90 days

(in accordance with **B.6.6 of ISO 7866:2012**)

SLC(Sustained Load Cracking) test

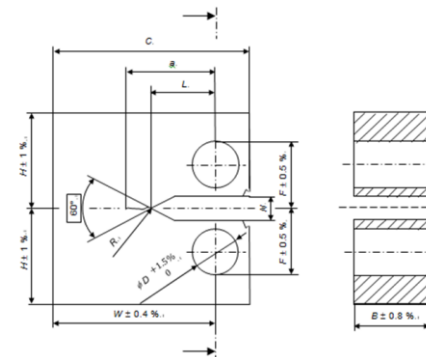
■ How to judge

The crack extension exceeds 0.16 mm or not under applied stress intensity factor value ($K_{IApp} = 0.056 \sigma_{0.2}$)

ref) K_{IApp} : equivalent to $\sigma_{0.2}$ at the tip of a crack of 1mm length

This test method was published as HPIS E 103:2018.

※HPI = High Pressure Institute of Japan



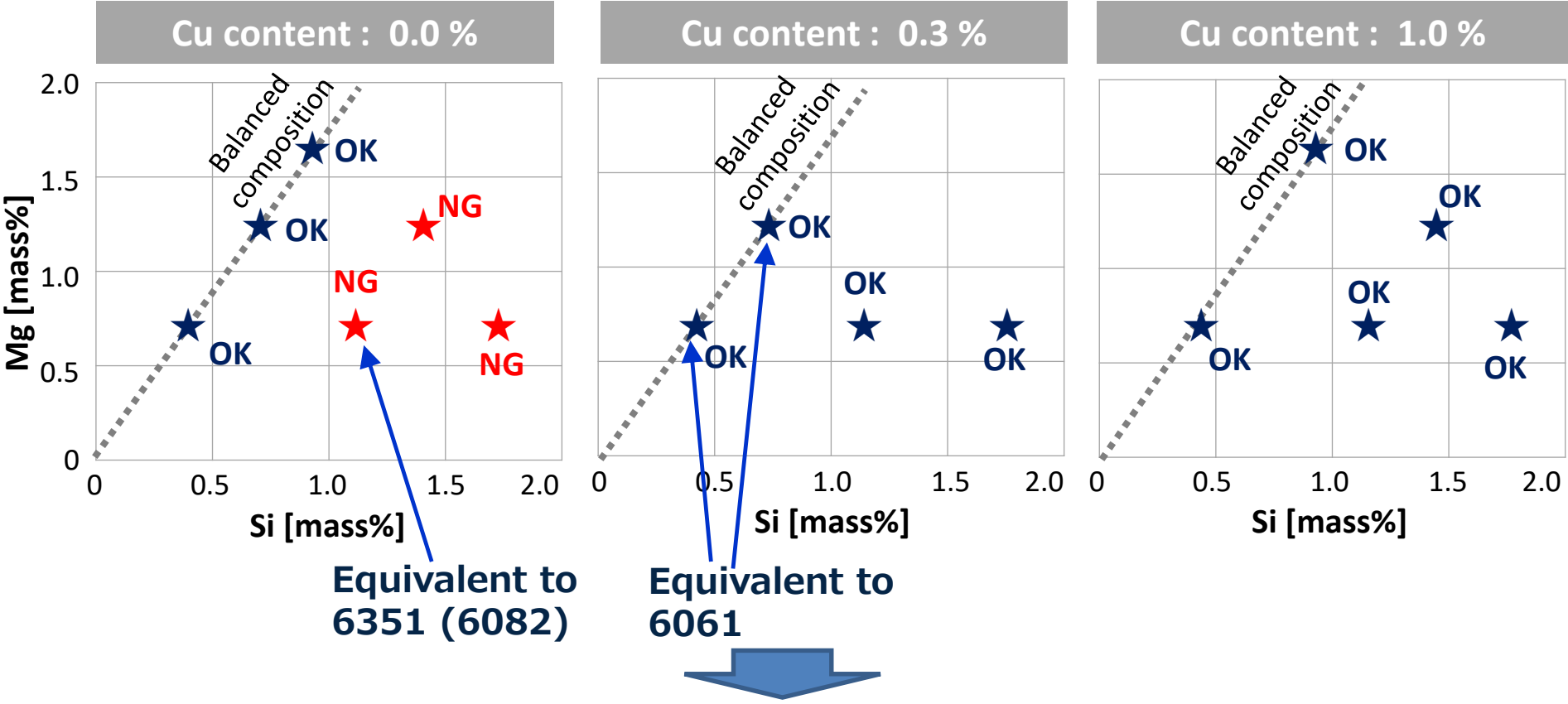
Example of specimen (CT)

Test results under humid air environment

from the 3th Meeting of IWG, 26-28 June 2018

Result of HG-SCC test sorted by main chemical contents (Mg, Si, Cu)

- Test condition : 25°C, RH85 %, 90 days
- Qualification : The crack extension is examined to exceed 0.16 mm or not.

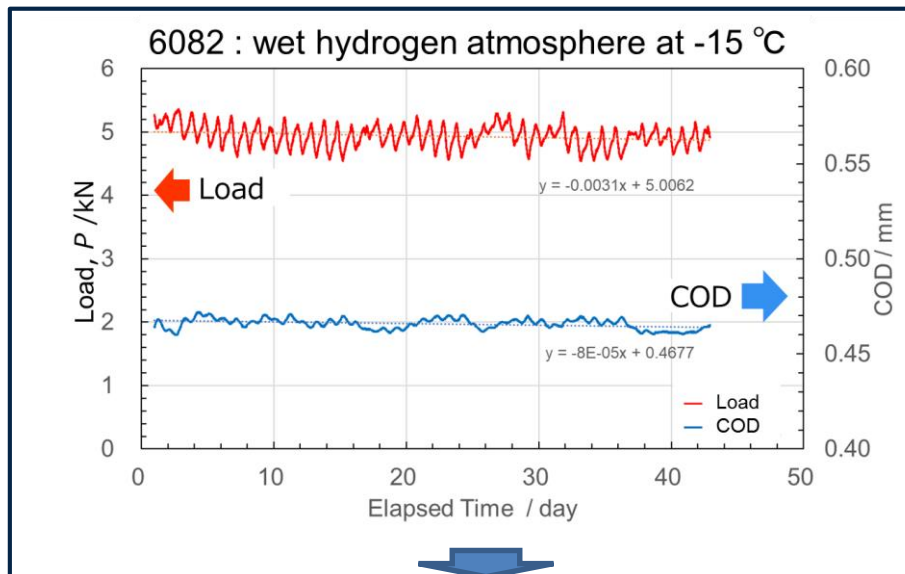


Materials can be evaluated correctly at the safety level
 6061 to be used : positive
 6351 (6082) with market accidents : negative

Test results under humid hydrogen environment

Result of HG-SCC test for 6082 comparing with 6061

- Test condition : Pressure: 10 MPa, Temperature : -15°C
(Target relative humidity : over 90 %)
- Test method : Rising road and constant displacement methods
- Qualification : Load decreasing rate and a crack opening displacement (COD).



- Load decreasing rate showed small amount like 0.003 kN / day.
- COD showed a slight downward tendency.

Ref.) 6061 showed the almost same result.

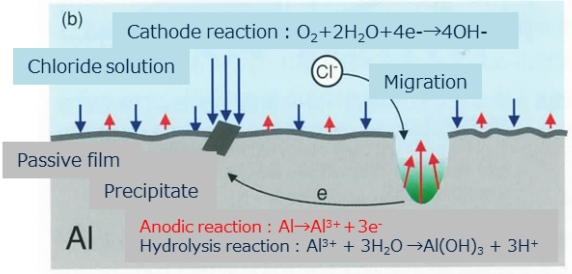
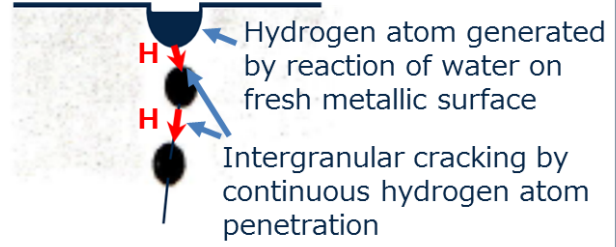


- 6082 did not show remarkable HG-SCC under humid hydrogen environment as well as 6061.
- The setting of test conditions under low temperature humid hydrogen environment is difficult and may have influenced.
- This results should be explored deeply from an academic point of view.

The necessity of HG-SCC test method for aluminum alloys

from the 7th Meeting of IWG, 6-7 November 2019

- There are 2 types of corrosion phenomena in aluminum alloys.
- HG-SCC test method for aluminum alloys is necessary for the evaluation of SCC from both outside and inside of the containers.

SLC : Sustained Load Cracking
SCC : Stress Corrosion Cracking

Type	Anodic dissolution	SCC in humid gas environment
Principle	Electrochemical corrosion by salt water 	SCC by the reaction of metallic Al and H ₂ O 
Reaction	Anodic reaction : $\text{Al} \rightarrow \text{Al}^{3+} + 3\text{e}^-$ Cathode reaction : $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$	$2\text{Al} + 3\text{H}_2\text{O} \rightarrow \text{Al}_2\text{O}_3 + 6\text{H}$
Characteristics	<ul style="list-style-type: none"> Need oxygen and solution Need Cl⁻ (break passive film) Not occur in high pressure H₂ (no oxygen and no solution) <p>⇒ Occur only outside of containers</p> 	<ul style="list-style-type: none"> Occur under the presence of H₂O Crack growth by accumulation of hydrogen atoms at the crack tip (on fresh metallic surface), not by dissolution of metal into ion <p>⇒ Occur both outside and inside of containers</p> 
Evaluation	Current test method applied by each car OEM	※ HG-SCC test method (Improved SLC test) proposed by Japan for GTR13

※ HG-SCC test method is different from H₂ compatibility test method in high pressure hydrogen gas environment.

Summary

- **HG-SCC test method can correctly determine the availability of aluminum alloys for the containers under humid environment (like the distinction between 6061 alloy and 6082 alloy).**
- **6082 alloy did not show remarkable HG-SCC under humid hydrogen environment as well as 6061 alloy. However, more academic research will be needed.**
- **HG-SCC test method is still important as screening test of aluminum alloys under the external humid environment of the containers.**
- **Japan will prepare the requirements (Part 2) and rationale (Part 1) for the GTR documents until the next GTR13 IWG.**
- **Each CP position must be the same as material compatibility test method.**

**Thank you for
your kind attention**