Renewable Energy

Development of Technologies for Predicting the Progression of Hydrogen Tank Failure

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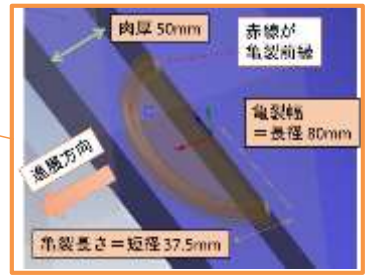
Rapid-fracture evaluation using stress intensity factor K K>K_C

Pressure 105MPa

Tank with cracks on the inside



Normalized crack length (=crack length/wall thickness)

Stress intensity factor K (MPa・$m^{0.5}$)

0.75	0.5	0.25
146	101	71

Fracture toughness value of low alloy steel K_C (MPa・$m^{0.5}$)
in the atmosphere 200-250 in the hydrogen 50-100

Fig 1 Determining the rapid destruction of hydrogen tank

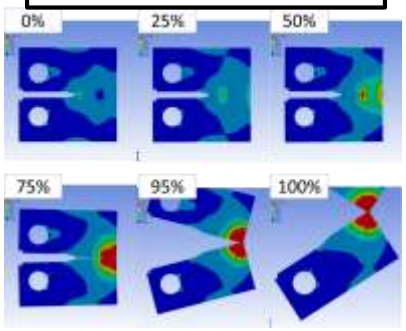
Crack growth analysis by fatigue crack growth test specimens

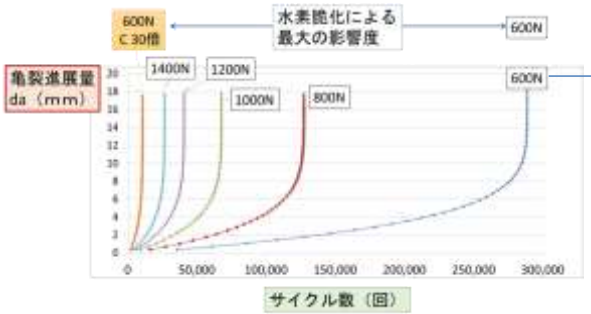
Repeated load cycles

ΔP

Fatigue crack growth test piece

Stress distribution





Load fluctuation ΔP

※Equivalent to pressure fluctuations in tanks

※For tanks, this corresponds to the number of fills.

Fig 2 Crack growth analysis of fatigue crack growth test specimens

Technical Issues to Address

Hydrogen’s “hydrogen embrittlement” property makes metals brittle, limiting the materials that can be used for hydrogen tanks to expensive options. This also requires expensive annual statutory inspections.

In the future, it is expected that regulations will be relaxed to expand the use of hydrogen, allowing the use of cheaper materials, extended inspection intervals, etc. However, there is an urgent need to develop inspection technology that ensures safety.

Research Contents

Hydrogen tanks are subject to "fatigue failure", where small scratches (cracks) on the inside of the tank that are invisible from the outside gradually grow and eventually break.

The first report showcased our development of a technology utilising image processing with a camera to detect cracks on the inner surface from deformation observed on the outer surface.

This year, we have developed computer simulation (CAE) technology using "fracture mechanics", which can accurately assess crack progression, to evaluate the severity of detected cracks.

Summary

We performed a rapid fracture assessment and crack growth analysis that could potentially lead to serious accidents, such as hydrogen leakage. We confirmed the effectiveness and validity of our analysis by comparing it with theoretical formulae and fatigue crack test results. When applied to tank inspections, utilising a graph with the number of cycles (representing the number of fills) on the horizontal axis is considered an effective approach.

We plan to conduct experiments utilising tanks to validate the predictive accuracy of the CAE calculations in the future.

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