原子力学会水化学部会の定例会
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423および453Kの高温純水中における鋭敏化ステンレス鋼のSCC感受性に及ぼす過酸化水素の影響

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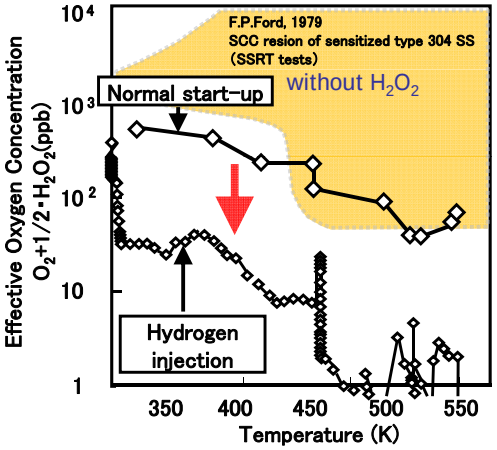
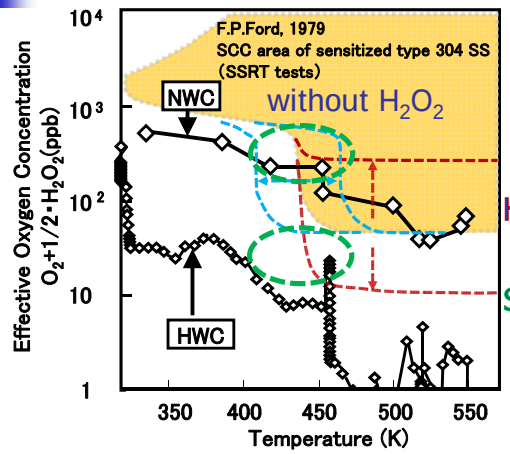
Introduction

- At plant start-up in BWR hydrogen peroxide and oxide concentration increase and dynamic distortions occur
  ↓
- Severe condition for structural materials
  ↓
- Hydrogen injection during start-up



Introduction



H_2O_2 changes border ?

SCC susceptibility at 423K and 453 K with H_2O_2 ?

Purpose and Exeriments

Purpose

- Effect of hydrogen peroxide on SCC susceptibility
- Effect of hydrogen peroxide on oxide film

Experiments

- SSRT tests of sensitized type 304 SS
- TEM observation, Laser Raman spectrometry of oxide film

Experiment

Material

	C	Si	Mn	P	S	Ni	Cr	Fe
Type 304 SS	0.050	0.62	1.00	0.027	0.005	8.16	18.25	Bal.

Sensitization; 893 K × 24hr, air cooled

Surface; #600 polished

Tests

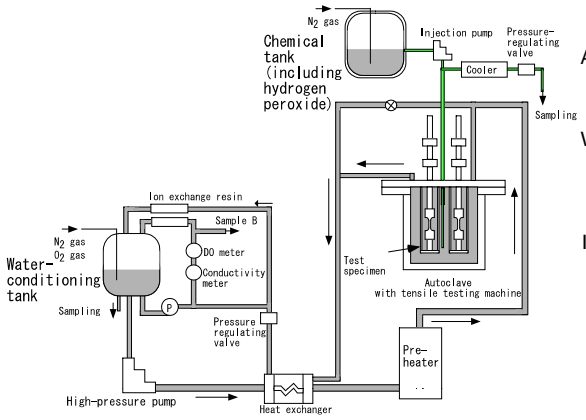
SCC tests	**SSRT (plate; gauge 20mm(l) × 5mm(w) × 2mm(t))**
Strain rate	**4.2 x 10^{-7} /sec**

Experiment

Water condition

Temp. (K)	EOC (ppb)	DO, at 293 K (ppb)	H_2O_2 at 293 K (ppb)	Nuber of specimens
453	400	400	0	4
		25	750	4
	45	45	0	4
		5	80	4
	27	10	33	4
	20	8	24	4
423	400	50	700	4
	47	10	74	4

Test loop

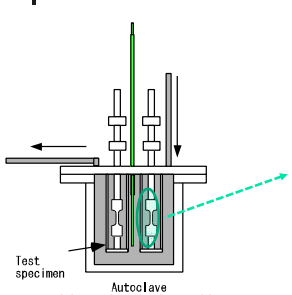


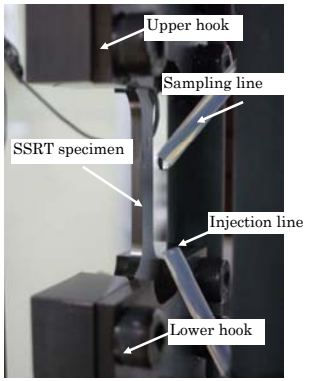
Autoclave
to tensile specimens

Water circulating system
to control oxygen concentration in water conditioning tank

Injection/sampling system
to inject H_2O_2 and to sample water close to SSRT specimen through Teflon lining pipe.
to control H_2O_2 concentration in the vicinity of SSRT test specimens by changing H_2O_2 concentration in chemical tank and injection flow rate.

Overview of specimen setting

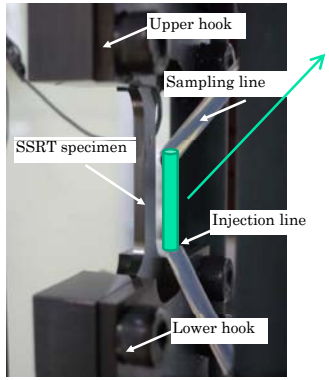




H_2O_2 was injected from the bottom of SSRT specimen

H_2O_2 was sampled from the middle of SSRT specimen

Decomposition in sampling and injection line



Directly connecting injection line to sampling line, 99.5% of H_2O_2 concentration in chemical tank was detected in sampled water at 453 K.

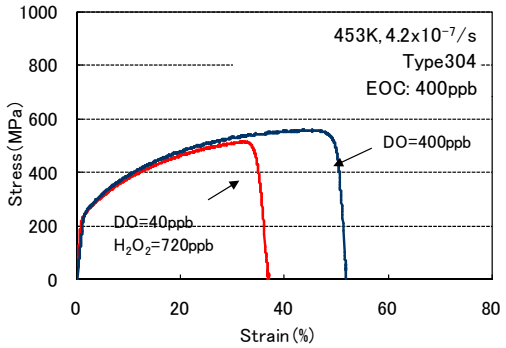
Decomposition of H_2O_2 in injection and sampling line was very low.

During SSRT testing, 85% of H_2O_2 in sampling line at 293 K were detected in sampled water at 453 K.

720~765 ppb H_2O_2 at 293 K

⇒ 615~657 ppb H_2O_2 at 453 K

Results of SSRT tests, EOC=400ppb



Specimens tested under H_2O_2 injection condition were decreased in elongation.

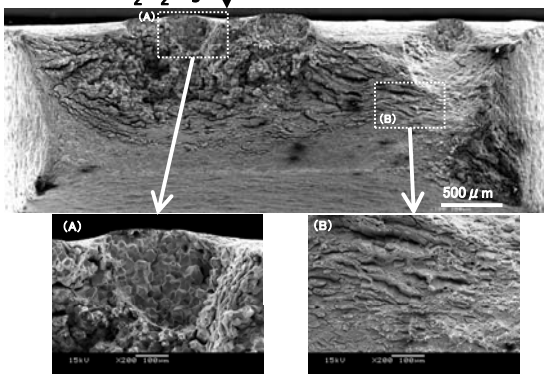
Tensile properties

EOC (ppb)	H_2O_2 (453 K) (ppb)	H_2O_2 (453 K) (ppb)	0.2 % proof stress (MPa)	Tensile strength (MPa)	Elongation (%)	Reduction of area (%)
400	0	0	248	580	50	63
			231	546	55	68
			237	560	52	71
			228	571	53	70
400	720	617	227	516	37	51
	764	657	228	395	16	26
	736	563	225	412	17	15
	748	642	226	466	27	48

H_2O_2 injection reduced TS, EL and R.A.

Appearance of fracture surface after SSRT test.

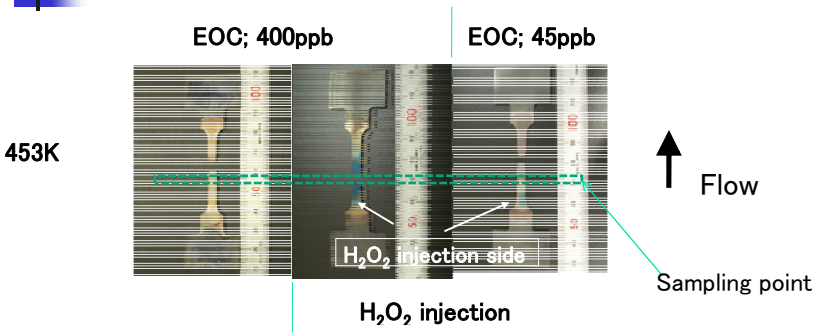
H_2O_2 injection side



453K, EOC; 400ppb, H_2O_2 injection

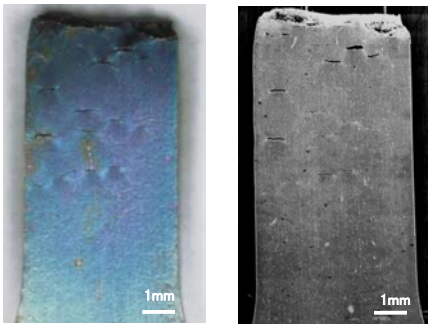
IGSCC fractures were observed.

Appearance of specimens after SSRT tests



H_2O_2 injection
↓
Changed the color of oxide film.

Appearance of specimens after SSRT tests



Optical microscopy SEM image

453K, EOC; 400ppb, H_2O_2 injection

Many SCC cracks were observed on H_2O_2 injection side.
And counted number of SCC crack

Rate of SCC on fracture surface
Number of cracks on the surface

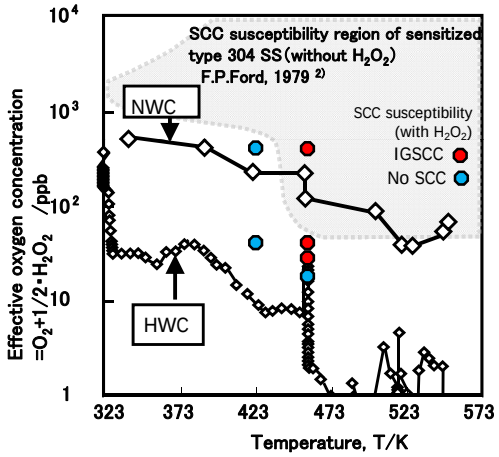
EOC (ppb)	H_2O_2(RT) (ppb)	H_2O_2(453K) (ppb)	SCC	Rate of SCC (%)	Number of SCC	
					H_2O_2 side	Another side
400	0	0	No	0	0	0
			Observed	3.9	0	0
			No	0	0	0
			No	0	0	0
400	720	617	Observed	22.7	39	0
	764	657	Observed	63.7	32	0
	736	563	Observed	67.4	47	0
	748	642	Observed	41.1	6	0

SCC cracks were observed on only H_2O_2 injection side

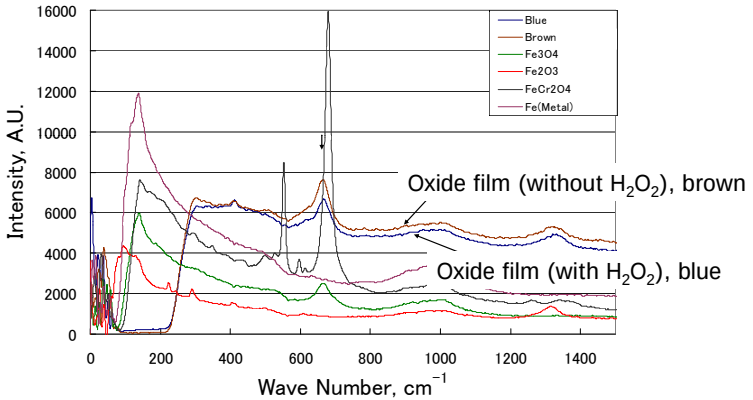
SSRT test results

Temperature (K)	EOC (ppb)	H_2O_2 injection	SCC occurance / specimens */4
453	400	No	1/4
		Yes	4/4
	45	No	0/4
		Yes	1/4
	27	Yes	2/4
	20	Yes	0/4
423	400	Yes	0/4
	47	Yes	0/4

SSRT test results



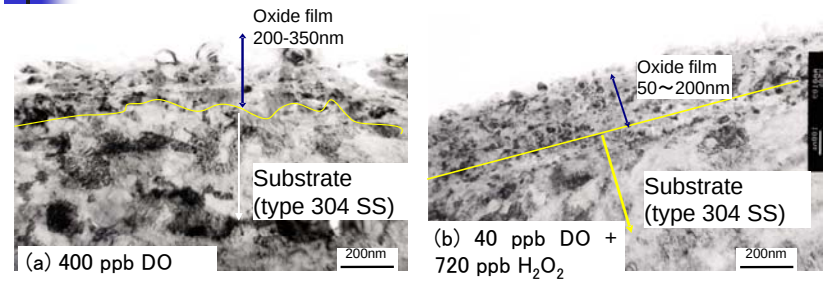
Laser Raman spectrometry



Oxide films are mainly consisted of Fe_3O_4 (Magnetite)

No difference between oxide films tested under water condition with or without H_2O_2

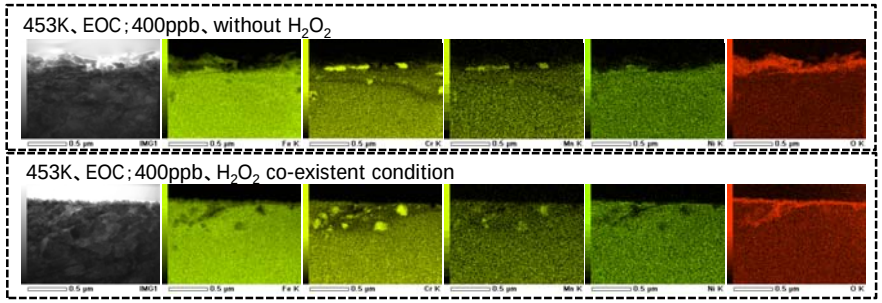
TEM observation



TEM micrographs of cross sections of sensitized type 304 SS tested under the conditions of 400 ppb EOC without H_2O_2 (a) and with H_2O_2 (b) at 453 K.

H_2O_2 injection makes planar surfaces of oxide film.

TEM observation



H_2O_2 injection thins oxide film thickness.

Conclusion

- The addition of H_2O_2 increases the SCC susceptibility of sensitized type 304 SS at 453 K.
- SCC susceptibility was not observed under 400 ppb EOC condition with and without H_2O_2 at 423 K.
- The addition of H_2O_2 changes the surface shape of oxide film in sensitized type 304 SS, from wavy to planar and thins oxide film thickness.

Thanks for your attention !