

Turbine Blade

A Study on the Corrosion and Corrosion Fatigue Characteristics of Turbine Blade in Power Plant

* • * • ** • **

* 150

** 300

12Cr , 60 , 90 2.0, 3.5, 5.0wt.%

NaCl 0.01, 0.1, 1M Na₂SO₄ 가 ,

3.5wt.% NaCl 1M Na₂SO₄ 가 가 .

가 가 가 . 가

3.5wt.% NaCl , 1M Na₂SO₄ ,

. , 3.5wt% NaCl 1M Na₂SO₄

가 , 가

가 . , 3.5wt% NaCl 1M Na₂SO₄ 가

가 가 가 가 가

. , 가 가 ,

가 .

Abstract

Corrosion characteristics on the 12Cr alloy steel of turbine blade was investigated in 2.0, 3.5, 5.0wt% NaCl and 0.01, 0.1, 1M Na₂SO₄ solution by electro-chemical polarization test. Among the conditions, corrosion rates were the fastest at 3.5wt% NaCl and 1M Na₂SO₄ solution. Also, as the temperature was increased, corrosion rates were faster. To evaluate corrosion fatigue characteristics, test solutions were used in 3.5wt.% NaCl solution, 1M Na₂SO₄ solution and distilled water. Test temperature was identified

with the case of polarization test. Crack growth characteristics at the all conditions were not distinguished under room temperature. But, as the temperature was increased, crack growth rates were faster than the non-degraded case. The reason was changed crack growth mechanism by increasing the activity of corrosive factors. Generally, fracture surfaces were showed trans-granular pattern at the beginning, and room temperature. As the temperature was increased and crack was propagated, fracture surfaces were showed inter-granular pattern.

1.

(Turbine blade), 64%가
 (low pressure stage) (vapor) (fatigue) 가 .
 , 가 (1) 가 .
 , 가 ,
 가 .^[1]
 12-13 %Cr 가 ,
 , 가 .
 , (condenser), (deminerlizer system),
 , mist ,
 , (chloride),
 (sulfide) , (electro-chemical
 reaction) (pit)가 .
 가 ,
 (stress concentration) (fatigue crack) ,
 (fracture
 mechanism) , 가
 ,
 12Cr 가 ,
 가 ,
 가

2. 12Cr 가

2.1

가 (E_{corr}) , (i_{corr}) , (i_p) , (E_{pp}) , (i_c) , (E_B) 가
 , ASTM G5 (Making potentiostatic and potentiodynamic anodic polarization measurement) .^[2] (corrosion rate) Faraday
 (1) .

$$\text{Corrosion rate} = \frac{0.13 \times i_{corr} (\text{mA/cm}^2) \times \text{E.W}}{\text{density}(\text{g/cm}^3)} \quad (1)$$

$$\text{E.W. (equivalent weight)} = \sum f_i M_i / n_i$$

f_i : , M_i : , n_i : 가

(1) , (corrosive current density) 가 , Tafel
 .^[3] Tafel . Tafel
 - Tafel
 (i_{corr})가 .

12Cr , Table 1 .

Table 1 Chemical composition and mechanical properties of 12Cr alloy steel. (wt.%)

Element	C	Si	Mn	P	S	Ni	Cr	Mo	Cu
Content(%)	0.16	0.34	0.46	0.016	0.003	0.18	11.9	0.09	0.06
Yield strength (MPa)			Ultimate tensile strength (MPa)			Elongation (%)			
989.4			1205			13			

Fig. 1 $10 \times 10 \times 10 \text{ mm}$, Struers (epoxy)
 (mounting) , Ameron Amercoat 90
 (painting) 24 , 600-grit SiC
 paper , Schlumberger Potentiostat (SI 1286) .
 (corrosion cell) Fig. 2 .
 (working electrode) (counter electrode) 2
 (reference electrode) (calomel electrode)
 .
 (cotton) 가 , .

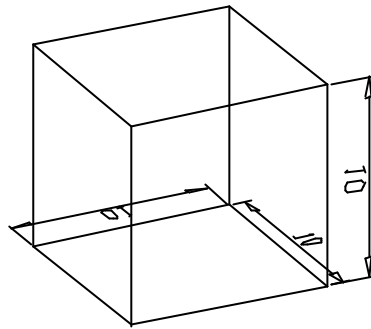
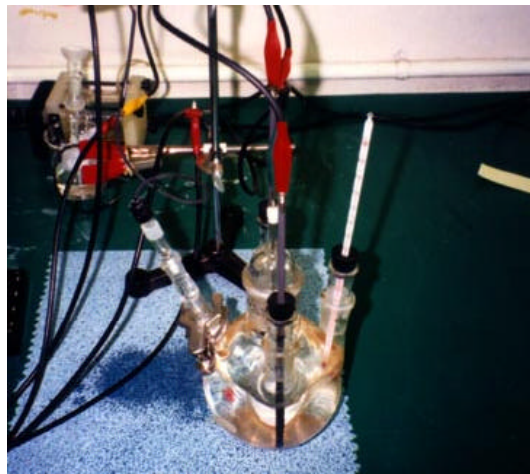
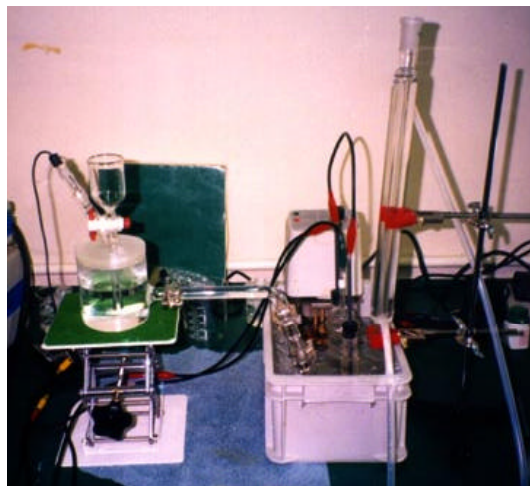


Fig. 1 Configuration of specimen for polarization test



(a) Corrosion cell for polarization test at ambient temperature



(b) Corrosion cell for polarization test at high temperature

Fig. 2 Corrosion cell for polarization test.

(open circuit potential) 15
 (potentio-dynamic polarization) (scan rate) 0.166 mV/s
 가
 가 가
 가
 NaCl
 2.0wt.%, 3.5wt.%, 5.0wt.%, Na₂SO₄ 0.14wt.%(0.01M),
 1.4wt.%(0.1M), 12.7wt.%(1M)
 가 25, 60, 90

2.2

1) NaCl

Fig. 3 NaCl (25, 60, 90) (2.0wt.%, 3.5wt.%, 5.0wt.%)

, Tafel NaCl
 Table 2 NaCl 가
 3.5wt% 가 가 가 가

Table 2 Electro-chemical corrosion characteristics in NaCl solutions by potentiodynamic polarization test.

	NaCl solution (wt.%)								
	25			60			90		
	2	3.5	5	2	3.5	5	2	3.5	5
Corrsion Rate (mpy)	0.017	0.059	0.047	0.450	2.949	2.856	15.575	29.67	27.12
E _{corr} (mV vs. SCE)	-64	-182.5	-184.6	-215.2	-292.6	-287.2	-188.1	-232.2	-272.0

12Cr

, 0.18wt.% Ni

P Cu 가

[4] , , 가 , 가 (dissolved oxygen) , (Cl⁻ ion) 가 가 , 3.5wt% NaCl , NaCl 가 3.5wt% 가 [5] 3.5wt% NaCl 가 가 가 가 [6]

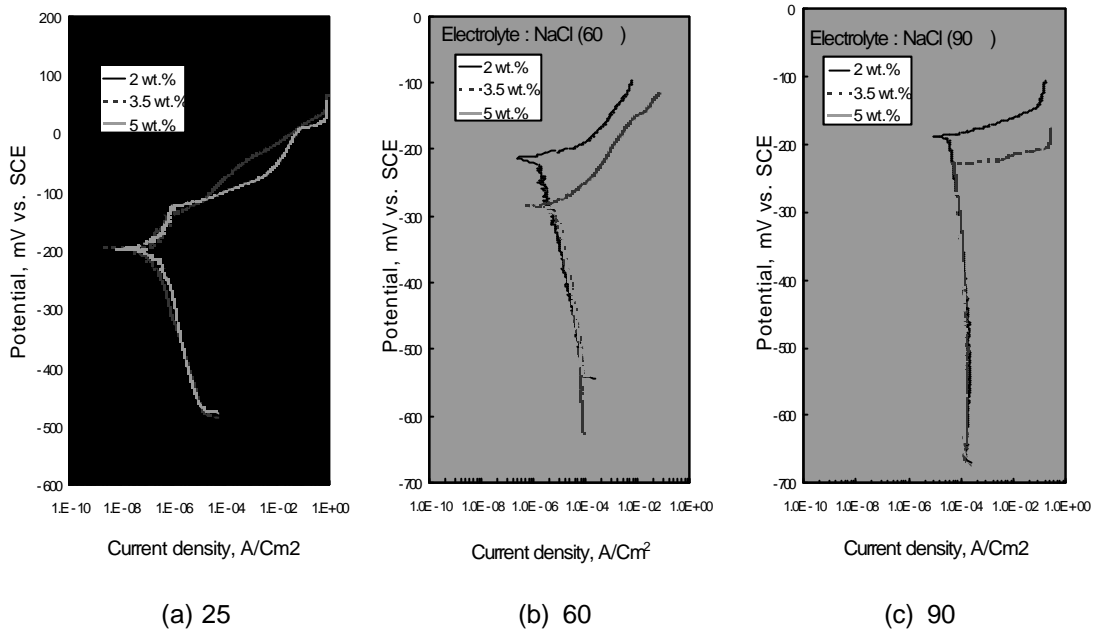


Fig. 3 Potentiodynamic polarization curves in NaCl solution.

2) Na₂SO₄ . Fig. 4 Na₂SO₄ (25 , 60 , 90) (0.14wt.% (0.01M), 1.4wt.% (0.1M), 12.7wt.% (1M)) . Tafel Table 3 , Na₂SO₄ 가 가 , NaCl , 12Cr 가 가 , 가 가

가 가 , 가 , 가
 , 가 가
 , Na₂SO₄ NaCl (oxygen, O²⁻)
 ,
 [5],[6]

Table 3 Electrochemical corrosion characteristics in Na₂SO₄ solutions by potentiodynamic polarization test

	Na ₂ SO ₄ solution (wt.%)								
	25			60			90		
	0.14	1.4	12.7	0.14	1.4	12.7	0.14	1.4	12.7
Corrsion Rate (mpy)	0.008	0.012	0.056	0.057	0.082	0.118	0.173	0.193	0.393
E _{corr} (mV vs. SCE)	-168.5	-149.8	-246.7	-116.8	-117.7	-180.0	-65.7	-33.4	-55.2

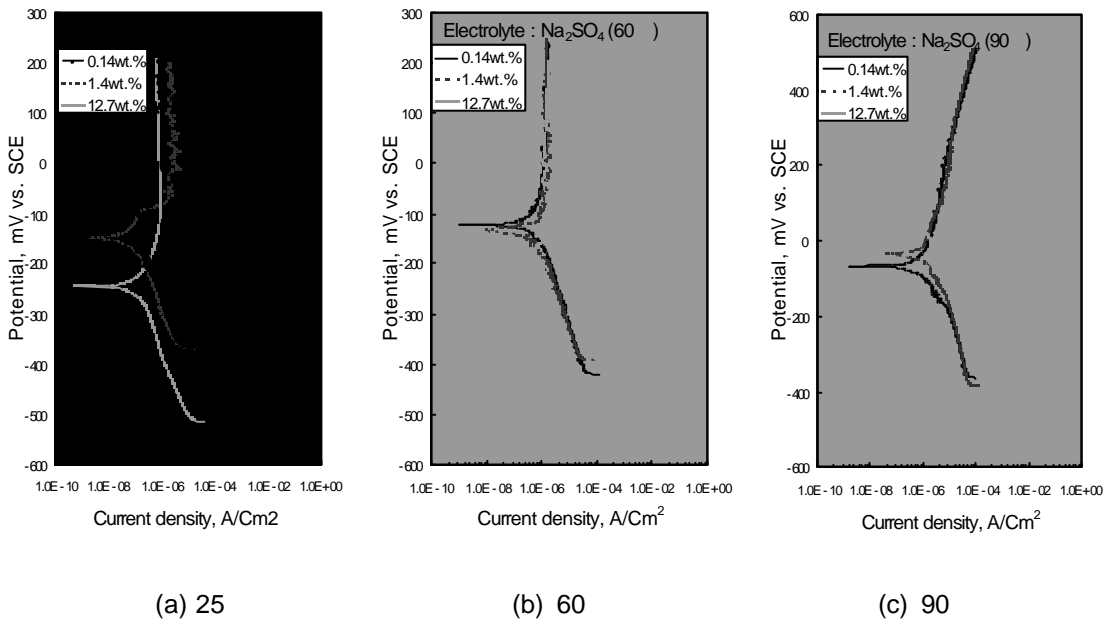


Fig. 4 Potentiodynamic polarization curves in Na₂SO₄ solution.

3.

12Cr

가

, 12Cr

가

12Cr

가

Table 4

ASTM E647^[7]

3.1

(horizontal type)

Fig. 5

(2)

(calibration curve)

(DCPD)

(DC power regulator)

Hicks Pickard^[8]가

Table 4 Test methods and environments for evaluating corrosion fatigue characteristics.

Corrosion Fatigue Test ()	Air		distilled water		3.5wt.% NaCl solution			1M Na ₂ SO ₄ solution		
	25	25	60	90	25	60	90	25	60	90

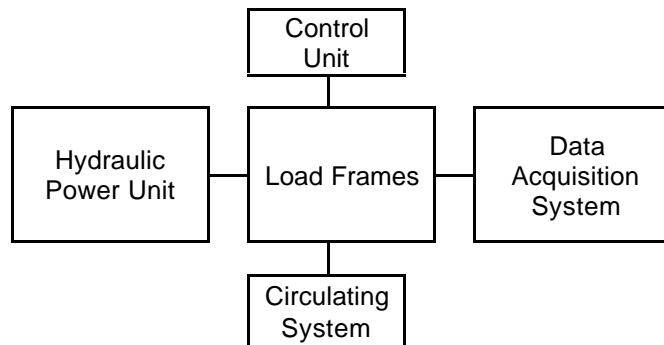


Fig. 5 Schematic diagram of horizontal corrosion fatigue tester.

$$\left(\frac{a}{W}\right) = -0.273\left(\frac{V}{V_r}\right)^3 + 1.194\left(\frac{V}{V_r}\right)^2 - 1.2115\left(\frac{V}{V_r}\right) + 0.575 \quad (2)$$

a: Crack length(mm), W: Width(mm), V: Measuring voltage(V), Vr: Reference Voltage(V)

3.2

Fig. 6 가 , 3.5wt.% NaCl
 12.7wt.%(1M) Na₂SO₄ 가 12Cr
 , Table 5 Pari's law
 C m .
 12Cr , .
 a) , Fig. 6 ,
 , 가 DK
 가 가 . 가
 , 가 가 (crack growth
 mechanism) 가 , 가 Fig. 7(a)
 (trans-granular type) , Fig. 7(b) (90)
 , 가 (inter-granular type)가
 + + (dimple) 가
 가 .
 b) 3.5 wt.% NaCl
 DK 가 가 . 가
 , 가 Fig. 7(c) , DK 가 가
 가 + 가 a/W=0.7 가
 , 가 가
 가 가 .
 c) 12.7wt%(1M) Na₂SO₄
 , 가 가
 . , Fig. 7(d) 3.5wt.% NaCl
 . DK + +
 , DK 가 가 가 +
 가 DK
 , 60 90 가

(Cl, SO₄²⁻)

, 가 , DK 가 가
가

Table 5 Experimental estimation of **C, m**.

	Air	distilled water			NaCl solution			Na ₂ SO ₄ solution		
		25	60	90	25	60	90	25	60	90
C	8E-8	1E-8	3E-8	1E-9	2E-9	1E-8	1E-8	7E-8	1E-8	3E-10
M	2.28	2.93	3.55	4.09	3.16	3.28	4.29	3.08	3.16	4.36

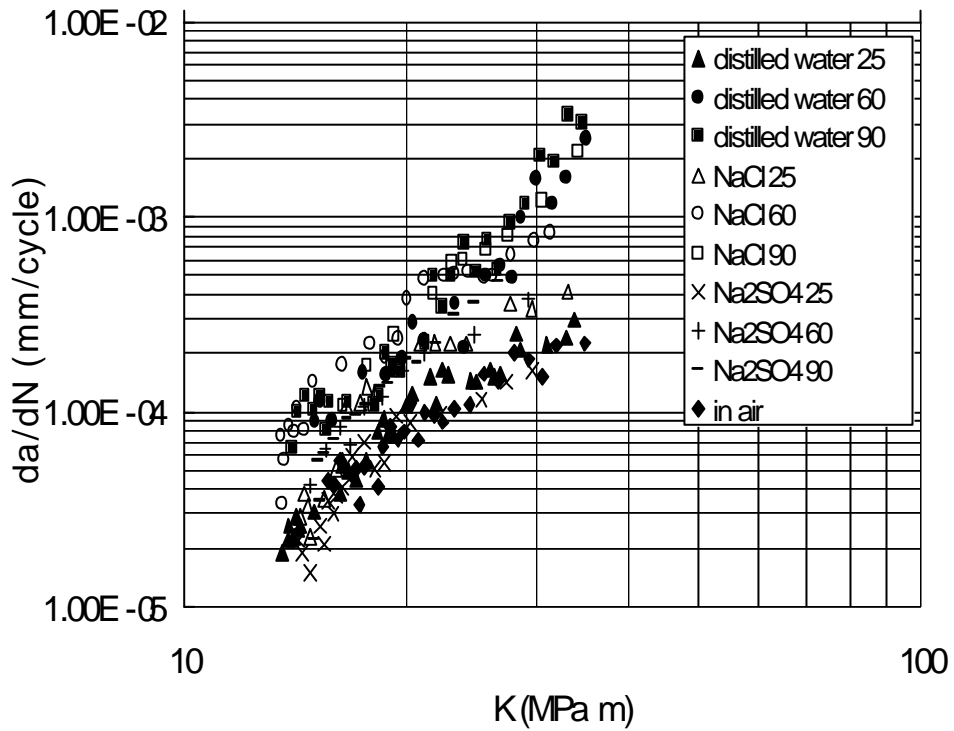
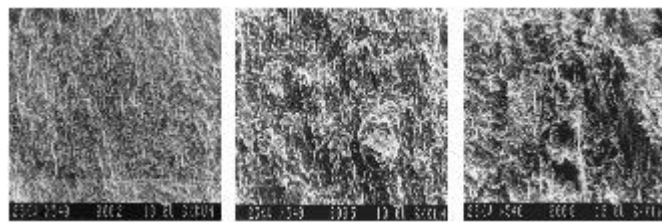
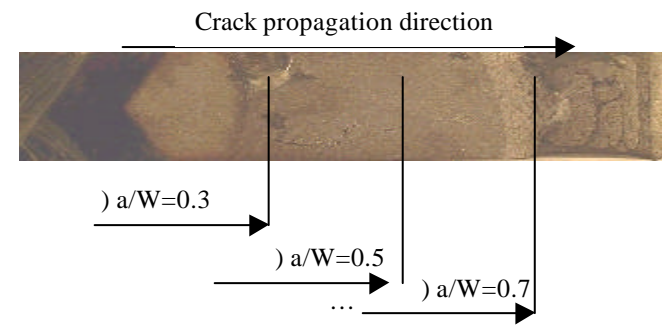
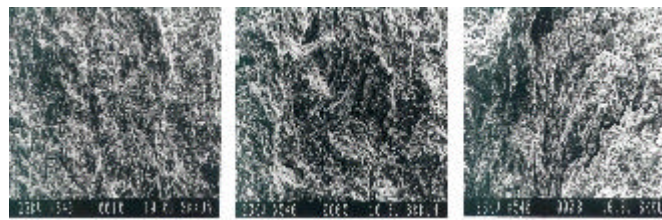


Fig. 6 Relations between da/dN and DK



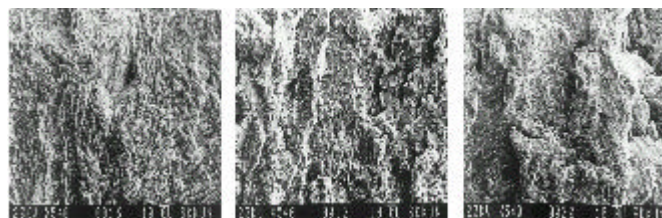
() $a/W=0.3$ () $a/W=0.5$ () $a/W=0.7$

(a) In air



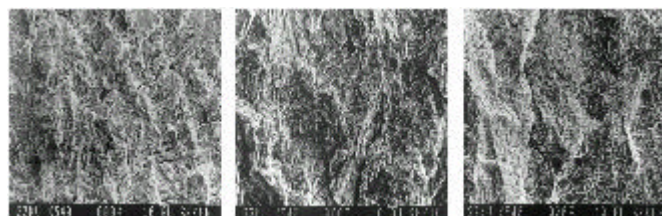
() $a/W=0.3$ () $a/W=0.5$ () $a/W=0.7$

(b) Distilled water at 90



() $a/W=0.3$ () $a/W=0.5$ () $a/W=0.7$

(c) 3.5wt.% NaCl solution at 90



() $a/W=0.3$ () $a/W=0.5$ () $a/W=0.7$

(d) Na_2SO_4 solution at 90

Fig. 7 Fractographs of fracture surface.

5.

12Cr
가 ,
가
(1) 가 12Cr 가
, 3.5wt.% NaCl 12.7wt.%(1M) Na₂SO₄ 가 ,
가 가 ,
(2) , 3.5wt% NaCl 12.7wt% Na₂SO₄
가 , 가
가 .
(3) , 3.5wt% NaCl 12.7wt% Na₂SO₄ 가 가
가 가 가 가
, 가 가 ,
가 .

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