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Fatigue Crack Growth Tests for Mod.9Cr-1Mo Steel at High Temperature Conditions

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1. Introduction

Mod.9Cr-1Mo steel (G91) is the currently favored structural material for several high temperature components of a Sodium-cooled Fast Reactor[1] and it became a registered material for ASME Section III, Subsection NH[2] in 2004. The creep-fatigue crack initiation and growth tests for a G91 tubular specimen including a machined defect have been performed by Kim[3]. The fatigue crack growth tests a G91 compact tension (CT) specimen have been performed in this study.

2. Test Procedures

Fatigue crack growth tests have been performed using the 1/2” CT specimen shown in Fig.1 by satisfying ASTM E647 standard[4] and the chemical composition of the Mod.9Cr-1Mo steel is shown in Table 1. The fatigue crack growth rates from a near threshold to a K_{max} controlled instability were determined. Chevron notch was prepared by an electric discharge machining and a 3mm precracking was made according to the E647 standard.

DCPD (Direct Current Potential Drop) method was utilized to measure the crack growth size as shown in Fig.2 and the appropriate calibration curve was obtained. Calculated error, obtained by applying the ASTM E1457 procedure[5], is 1% which is much smaller than the allowable tolerance value of 15%. The relationship between the voltage output and the crack growth is shown in Fig.3.

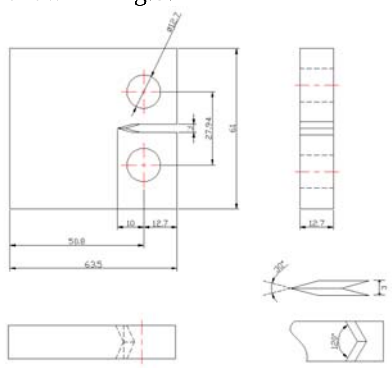

Fig. 1 CT specimen for the fatigue crack growth test

The load ratio of 0.3 was applied and three temperature values (500℃, 550℃, and 600℃) were applied. Two specimens were tested for each condition. Maximum loading of 600kg_f was applied sinusoidally at a frequency of 20Hz.

Table 1. Chemical composition of the G91 steel (wt.%)

C	Si	Mn	S	P	Cr	Mo	V	Nb	Al	Ni	N
0.1	0.41	0.4	0.001	0.013	8.49	0.94	0.21	0.08	0.01	0.1	0.06

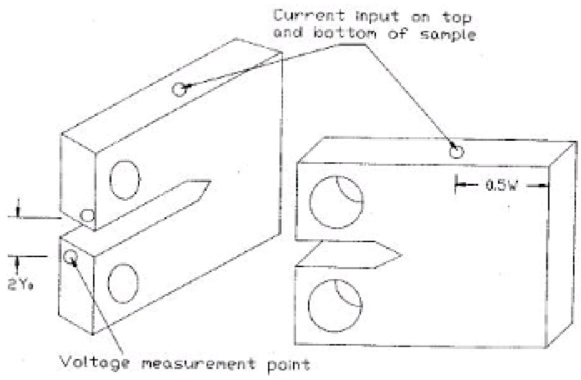

Fig. 2 Input Current and Voltage Lead Locations

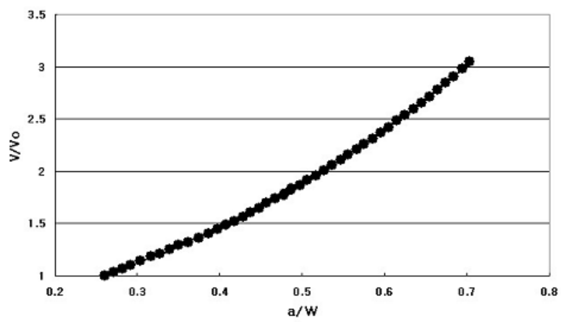

Fig.3 V/Vo-a/W calibration curve

Fatigue crack growth is often expressed as the Paris Law as shown in Eq. (1) and this can describe the linear growth region as well. The da/dN-$\triangle K$ relationships obtained from the tests for the temperature values of 500℃, 550℃, and 600℃ are shown in Fig.4 for the load ratios of 0.3.

$$da/dN = C\left(\Delta K\right)^m \qquad (1)$$

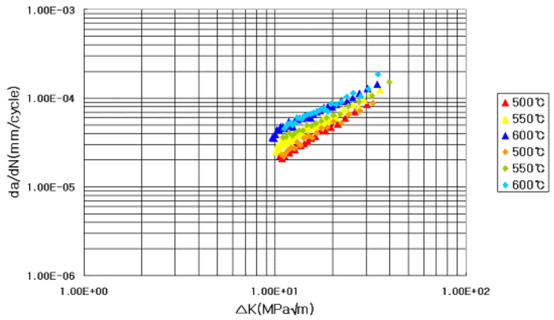

Fig 4. da/dN-$\triangle K$ for the load ratio of 0.3

The parameters C and m in the Paris Law equation are determined as shown in Table 2.

Table 2. Fatigue crack growth rate equations

Temperature (℃)	$da/dN = C\Delta K^m$
500	$da/dN = 1\times10^{-6}\Delta K^{1.31}$
	$da/dN = 1\times10^{-6}\Delta K^{1.22}$
550	$da/dN = 2\times10^{-6}\Delta K^{1.13}$
	$da/dN = 3\times10^{-6}\Delta K^{1.06}$
600	$da/dN = 5\times10^{-6}\Delta K^{0.96}$
	$da/dN = 4\times10^{-6}\Delta K^{1.02}$

3. Test Results and Discussions

The fatigue crack growth tests for a G91 compact tension (CT) specimen were performed for a load ratio of 0.3 at high temperature conditions of 500℃, 550℃, and 600℃, respectively. Two specimens were tested for each condition and their results were shown in Fig. 4. As temperature increases, the fatigue crack growth rate increases and the corresponding Paris equations were determined as shown in Table 2. Currently, more tests are in progress with applying sinusoidal loading at slow frequencies between 0.1 and 1Hz. These test results would contribute to the development of a high temperature leak before break assessment for a Mod.9Cr-1Mo steel pipe in a SFR.

Acknowledgement

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