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High Temperature Fatigue Crack Growth Tests for Mod.9Cr-1Mo Compact Tension Specimen at 20 Hz Loading Frequency

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1. Introduction

Mod.9Cr-1Mo steel (G91) is currently the 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. It was chosen as a candidate material as IHTS piping and heat exchangers for a KALIMER-600[3]. While ASME Subsection NH provides some material properties of Mod.9Cr-1Mo steel for a design purpose at high temperature conditions, there is lack of material properties such as fatigue crack growth and creep crack growth especially for robust structural integrity evaluations.

The creep-fatigue crack initiation and growth tests for a G91 tubular specimen including a machined defect have been performed by Kim[4] and it was attempted to assess a high temperature crack behavior of Mod.9Cr-1Mo side plate specimen by Lee[5]. The fatigue crack growth tests for Mod.9Cr-1Mo compact tension (CT) specimen were performed by Kim[6] at some test conditions and further tests have been conducted at different test conditions in this study.

2. Fatigue Crack Growth Tests

Fatigue crack growth tests have been performed using the 1/2" CT specimen shown in Fig. 1 by satisfying ASTM E647 standard[7] 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 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 by applying the ASTM E1457 procedure[8]. The relationship between the voltage output and the crack growth is shown in Fig. 3.

In a previous study[6], fatigue crack growth tests were performed at three temperature values of 500℃, 550℃, and 600℃, respectively, by applying the load ratio of 0.3 and the resultant crack growth speeds were shown as a function of ΔK in Fig. 4. Two specimens were tested for each condition. The maximum loading of 600kg_f was applied sinusoidally at a frequency of 20Hz.

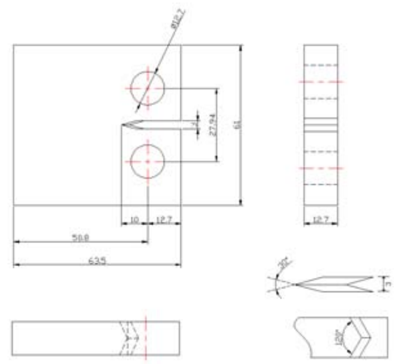

Fig. 1 CT specimen for the fatigue crack growth test

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

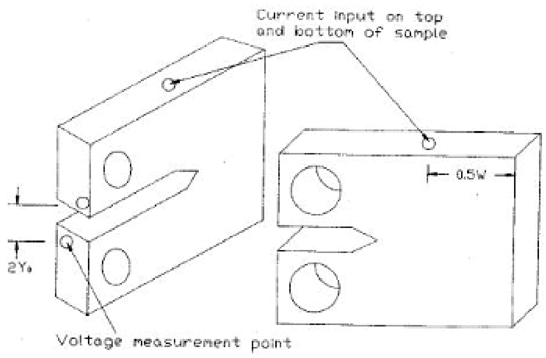

Fig. 2 Input current and voltage lead locations

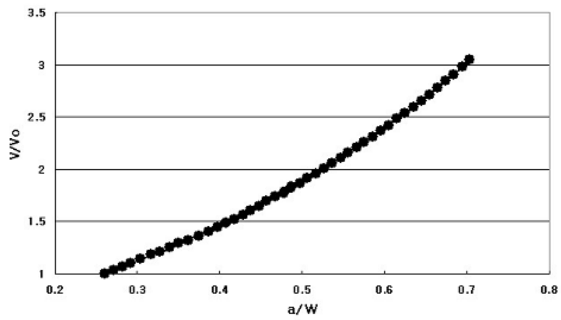

Fig. 3 V/Vo-a/W calibration curve

In this study, fatigue crack growth tests have been performed at three temperature values of 500℃, 550℃, and 600℃, respectively, by applying the load ratio of 0.1 and the test results were shown Fig. 5. Two specimens were tests for each condition.

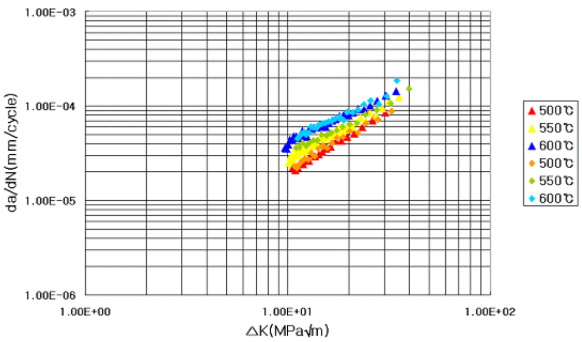

Fig. 4 da/dN-△*K* for the load ratio of 0.3

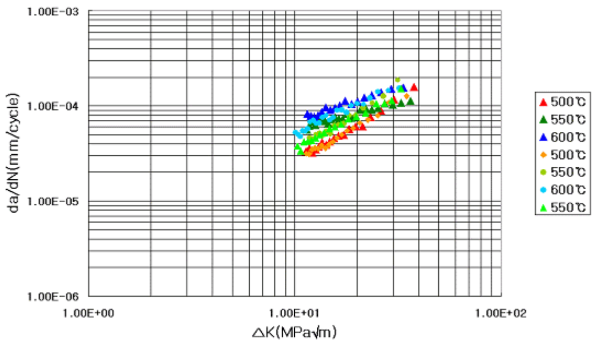

Fig. 5 da/dN-△*K* for the load ratio of 0.1

Fatigue crack growth is often expressed as the Paris Law as shown in Eq. (1) and this can also describe the linear growth region. The crack growth speed (da/dN) as a function of △*K* obtained from the test results shown in Fig. 4 and Fig. 5 can be expressed as Eq.(1) and corresponding parameters *C* and *m* in the Paris Law equation are determined as shown in Table 2.

$$da/dN = C(\Delta K)^m \quad (1)$$

Table 2. Comparison of fatigue crack growth rate equations for different load ratios of 0.1 and 0.3

Materials	Stress Ratio (R)	Temperature (℃)	$da/dN = C\Delta K^m$
G91	0.1	500	$da/dN = 1\times10^{-6}\Delta K^{1.3068}$ $da/dN = 1\times10^{-6}\Delta K^{1.2812}$
		550	$da/dN = 1\times10^{-6}\Delta K^{1.3861}$ $da/dN = 3\times10^{-6}\Delta K^{1.1267}$
		600	$da/dN = 1\times10^{-5}\Delta K^{0.7175}$ $da/dN = 6\times10^{-6}\Delta K^{0.9569}$
	0.3	500	$da/dN = 1\times10^{-6}\Delta K^{1.3072}$ $da/dN = 1\times10^{-6}\Delta K^{1.224}$
		550	$da/dN = 2\times10^{-6}\Delta K^{1.128}$ $da/dN = 3\times10^{-6}\Delta K^{1.061}$
		600	$da/dN = 5\times10^{-6}\Delta K^{0.9628}$ $da/dN = 4\times10^{-6}\Delta K^{1.0222}$

3. Results and Discussion

The fatigue crack growth tests for a Mod.9Cr-1Mo compact tension specimen were performed for a load ratio of 0.1 at high temperature conditions of 500℃, 550℃, and 600℃, respectively, and results were compared with previous test results for the case of applying a load ratio of 0.3. The crack growth speeds for each load ratio were obtained as a function of Δ K and compared each other. It was found out that the fatigue crack growth speed increases as temperature increases, and the crack growth speed increases as load ratio decreases.

Acknowledgement

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