High Temperature FCG of G91 Steel for Different Frequencies

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1. Introduction

Mod.9Cr-1Mo steel (G91) is adopted as the structural material for several high temperature components of a Sodium-cooled Fast Reactor[1] after it became a registered material in ASME Section III, Subsection NH[2] in 2004. It was chosen as a candidate material for IHTS piping and heat exchangers used in KALIMER-600[3] as well as Japan Sodium-cooled Fast Reactor JSFR[4]. The material data of fatigue crack growth and creep crack growth for robust structural integrity evaluations lacks in Subsection NH while it provides some material properties of G91 steel for design purposes at high temperature conditions. Creep-fatigue crack initiation and growth tests for a G91 tubular specimen, including a machined defect, have been performed by Kim[5] and it attempted to assess a high temperature crack behavior of G91 side plate specimen by Lee[6]. The fatigue crack growth tests of a G91 compact tension (CT) specimen were performed by Kim[7, 8] at 20Hz and 0.1Hz loading frequencies, respectively. The effect of loading frequency on the behavior of high temperature fatigue crack growth was assessed at 550℃ for load ratio of 0.1[9]. In this study, more tests were performed and the effect of loading frequency at 500℃ and 600℃ was assessed.

2. Fatigue Crack Growth Tests

Fatigue crack growth tests were performed using the 1/2” CT specimen shown in Fig. 1 by satisfying ASTM E647 standard [10] and the chemical composition of the G91 steel is shown in Table 1. The fatigue crack growth rates from a near threshold to a K_{max} controlled instability were determined. A Chevron notch was prepared by electric discharge machining and a 3mm pre-crack was made according to the E647 standard.

DCPD (Direct Current Potential Drop) method was utilized to measure the crack growth size and the appropriate calibration curve was obtained by applying the ASTM E1457 procedure[11].

In a previous study, 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 0.1, respectively. Loading frequencies of 20Hz and 0.1Hz were applied, respectively. In this study, fatigue crack growth test was conducted at 500℃, 550℃, and 600℃, respectively, by applying the load ratio of 0.1 at different loading frequencies 0.1Hz, 1Hz, and 20Hz, respectively. The effect of loading frequency was assessed.

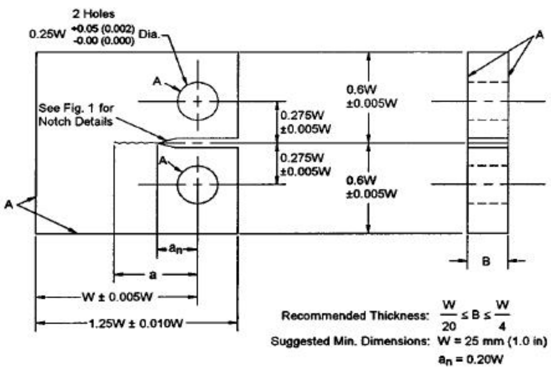

Fig. 1 CT specimen for the fatigue crack growth test

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 shows the crack growth rate with respect to $\triangle K$ for the load ratio of 0.1 by applying 3 different values of loading frequencies 0.1Hz, 1.0Hz, and 20Hz, respectively, at 500℃.

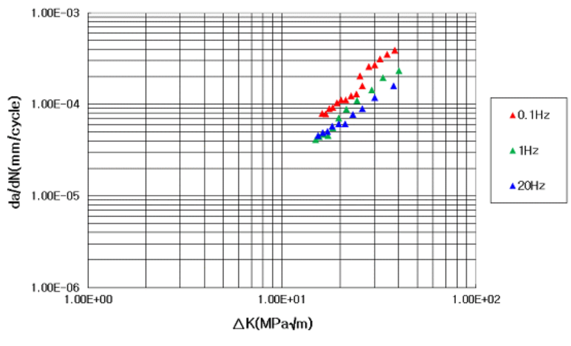

Fig. 2 da/dN-$\triangle K$ for various loading frequencies (load ratio of 0.1 at 500℃)

Fig. 3 shows the crack growth rate with respect to $\triangle K$ for the load ratio of 0.1 for loading frequencies of 0.1Hz, 1.0Hz, and 20Hz, respectively, at 550℃.

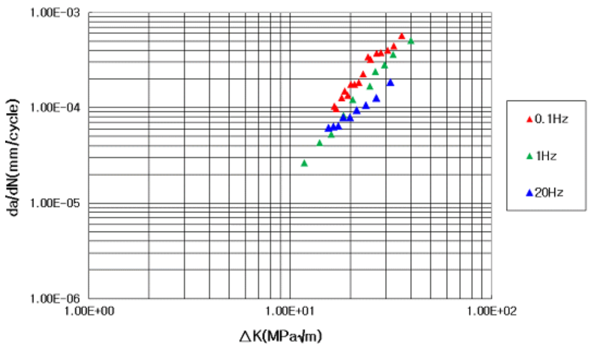

Fig. 3 da/dN-△*K* for various loading frequencies (load ratio of 0.1 at 550℃)

Fig. 4 shows the crack growth rate with respect to △*K* for the load ratio of 0.1 for loading frequencies of 0.1Hz, 1.0Hz, and 20Hz, respectively, at 600℃.

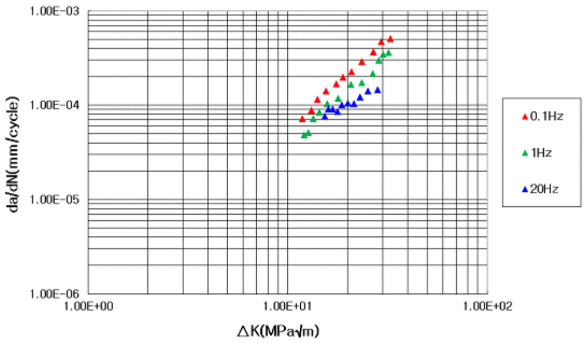

Fig. 4 da/dN-△*K* for various loading frequencies (load ratio of 0.1 at 600℃)

It is known that the fatigue crack growth rate increases as loading frequency decreases at high temperature while the effect of loading frequency is not significant at low temperature. As shown in Fig. 2 ~ Fig.4, the fatigue crack growth rate increases as loading frequency decreases.

3. Results and Discussion

The fatigue crack growth tests for a G91 compact tension specimen were performed for a various loading frequencies. The effect of loading frequencies on the fatigue crack growth behavior was reviewed and it was found out that the fatigue crack growth rate increases as temperature increases and the load ratio increases at a specific loading frequency. At a specific temperature condition, the fatigue crack growth speed increases as a loading frequency decreases.

Acknowledgement

This study was supported by the Korean Ministry of Education, Science & Technology through its National Nuclear Technology Program.

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