Life Evaluation of High Cr Alloy Weldment according to the Oxidation Properties

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1. Introduction

There has been strong environmental and economic pressure to increase the thermal efficiency of fossil fuel power stations and this has led to a steady increase in steam temperature and pressure resulting in worldwide plans for ultra super-critical power plants. Therefore, in order to improve the thermal efficiency of power plants, there has been a strong drive to develop heat resistant steels with excellent creep, high temperature fatigue and thermal fatigue resistant properties as well as superior oxidation and corrosion resistant properties. Cr-Mo steels are extensively used for high temperature components in power plants [1]. In this study, the test materials were P122 alloy which have been developed for ultra super-critical power plant. In power plants, lot of mechanical components is welded and generally, HAZ is reported to be the weakest part of the welded components and serves as frequent crack initiating sites [2, 3]. Also, HAZ was found to have the lowest toughness in welded joints [2]. In characterizing the mechanical property of heat resistant alloys, the fundamental knowledge of oxidation at high temperature is of great importance. Oxidation has been considered to be the major detrimental phenomenon that interacts with low cycle fatigue in high temperature range. It is reported also to influence the crack initiation process in alloys and the large fraction of fatigue life is spent in the crack initiation process. Therefore, it is very important to approach such problems from the view point of high temperature material properties.

2. Experimental Procedure

2.1 High temperature fatigue crack growth test

Specimens were prepared and the tests were performed according to ASTM E 1457. Fatigue crack growth tests were conducted in accordance with ASTM E 647. The crack length was measured by traveling microscope and the DCPD (direct current potential drop) method.

2.2 Oxidation test

The samples for oxidation tests were cut to a size of 3x5x7mm with the electrodischarge machine from the weld metal, the base metal and HAZ of the P92 alloy. They were ground to a 2000-grit emery paper, cleaned in acetone, and oxidized at 550, 600, 650 and 700°C up to 500 hr in air in an electrical furnace.

3. Results and Discussion

The oxidation rate was satisfied the parabola law with researches [4, 5]s that we present the crack growth rate in which it considers the time dependent behavior, the Arrehenius relational expression was used and the crack growth speed type was expressed. The crack growth can be expressed as the following functional relation.

$$da/dN = g(\Delta K, Q, T) \tag{1}$$

Where Q is the activation energy and T is Kelvin temperature.

3.1 The fatigue crack growth rate equation with temperature

The cracking growth rate to be reviewed which it considers the temperature influence by using the fatigue cracking growth rate it shows in the method (1). As follows, a function was expressed in the equation (1) including △K and temperature T.

$$da/dN = C_1 \Delta K^{\tau_1} T^{\tau_2} \tag{2}$$

The τ_1 and τ_2 calculated by the fatigue crack growth test results of P122 weldment(Base metal, Weld metal and HAZ) with f=20Hz and R=0.1 at 600℃ ~ 700℃. The MINITAB 14.12 which is the commercial statistical program was utilized and the multiple linear regression analysis was accomplished. In order that the accuracy of the equation (2) was confirmed, the real test result value of being measured and the value predicted using equation (2) were shown in the Fig. 1 ~ 2. It was compared with the shown in the graph slope of the points is predicted slope of the solid line in which and the relatively high accuracy near to 1 was shown.

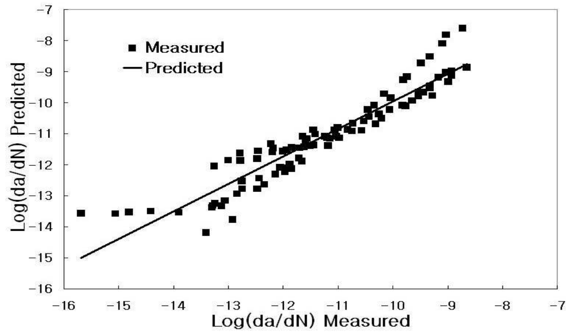

Fig. 1. Predicted da/dN vs. measured da/dN for base metal

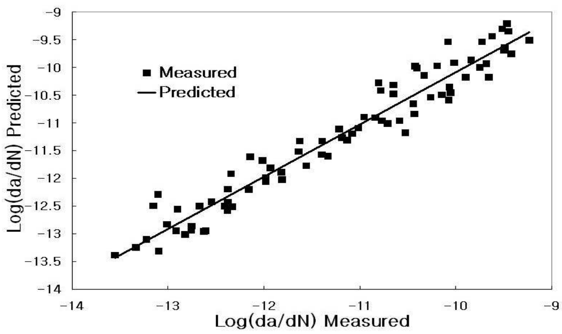

Fig. 2. Predicted da/dN vs. measured da/dN for HAZ

3.2 The fatigue crack growth rate equation with temperature and activation energy of oxidation

The equation (1) expressed like the equation (3) including the activation energy Q in order to include the affect of the oxidation in the high temperature fatigue crack growth. The MINITAB 14.12 is the commercial statistical program, was utilized and the multiple linear regression analysis was carried out. As follows, a function was expressed in the equation (1) including △K, temperature T and activation energy Q.

$$da/dN = C(\exp\left(-\frac{Q}{RT}\right))\Delta K^{\tau_1} T^{\tau_2} \quad (3)$$

In order that the accuracy of the equation (3) was confirmed, the real test result value of being measured and the value predicted using equation (3) were shown in the Fig. 3 ~ 4.

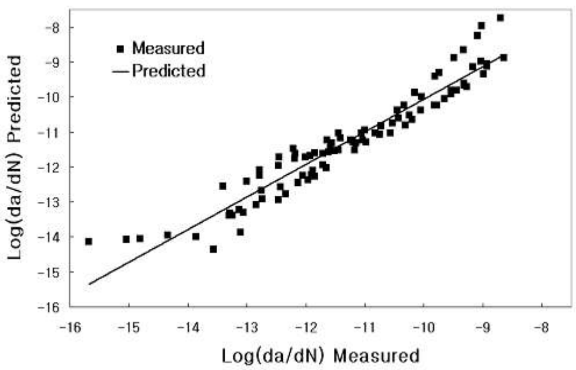

Fig. 3. Predicted da/dN vs. measured da/dN for base metal

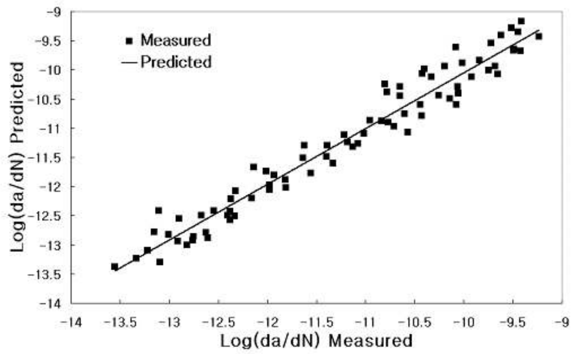

Fig. 4. Predicted da/dN vs. measured da/dN for HAZ

4. Conclusions

The fatigue crack growth rate equation (3) adding activation energy Q will be able to predict lifetime of fatigue crack growth at high temperature which is more accurate than equation (2)

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