Creep Life Assessment of Alloy 690 Steam Generator Tube using Larson-Miller Parameter

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1. Introduction

Alloy 690 material which has higher Cr content than Alloy 600 has been replaced for the steam generator (SG) tube due to its high corrosion resistance against stress corrosion cracking (SCC). In the research field of severe accident of nuclear power plant (NPP), severe accident initiated SG tube rupture leading to containment bypass-integrated risk assessment is one of important research to prevent a significant radioactive release to the environment [1-3]. To analyze progression of severe accidents in NPP, MELCOR code is widely used. Creep rupture model is integrated to analyze SG rupture in the MELCOR code. Analysis is usually performed based on creep property of alloy 600 because there is lack of research on the high temperature creep rupture and life prediction model of alloy 690. Therefore, in this study, several creep tests were carried out, and creep life was evaluated for alloy 690 SG tubing material using the Larson-Miller Parameter (LMP) method [4].

2. Creep Test

Fig. 1 shows creep specimen used in this study. Tube-type specimen was used, the tube was not flattened for having the residual stress of the tube during manufacturing process. Reduced section of the specimen is 19 mm long and the width is 4 mm. Uniaxial creep rupture tests were conducted at 650°C-850°C with applied stress ranging from 30 to 300 MPa. Creep strain data and elapsed times were recorded automatically by using data acquisition system. Time to rupture and steady-state creep rate were obtained by analyzing experimental creep curves. The creep properties such as the creep rupture time (hour, t_r), creep strain rate (steady-state creep rate, SSCR) and test conditions (temperature (T) and stress (σ)) are summarized in Table 1. Total of 27 data (so far) obtained from the experiment. Rupture time decreases with increasing stress, and more loads are required as the temperature decreases at same rupture time as summarized in Table 1.

3. Creep Life Prediction using LMP

Larson-Miller parameter is one of the widely used creep life prediction and extrapolation method. The parameter of LMP method given as

$$P_{LM} = C_1 \log(\sigma) + C_2 \quad (1)$$

$$P_{LM} = \mathrm{T}(\log t_r + C_3) \quad (2)$$

where, T is the absolute temperature (Kelvin, K), t_r is the rupture time (sec), σ is the applied stress (pascal, Pa) and C_1-C_3 are material specific constant.

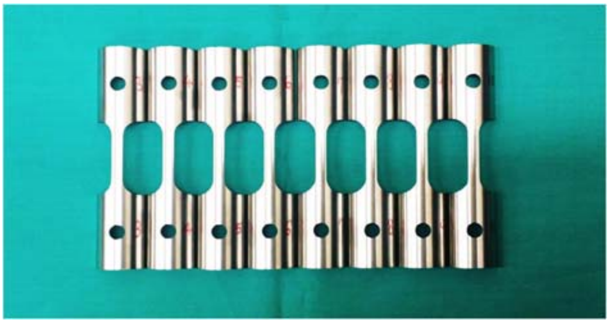

Fig. 1. Geometry of creep specimen

Table 1 Experimental condition and results of creep tests

T(°C)	Stress(MPa)	Tr(hr)	SSCR(1/hr)
650	300	12.0	2.670.E-02
650	250	52.9	6.260.E-03
650	230	64.5	4.980.E-03
700	120	214.6	1.130.E-03
700	110	303.0	7.272.E-04
700	100	386.0	5.580.E-04
700	90	644.1	2.707.E-04
700	80	865.6	1.717.E-04
700	250	5.4	6.300.E-02
700	180	28.0	1.142.E-02
750	100	39.1	3.550.E-03
750	80	98.1	1.730.E-03
750	70	177.6	9.252.E-04
750	50	575.6	1.462.E-04
750	40	779.1	7.468.E-05
750	150	11.7	2.560.E-02
800	50	78.1	1.790.E-03
800	40	194.6	5.436.E-04
800	60	43.0	3.610.E-03
800	30	507.7	1.974.E-04
800	70	38.0	4.830.E-03
800	35	488.6	2.250.E-04
800	90	12.8	1.832.E-02
850	60	10.0	2.010.E-02
850	50	24.6	8.590.E-03
850	40	35.3	4.080.E-03
850	30	93.0	1.400.E-03

The basic concept of LMP is that the creep life decreases with increasing temperature when the stress is fixed.

According to the experimental results, the relationship between applied stress and LMP was fitted and shown in Fig. 2. An optimum material specific constant, C_1-C_3, in the master curve was investigated to be C_1=-3973.7, C_2=48627.9 and C_3=11.26339 which were calculated in units of Kelvin (Temperature), Pa (Stress), and second (t_r). LMPs were determined for various C_3 values. Using coefficient of determination (COD), R^2 was 0.99 for optimal constant C_3=11.26339.

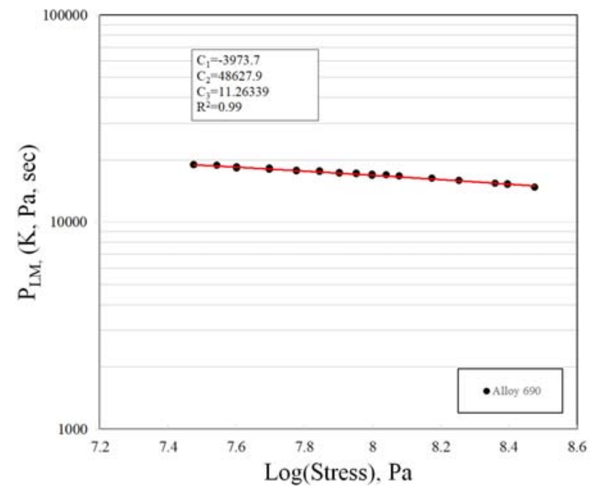

Fig. 2. The plot of LMP vs. logarithm of stress

In this study, creep life of alloy 690 SG tube was predicted using LMP method. However, the number of creep data is insufficient to predict creep life so far, and limitation exists to predict the accurate creep life. The short term creep tests for the C-SGTR (consequential steam generator tube rupture) analysis and the long term creep tests for the creep life prediction (extrapolation) are required. In the future, a larger number of creep tests will be carried out to improve accuracy of creep life prediction.

And one more consideration in this regard is that the constant C of LMP is a function of stress in nature. LMP constant C value depends on the applied stress, hence, modified LMP technique is required to provide a better realistic prediction. Although not presented in this paper, the author is considering various creep life prediction models such as Orr-Sherby-Dorn (OSD), Manson-Haferd Parameter (MHP), and Wilshire's approach for creep life evaluation of alloy 690 SG tube [5-8].

4. Conclusions

In this study, the creep test were conducted for Alloy 690 tube-type specimen at various temperature and stress. The creep life was estimated using the Larson Miller parameter. The parameters of LMP were determined using 27 of creep test data as follows (units: Kelvin, Pascal, second):

C_1=-3973.7, C_2=48627.9, C_3=11.26339

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