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Creep-Fatigue life with Hold Time for Modified 9Cr-1Mo.

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1. Introduction

9Cr-1Mo steel has a good mechanical properties and a lower thermal expansion coefficient than austenitic stainless steel. 9Cr-1Mo steel is a candidate material for reactor vessel for VHTR. The reactor vessel of VHTR is operated at about 450℃ during normal condition but temperature increases during accident condition. At this temperature, fatigue occurs during start-up and cool-down, and creep occurs during normal operation. Creep-fatigue damage by the interaction between fatigue and creep is an important factor that limits VHTR reactor vessel life.

In this study, effect of hold time on low cycle fatigue behavior of 9cr-1Mo at 600℃ was investigated in air.

2. Experimental procedure

9Cr-1Mo steel was commercial steel. Chemical composition was shown in Table 1.

Table 1. Chemical composition of Mod. 9Cr-1Mo.

C	Mn	Cr	Ni	Mo	Nb	V
0.085	0.379	9.37	0.09	0.91	0.08	0.19

Heat treatment
Normalizing : 1050℃, Tempering : 770℃

LCF tests were carried out at 600℃ and strain rate was $2x10^{-3}$/s under strain control. Hold time experiments were carried out using a trapezoidal waveform. Creep-fatigue interaction tests were conducted by introducing hold time at peak tension and in peak compression for periods in the range 1,5,10min. Fatigue specimens was 8mm diameter and 16mm gauge length. Fatigue life was defined as 25% reduction of tensile peak stress of $1/2N_f$.

All test were conducted at air environment. Test temperature was maintained constant within ±2℃ during the period of the test.

3. Results

3.1. Fatigue and creep-fatigue life.

The fatigue and creep-fatigue life of specimens tested with hold time at 600℃ are shown in Fig. 1. Creep-fatigue life with tensile hold was less than compressive hold. Fatigue life decreased and the time to failure was increased with hold time. Variation of Creep fatigue life with tensile and compressive hold time is shown in Fig. 2. Creep fatigue life decreased with increase in hold time in tensile and compressive hold time. The peak stresses in fatigue and creep-fatigue tests are shown in Fig.3. There was softening with cycles for fatigue and creep fatigue.

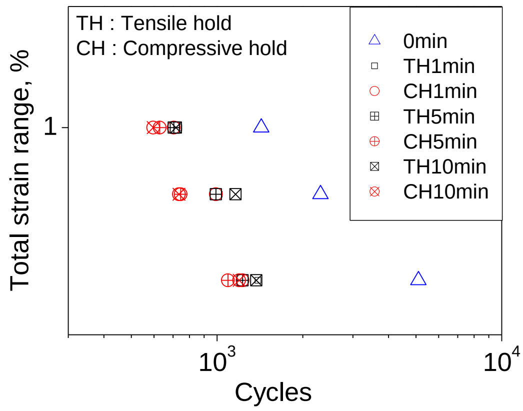

Fig. 1. Fatigue and creep-fatigue life at 600℃

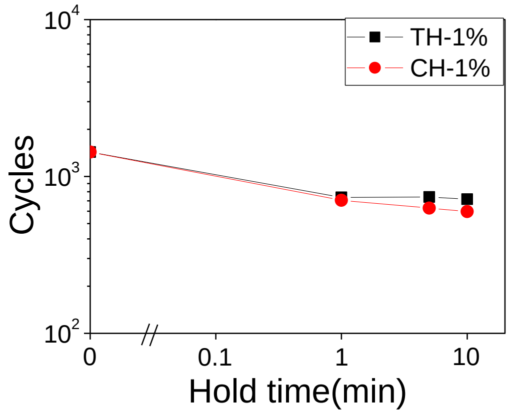

Fig.2. Relation between hold time and number of cycles.

3.2. Stress relaxation during hold time

Stress relaxation during the hold time is shown in Fig. 4. Stress relaxation with tensile and compressive hold is almost the same during the 10min hold time. Stress relaxation is dereased with cycles for Creep fatigue.

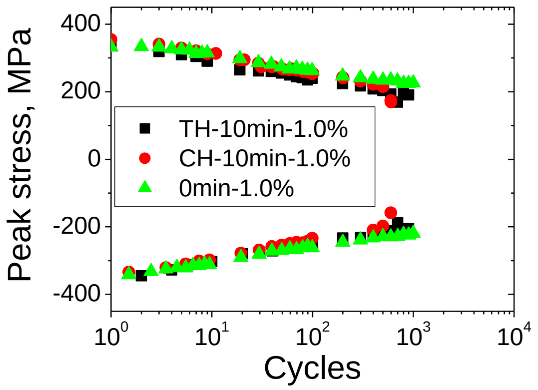

Fig. 3 Peak stress with cycle for fatigue and creep-fatigue specimens tested at 1.0% and 600℃.

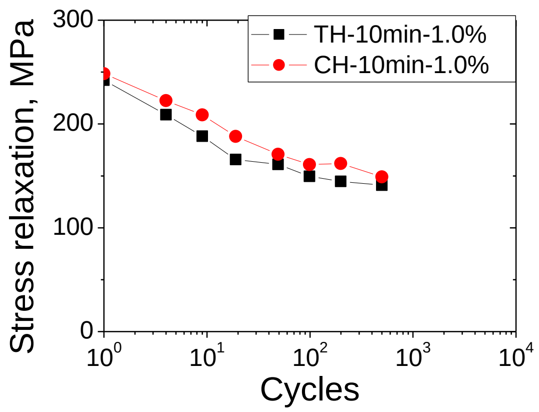

Fig. 4 Stress relaxation with cycles during the hold time.

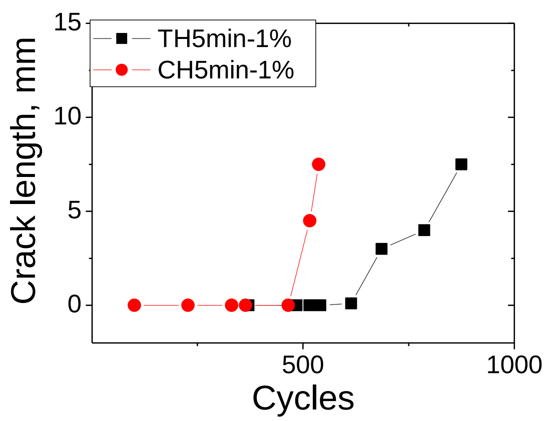

Fig. 5 Crack length with cycles.

3.3. Crack initiation percentage.

Crack length with cycles is shown in Fig. 5. Crack initiation percentage of TH is about 70%. And Crack initiation percentage of CH is about 80%. Striation spacing with hold time is almost same. Crack initiation of creep-fatigue is more important than crack propagation.

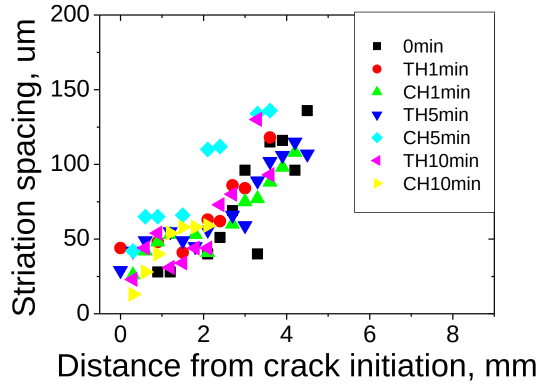

Fig. 6 Striation spacing.

4. Conclusions

Creep-fatigue life was less than fatigue life, and creep-fatigue life with compressive hold was less than that of tensile hold. Creep-fatigue life was decreased by hold time. Stress relaxation of TH and CH are almost same. Crack initiated at about 70% of fatigue life.
Crack initiation of creep-fatigue is more important than crack propagation.

Acknowledgement

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