Fatigue Properties of Mod. 9Cr-1Mo with Heat Treatment

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1. Introduction

Ferritic/Martensitic steel has a good mechanical properties and a lower thermal expansion coefficient than austenitic stainless steel. Mod. 9Cr-1Mo steel is a candidate for reactor vessel for VHTR but creep properties of Mod. 9Cr-1Mo steel above 600℃ is less than austenitic stainless steel. Chemical composition, precipitation, heat treatment, and delta ferrite content were controlled to improve creep properties. Fatigue properties at high temperature should be also evaluated with the metallurgical parameter for VHTR vessel. In this study, high temperature fatigue properties were investigated with heat treatment condition of Mod. 9Cr-1Mo steel.

2. Experimental procedure

Mod. 9Cr-1Mo steel was prepared by vacuum induction melt and hot rolled to 15 mm thickness. 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

One step heat treatment was at normalizing and 700-780℃ tempering. Two step heat treatment was normalizing and 600-750℃, 730-780℃ tempering.

Tensile tests were conducted at RT-700℃ and strain rate was $2x10^{-3}$/s. Tensile test specimen was 1.65mm thick, 6.25 mm width, 25 mm gauge length.

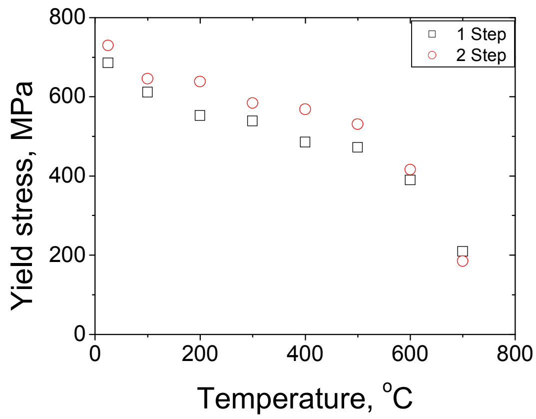
LCF tests were conducted at RT-600℃ and strain rate was $2x10^{-3}$/s under strain control. Fatigue specimens was 7 mm diameter and 8mm gauge length. Waveform was triangular and fully reversed. Fatigue life was defined as 25% reduction of tensile peak stress.

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

3. Results

3.1. Tensile properties

Yield stress and elongation are show in Fig. 1. Yield stresses of 2step is a little high to 500℃ but almost same above 600℃. Elongation of 2step is a little lower than that of 1step but the amount was not great.



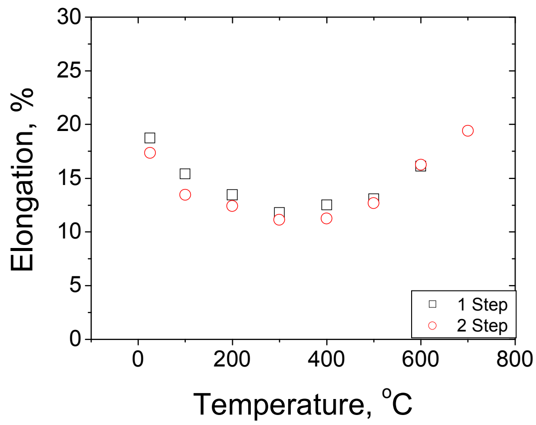


Fig. 1. Tensile properties of Mod. 9Cr-1Mo with temperature.

3.2. LCF properties

LCF life was shown in Fig. 2. LCF life with heat treatment was almost same at RT and 600℃. Fatigue strength with cycles was shown in Fig. 3.

Fatigue strength of 2 step heat treatment was higher than that of 1 step heat treatment. 2 step heat treatment increased tensile and fatigue strength. It is considered that the increase of strength by 2 step heat treatment is due to the increase of precipitates

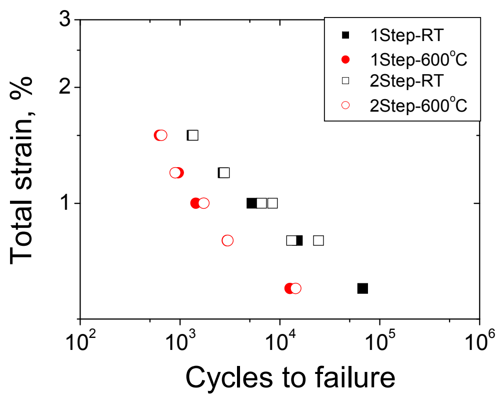


Fig. 2. LCF life of Mod. 9Cr-1Mo with heat treatment.

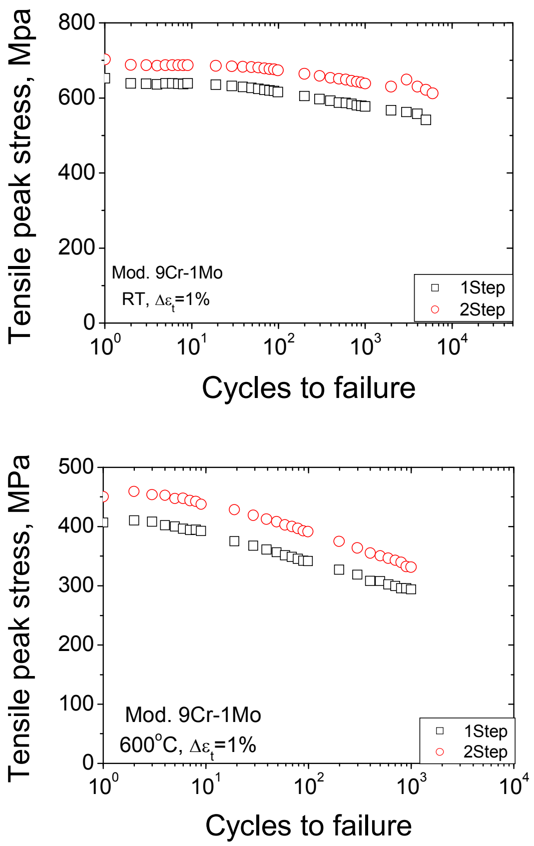


Fig. 3. Tensile peak stress with heat treatment

. There was softening with cycles for fatigue of Mod. 9Cr-1Mo steel. The behavior of softening was almost same at RT and 600℃ but the amount of softening was more severe at 600℃ than at RT. It is reported that the softening is due to the annihilation of dislocations. The movement of dislocation is easy at high temperature and the softening is severe at 600℃.

4. Conclusion

Yield stress of 2 step heat treatment increases tensile and fatigue strength but elongation is almost same with 1 step heat treatment.

LCF life is not different with heat treatment. There is softening at RT and 600℃. The softening at 600℃ is greater than that at RT.

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