Creep-Fatigue Behavior with Hold Type for High Cr Martensitic steel

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1. Introduction

9Cr steel has high strength and high thermal conductivity, low thermal expansion, and high resistance to the swelling by irradiation. 9C steel is applied to structures of future reactor such as cladding of nuclear fuel, heat exchanger, and reactor pressure vessel and pipe.

Thermal fatigue by temperature gradient due to heat-up and cool down and creep during normal operation are important factors to limit structural life. Interaction of fatigue and creep is more damaged than fatigue and creep which are applied separately. In this study, creep-fatigue behaviors of 9Cr steel with hold type and hold time are evaluated.

2. Experimental procedure

Chemical composition of commercial 9Cr-1Mo steel was shown in Table 1. Heat treatment was normalized at 1050℃ and tempered at 770℃.

Creep-fatigue test specimen was 16 mm gage length and 8 mm diameter. Specimen was taken as rolling direction. The gage section of the specimen was polished using a 1000 grit sand paper with strokes along the specimen axis. Creep-fatigue test was conducted at 600℃ under strain control. Holding during fatigue test was applied at tensile (TH) or compressive (CH) peak strain. Hold time was from 1 minute to 10 minute. Waveform was fully reversed triangular and strain rate was $2x10^{-3}$/s. All specimens were tested at air environment. Temperature was controlled within ¡2℃. Creep-fatigue life was defined as 25% reduction of $1/2N_f$.

Table 1. Chemical composition of 9Cr

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

3. Results

Fatigue and creep-fatigue life with hold type was shown in Fig. 1. Fatigue life decreased with hold at peak strain. Creep-fatigue life of tensile hold was higher than that of compressive hold.

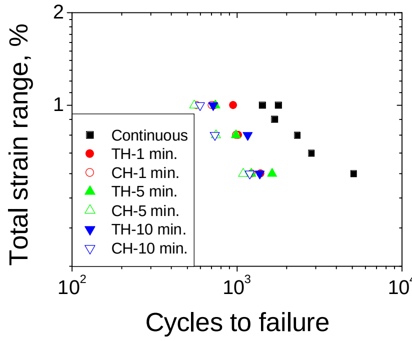

Fig. 1. Creep-fatigue life with hold type

Creep-fatigue life with hold time was shown in Fig. 2. Creep-fatigue life decreased with hold time. Creep-fatigue life decreased greatly at 1 min hold time but decreased gradually after 1 min. hold time.

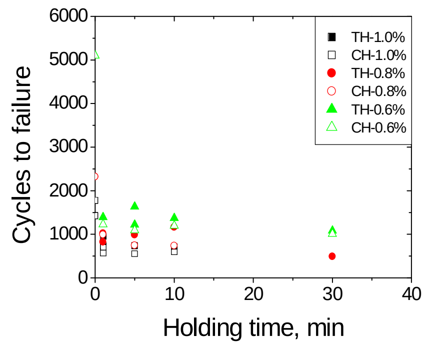

Fig. 2. Creep-fatigue life with hold time

Cyclic creep-fatigue stress was shown in Fig. 3. Creep-fatigue strength was softened with cycles. Creep-fatigue strength was almost same as hold type and hold time.

Stress relaxation curves with hold type during 10 min. hold time was shown in Fig. 4. Stress during hold time decreased greatly over short periods and gradually after 20 seconds. Amount of stress relaxation during hold time and type was shown with cycle in Fig. 5. Amount of stress relaxation decreased with cycles. Trend of stress relaxation with cycle was same with hold time, hold type, and strain range. Amount of stress relaxation at a high strain range was a little higher than that at low strain range.

Mean stress ((tensile peak stress + compressive stress)/2) with hold type and hold time was shown in Fig. 6. Mean stress of tensile hold was negative and that of compressive hold was positive. Mean stress of fatigue was almost zero.

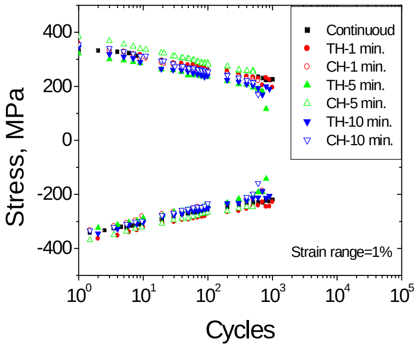

Fig. 3. Cyclic creep-fatigue stress with hold type

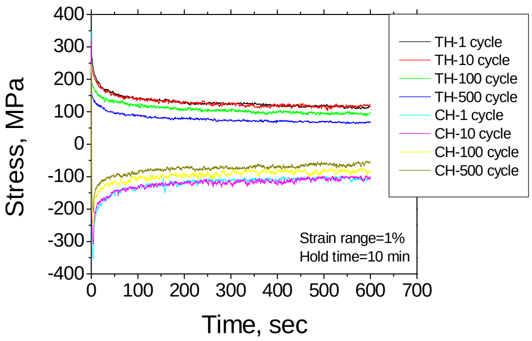

Fig. 4. Stress relaxation curve with hold time

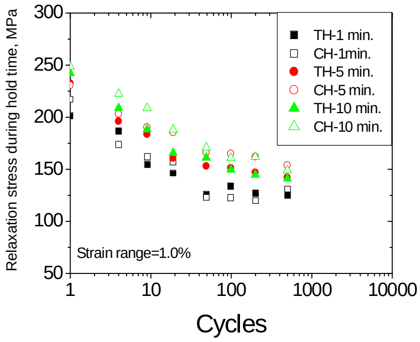

Fig. 5. Amount of stress relaxation with hold type during hold time

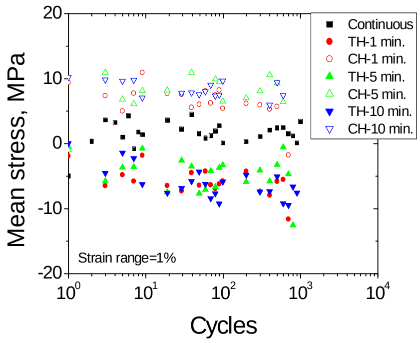

Fig. 6. Mean stress with hold type and hold time

4. Conclusion

Creep-fatigue life decreases with hold time. Creep-fatigue life of compressive hold type is lower than that of tensile hold type. Creep-fatigue strength is not different with hold type and hold time. Amount of stress relaxation decreases with cycle but increases with hold time. Mean stress is positive for compressive hold but negative for tensile hold.