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Evaluation of Factors Affecting Fatigue Properties of 9Cr-1Mo

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1. Introduction

9Cr-1Mo steel has high strength and high thermal conductivity, low thermal expansion, and high resistance to the swelling by irradiation. 9Cr-1Mo steel is applied to structures of future reactor such as cladding of nuclear fuel, heat exchanger, and reactor pressure vessel and pip. The structures for future reactor are operated for 40-60 years at high temperature and the mechanical properties of structures are degraded during operation. Mechanical properties are affected by many factors such as operating environment, temperature, heat treatment condition, production procedure, aging, stress condition, etc. The effect of these factors is evaluated to apply proper margin to fatigue design curves.

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℃. Two step heat treatment was normalizing and 600-750℃, 730-780℃ tempering. The microstructure after heat treatment was martensite shown in Figure 1.

Welding process was SMAW (Shielded Metal Arc Welding) and filler metal was E9016-G. Currency was 120-160A and voltage was 20-26V. Post heat treatment after welding was conducted at 750℃.

Three type of fatigue test specimen was chosen as 8 mm gage length and 7 mm diameter, 13 mm gage length and 6.5 mm diameter, 16 mm gage length and 8 mm diameter. Low cycle fatigue test 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. Fatigue test was conducted under strain control and fully reversed triangular waveform at RT-600℃ and strain rate was $2x10^{-3}$/s. All specimens were tested at air environment. Temperature was controlled within ¡ 2℃. Fatigue life was defined as 25% reduction of tensile peak stress. Base metal was aged at 600℃ and 10000 h.

3. Results

Fatigue life was increased in specimen of small gage length at RT and 600℃. Fatigue life was almost same in specimen diameter of 6.5 mm and 8 mm. Fatigue life was decreased with temperature. Fatigue life was decreased with welding. Fatigue life was not decreased at high strain range but decreased at low strain range. Fatigue life was not changed with heat treatment. Fatigue life was not changed with aging at 600℃ and 10000 h. Fatigue life was similar for commercial production and melting by VIM.

Scattering factor of fatigue life was 3 for welding and specimen geometry and 2 for heat treatment and temperature. Fatigue life was more affected by temperature and strain range than by specimen geometry, aging, welding, and heat treatment.

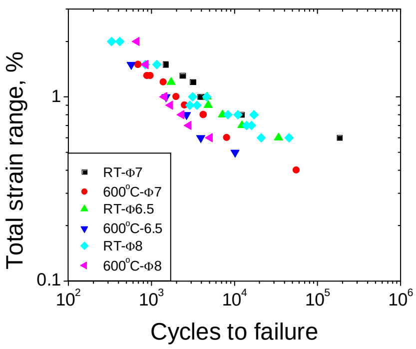


Fig. 1. Fatigue life with specimen geometry.

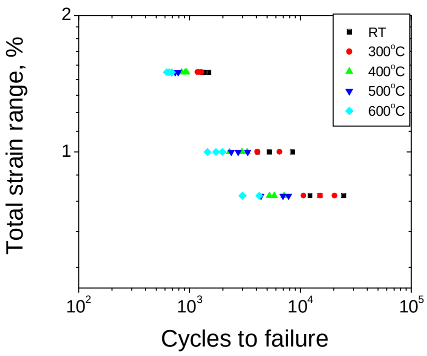


Fig. 2. Fatigue life with temperature.

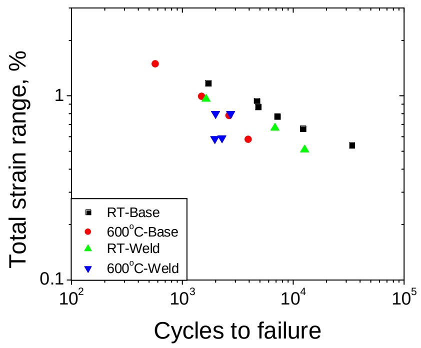


Fig. 3. Fatigue life with weld.

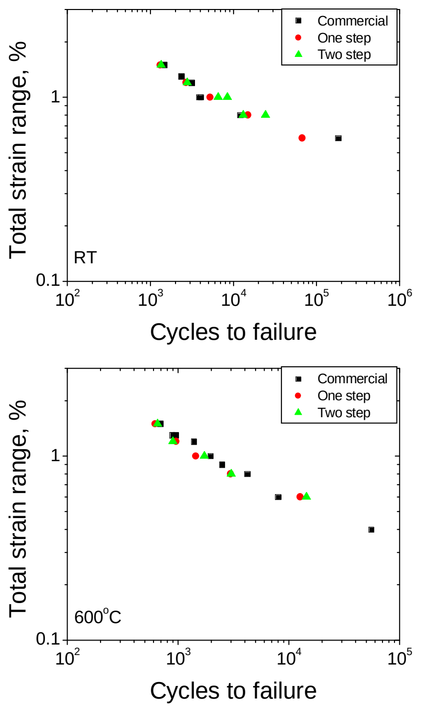
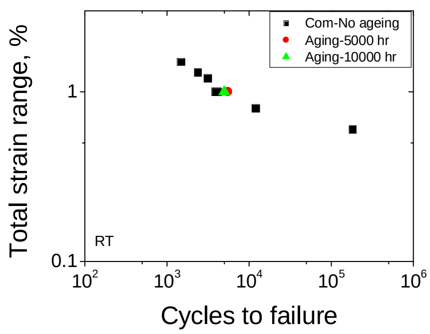


Fig. 4. Fatigue life with heat treatment.



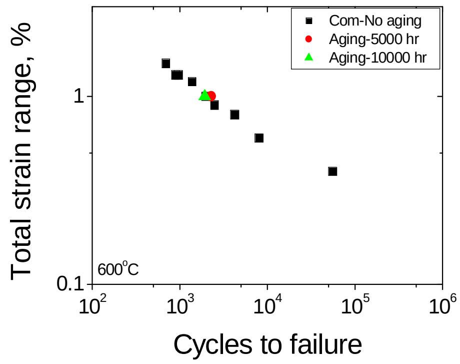


Fig. 5. Fatigue life with aging.

4. Conclusion

Fatigue life is increased when gage length is small. Fatigue life is decreased with temperature but almost same when specimen is aged or different heat treatment. Fatigue life is decreased with welding at RT but not decreased at high strain range at 600℃.