Effect of Cold Work on LCF and Thermal Fatigue Properties of 316 Stainless Steel

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1. Introduction

Internal structures and pipes are deformed by the cyclic heat up and cool down in nuclear power plant operated at high temperature and stress. Thermal expansion by thermal gradient is constrained and induced thermal stress. Thermal fatigue is due to the cyclic stress by the thermal gradient and thermal fatigue properties are different from mechanical low cycle fatigue (LCF) at isothermal temperature[1]. Cold worked 316 stainless steel is used for bolt of internal structure and exposed to thermal stress[2-4]. In this study, thermal fatigue and LCF properties are compared the different behavior is investigated.

2. Experimental procedure

2.1. Chemical composition

Solution annealed (SA) and 11% cold worked (CW) 316 stainless steels are tested and chemical composition is shown in Table 1.

Table 1. Chemical composition of 316 stainless steel (wt%)

	C	Si	Mn	P	S	Cr	Ni	Mo
SA	0.05	0.58	1.26	0.032	0.001	16.77	10.75	2.06
CW	0.06	0.41	1.51	0.030	0.001	17.03	10.83	2.20

2.2. Test condition

Tensile and LCF tests were conducted at RT and 600℃ and strain rate was 2x10^{-3}/s. Thermal fatigue tests were conducted at 200～600℃, 0% strain range and 0.0083Hz. Tensile test specimen was 6mm diameter and 25 gauge length and fatigue specimens was 7 mm diameter and 8mm gauge length. Thermal fatigue specimen was hollow type with 7mm outer diameter, 4mm inner diameter, and 8 mm gauge length. Waveform was triangular.. All tests was conducted at air environment.

3. Results

3.1. Tensile properties

Cold work increased yield and tensile strength and decreased elongation. Strain hardening exponent was decreased with cold work. Cold work increased stress relaxation.

3.2. LCF properties at isothermal temperature

LCF life with cold work was shown in Fig. 1. Fatigue life was increase with cold work at RT but decreased at 600℃. Tensile peak stress with cold work was shown in Fig. 2. Cyclic hardening at an early stage was shown in solution annealed steel but softening was shown in cold work steel.

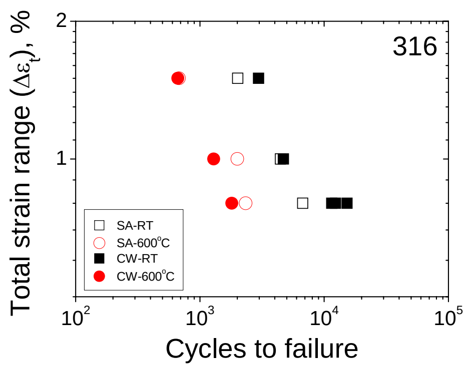

Fig. 1. LCF life with temperature for solution annealed and cold worked 316 stainless steel.

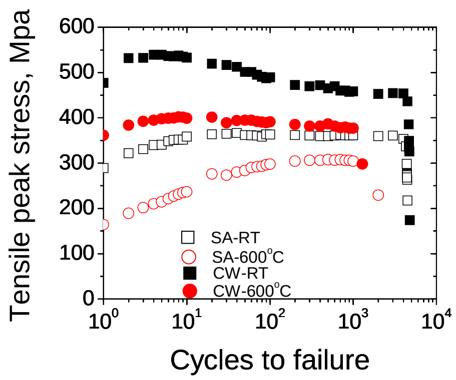

Fig. 2. Tensile peak stress with temperature solution annealed cold worked 316 stainless steel

3.3. Thermal fatigue properties

Thermal fatigue life with cold work was shown in Fig. 3. Thermal fatigue decreased with cold work at above 300℃ temperature change but increased at 200℃ temperature change.

Tensile peak stress with temperature change was shown in Fig. 4. Temperature change of 200～400℃ and 200～500℃ did not show the cyclic hardening at an early stage in solution annealed steel but temperature change of 200～600℃ showed the cyclic hardening. Cyclic hardening was not shown in cold worked steel.

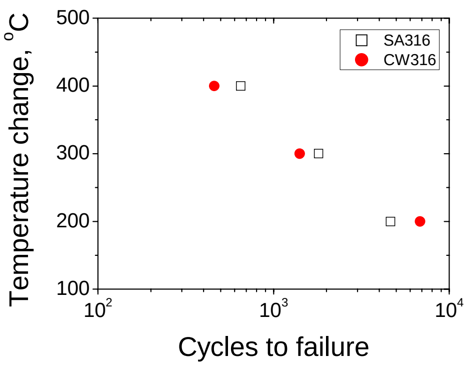

Fig. 3. Thermal fatigue life with temperature change for solution annealed and cold worked 316 stainless steel.

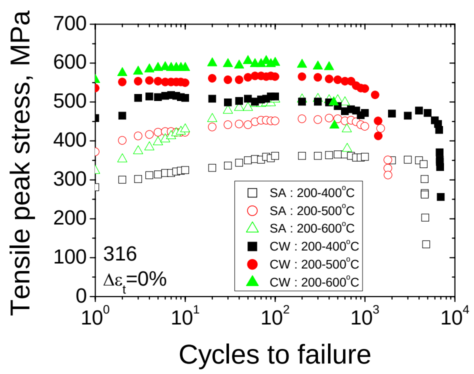

Fig. 4. Tensile peak stress with temperature change for solution annealed and cold worked 316 stainless steel.

4. Conclusion

Cold work increases yield stress but decreases elongation. LCF life is increased with cold work at RT but decreased at 600℃. Thermal fatigue life is decreased with cold work at above 300℃ temperature change but decreased at 200℃ temperature change.

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