Effect of strain induced martensite on low cycle fatigue properties of austenitic stainless steel

Dae Whan Kim*, Ji Hyun Yoon
Korea Atomic Energy Research Institute, Daedeok daero 989-111, Yuseong-gu, Daejeon
**Corresponding author: dwkim1@kaeri.re.kr*

1. Introduction

Austenitic stainless steels are used for the internal components of various product forms, such as baffle and former assembly, core barrels, support columns, core barrel flange, core plates, core support plates, hold down springs, guide tubes, fastener, and bolts because of corrosion resistance, toughness, ductility, strength, and fatigue properties in PWR environment. Martensite induced during low cycle fatigue (LCF) of austenitic stainless steels affects LCF properties[1,2]. Strain induced martensite is dependent on plastic strain range, temperature and chemical composition. In this study, LCF life is investigated as functions of temperature and chemical composition. LCF life is evaluated in the viewpoint of strain induced martensite.

2. Experimental procedure

Chemical compositions of commercial 316 and 304 stainless steels are given in Table 1.

Table 1. Chemical compositions of 316 and 304 stainless steels (wt%).

Spec. ID	C	Mn	Cr	Ni	Mo
316	0.05	1.26	16.77	10.75	2.06
304	0.05	1.68	18.23	8.15	-

A plate having a thickness of 15 mm was solution annealed at 1100℃ and water quenched. Cylindrical specimens with a gage diameter of 7 mm and a gage length of 8 mm were machined for LCF tests. LCF tests were carried out at RT and 300℃ under axial strain control using fully reversed triangular waveform. A strain rate was 2×10^{-3}/s. All specimens were tested in ambient air. Temperature was controlled within ±2℃ during the period of the tests. LCF life was defined as the number of cycles corresponding to a 25% reduction in the stabilized tensile peak stress.

The content of martensite induced by LCF test was detected on the fracture surface using Feritscope MP30. Strain distribution was investigated using Electron Back Scatter Diffraction (EBSD).

3. Results and Discussion

LCF life is shown as a function of temperature for 316 and 304 stainless steels in Fig. 1. LCF life increased with increasing temperature for both steels. LCF life of 316 stainless steel was similar at RT to that of 304 stainless steel and was shorter at 300℃ than that of 304 stainless steel. The magnitude of the increase in LCF life at temperature range from RT to 300℃ was 30% for 316 stainless steel and was 62% for 304 stainless steel.

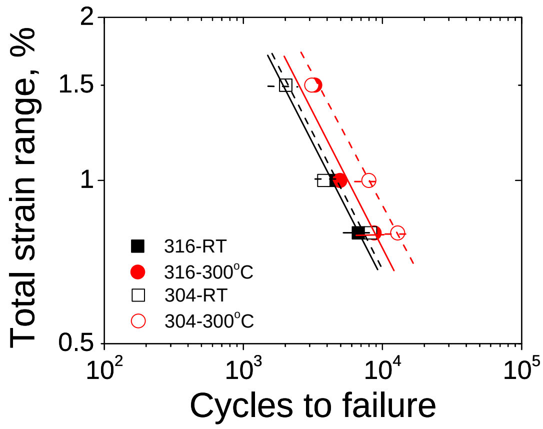


Fig.1. LCF life as a function of temperature for 316 and 304 stainless steels.

Martensite induced by LCF test at RT is shown in Fig. 2. Strain induced martensite of 304 stainless steel was much more than that of 316 stainless steel. Strain induced martensite was not detected at 300℃ for both steels.

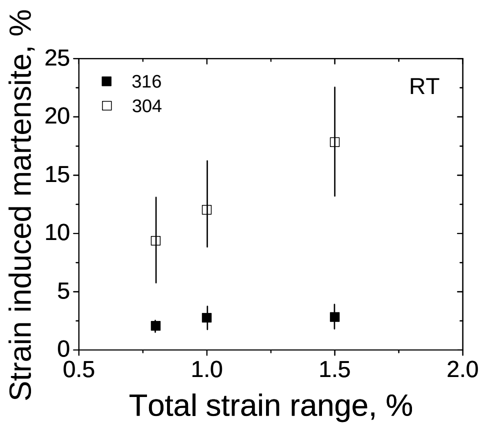


Fig. 2. Amount of strain induced martensite after LCF test at RT for 316 and 304 stainless steels.

Cyclic tensile peak stresses tested at total strain 1.0% are shown as a function of temperature for 316 and 304 stainless steels in Fig. 3. The stabilized cyclic peak stress decreased with increasing temperature for both steels. The stabilized cyclic peak stress of 316 stainless steel was higher than that of 304 stainless steel at RT and 300℃.

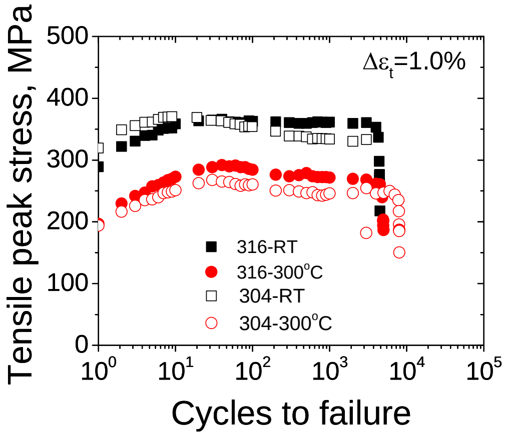


Fig. 3. Cyclic tensile peak stress as a function of temperature at total strain range of 1.0% for 316 and 304 stainless steels.

The increase of LCF life at 300℃ was related with the decrease of strain induced martensite because strain induced martensite was not detected at 300℃ for both steels. But LCF life was similar at RT for both steels having different strain induced martensite content and the stabilized peak stress was lower at RT for 304 stainless steel having more strain induced martensite. The amount of strain induced martensite is not consistent with the behaviors of LCF life and stabilized peak stress at RT for 316 and 304 stainless steels.

Strain distribution after LCF test is shown in Fig. 4. Strain was distributed homogeneously at RT but was concentrated at grain boundary at 300℃ for both steels. Strain induced martensite contributed to the dispersion of plastic strain into grain and the decrease of strain hardening.

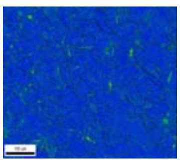
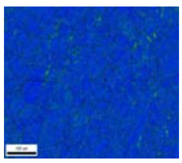
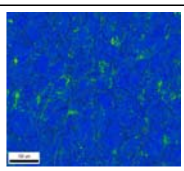
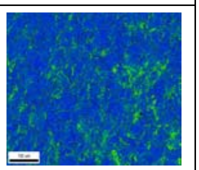
	316	304
RT		
300℃		

Fig. 4. Strain distribution as a function of temperature after LCF test at 1.0% for 316 and 304 stainless steels.

3. Conclusions

LCF life increases with the increase of temperature at temperature range from RT to 300℃ for 316 and 304 stainless steels. Strain induced martensite decreases with the increase of temperature. Strain induced martensite of 304 stainless steel is much more than that of 316 stainless steel. LCF life is not proportional to the amount of strain induced martensite. Strain induced martensite contributes to a homogeneous dispersion of plastic strain.

REFERENCES

[1] G. Baudry A. Pineau, Influence of strain-induced martensite transformation on the low cycle fatigue behavior of a stainless steel. Mater. Sci. Eng. Vol.28, p. 229, 1977.
[2] A.G. Pineau and R.M. Pelloux, Influence of strain-induced martensitic transformations on fatigue crack growth rates in stainless steels. Met. Trans. Vol.5, p.1103, 1974.