Table 3 Fatigue test conditions.

Specimen No.	Amplitude [MPa]	Number of cycles N [cycles]	Fatigue life ratio N/N_f [%]
No.350	350	0	0
		5,000	3
		15,000	9
		30,000	18
		55,000	33
		85,000	52
		125,000	76
		152,500	92
		164,000	100
No.370	370	0	0
		1,000	2
		3,000	5
		6,000	11
		12,000	22
		21,000	38
		36,000	65
		48,500	88
		54,500	100

3. RESULTS AND DISCUSSION

3.1 SEM observations

Crack observation on the surface are conducted by SEM at both notched and smooth side. As a result, it was confirmed that the crack was generated only in notched area where stress concentration had occured on both No.350 and No.370 specimen.

The results of SEM observation on No.350 specimen is shown in Fig.7. The initial main crack of 60 μm length was observed at N/N_f = 33%, and there were some micro-cracks of 5-40 μm length in same area. The main crack propagated accompanied with coalescence of micro-cracks with increase of number of cycle, and finally specimen was broken. As for No.370 specimen (not shown in figure), the initial main crack of 30 μm in length was observed at N/N_f = 22%. Finally, the main crack propagated and the specimen was broken.

3.2 Positron annihilation lifetime spectroscopy

Fig. 8 shows the relationship between the mean positron lifetime (τ_1 in Eq.1) and fatigue life ratio of No.350. The mean positron lifetime increased monotonically with the fatigue life ratio in both notched and smooth area on No.350. This increase indicates increase of lattice defect density (mainly dislocation density) in the specimen. The maximum of the mean positron lifetime is 125.4 ps in notched area just before fracture at N/N_f = 92%. Fig. 9 shows the relationship between the mean positron lifetime and the fatigue life ratio of No.370 specimen. As with No.350 specimen, the mean positron lifiteime increased monotonically in both notched and smooth area. The maximum of the mean positron lifetime is 127.4 ps in notched area just before fracture at N/N_f = 88%. These results show generation and accumulation of lattice defects in fatigue process on the identical specimen.

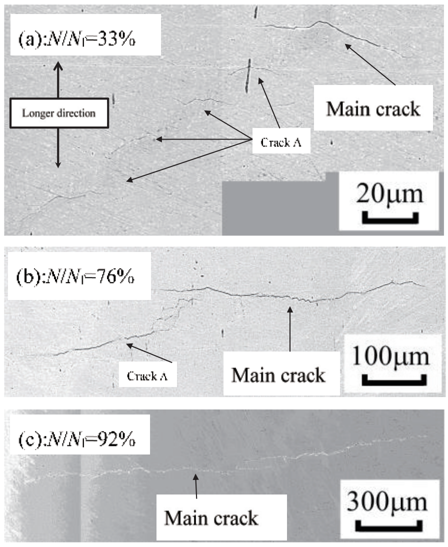

Fig.7 Results of SEM observation of No.350.

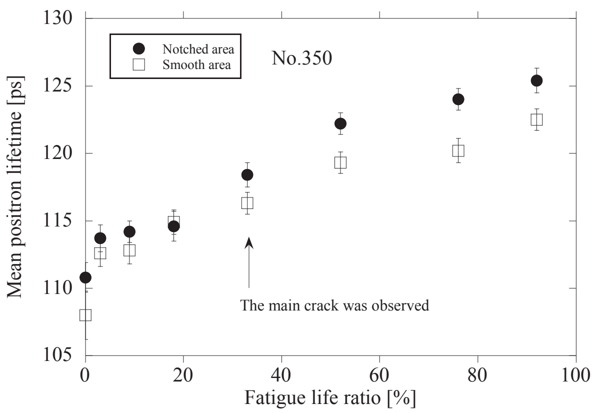

Fig.8 The mean positron lifetime of No.350.

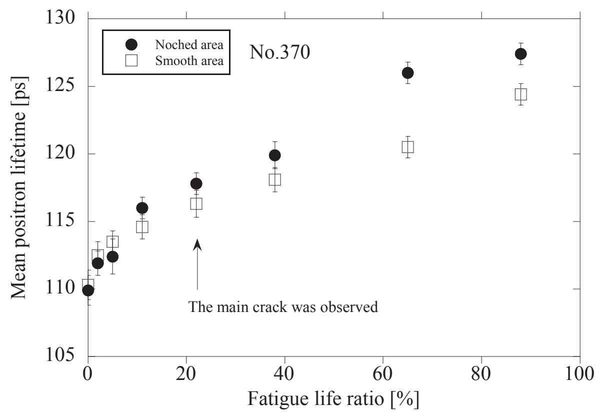

Fig.9 The mean positron lifetime of No.370.

When the mean positron lifetime in notched area was compared with that in smooth area, there is no obvious difference in the stage where crack was not observed. However, it was expected more lattice defects were introduced in notched area before crack initiation since cracks were generated by dislocation accumulations. One reason is considered that the influence of the position resolution of PALS. The resolution of X-Y direction of PALS is determined by the spot size of ^{22}Na, in this study, it is approximately 3 mmϕ. It is considered that since dislocation accumulations occurred in the more local region, the difference was unable to be confirmed.

On the other hand, in the stage where the crack was observed and propagated, the mean positron lifetime in the notched area is higher than that in smooth area. Further the difference between the two tended to increase as the fatigue life raito increased. These results show that more lattice defects were introduced in the region where cracks existed. It is considered that introduction and accumulation of dislocations has significantly occurd in clack-tip plastic zone.

Fig.10 shows the mean positron lifetime with the number of cycles in order to confirm the effect of stress amplitude. The mean positron lifetime of No.370 was longer than that of No.350 at same number of cycles. In the case of higher stress amplitude, shear stress to cause slip was also high. Therefore more lattice defects were introduced at same number of cycles on No.370 specimen which is a higher stress amplitude condition.

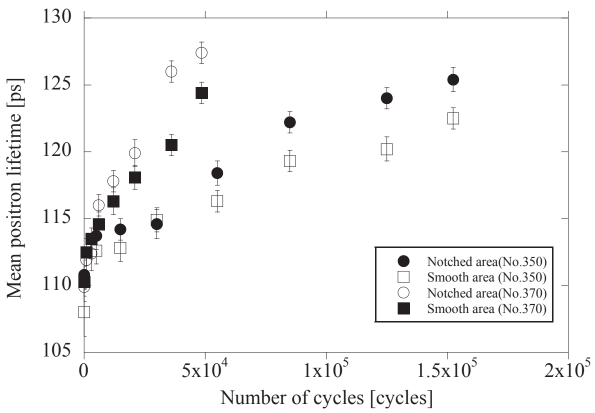

Fig.10 The mean positron lifetime with number of cycles.

4. CONCLUSION

In the present studies, the evaluation of fatigue damage of Type316 stainless steel specimen was carried out. The study was able to trace accumulation of fatigue damages of idenical specimens by using the novel PALS system. The following is a summary of the obtained results.

(1) The mean positron lifetime monotonically increased with fatigue life ratio. There was the same tendency in both specimens in which stress amplitude was 350 MPa and 370 MPa.

(2) There was no obvious difference in the mean positron lifetime between the notched and smooth area before cracks were observed. However, after cracks were observed, the mean positron lifetime in nothced area was higher than that in smooth area. This seems to be due to the effectt of crack-tip plastic zone.

(3) When the stress amplitude is higher, the mean positron lifetime was longer. It was considered that more lattice defects were introduced in high stress condition since shear stress was also high.

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