PRODUCT ANNOUNCEMENT
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Application of Positron Annihilation Lifetime Spectroscopy

INTRODUCTION

The positron annihilation lifetime spectroscopy (PALS) has been widely used for probing open volume defects in various materials [1]. PALS has been applied for detecting the fatigue damages and is considered to be an effective method to evaluate fatigue damages [2), 3)]. In previous studies, it was required to cut the specimens into two pieces, although PALS is essentially a non-destructive method. This is because PALS requires two same specimens to sandwich the positron source. In case of sandwiching a positron source with a specimen and another material, half of the positron wouldn't annihilate in the specimen and the positron lifetime spectrum is seriously contaminated by the false signals. Therefore it was difficult to continuously evaluate the accumulation of fatigue damages of the identical specimen by conventional PALS. As a technique to solve this problem, a novel method of PALS that does not require cutting out the specimen was developed by Yamawaki *et.al.*[4]. Briefly, the positron source is sandwiched between the specimen and a plastic scintillator which is a positron detector. The γ-ray signals relevant to the positron annihilation in the plastic scintillator are eliminated by application of anti-coincidence processing with the signal positron detected in the plastic scintillator. This technical paper describes the principle of the PALS system which is Positron Surface Analyzer developed by TOYO SEIKO and the results of several applications.

2. PALS PRINCIPLE AND PSA INTRODUCTION

2.1 Positron annihilation lifetime spectroscopy (PALS) principle

The positron is the anti-particle of an electron. When the electron and positron come together, they annihilate and produce two γ-rays having approximately 511 keV energy. The positron lifetime is the time distribution before positrons annihilate with electrons. The positron lifetime is inversely proportional to electron density of the site where positrons are annihilated. If lattice defects, such as dislocations and vacancies, exist in materials, positrons are attracted and are annihilated there. Since electron density is lower in such defects, positron lifetime becomes longer when compared with the defect-free materials (Fig.1). Further, the penetration depth of positron is about 100 micron, so non-destructive inspection could be possible.

Positrons are emitted from radioactive 22Na with γ-rays of 1.27 MeV. These γ-rays act as "start" signals. As is mentioned above, γ-rays of 511 keV are emitted when positrons are annihilated with electrons. These γ-rays act as "stop" signals. The positron lifetime is defined as time interval between start and stop signals. Approximately 10^6 events are accumulated to obtain positron lifetime spectrum with sufficient accuracy.

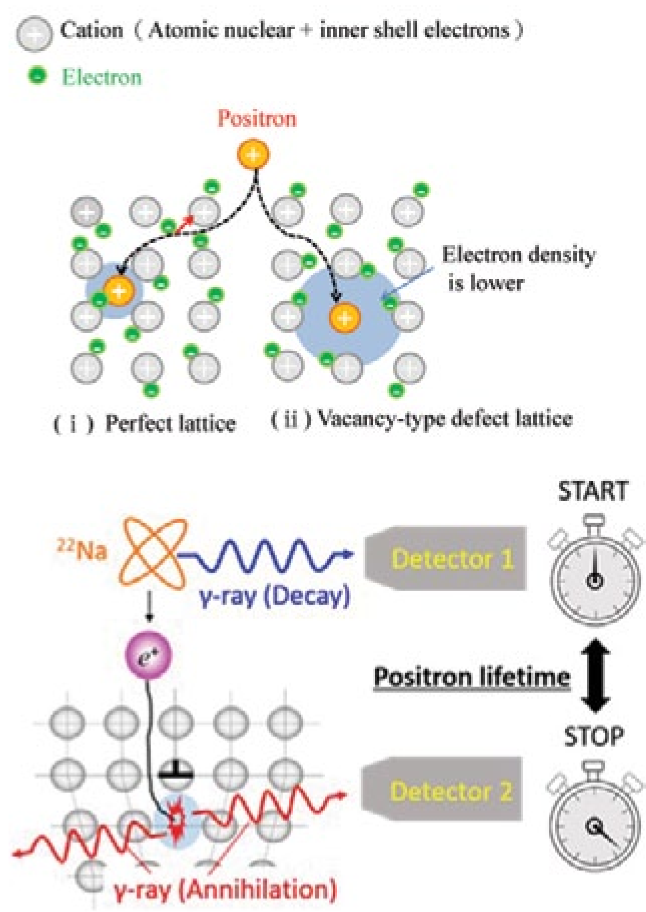

Fig. 1 The principle of Positron annihilation liftime spectroscopy

(a) Stand-alone type (b) Portable type

Fig. 2 Overview of Positron Surface Analyzer(PSA)

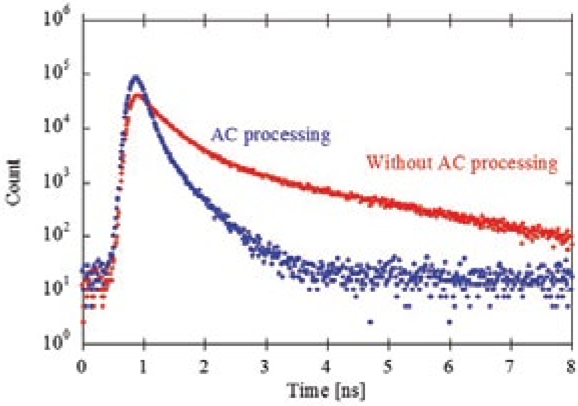

Fig. 3 Positron lifetime spectrum with and without AC processing

2.2 System of PSA

The overview of the PSA system is shown in Fig.2(a) stand-alone type and (b) portable type. The system consists of the positron source, two BaF^2 scintillation detectors, a positron detector, digital oscilloscope (DSO) and PC. The positron source is sealed radioactive sources of 22Na [5]. 22Na is sealed with two thin Kapton films. This positron source can be used without legal regulations or qualified person since radioactivity is under the lower limit. The positron detector is used for anti-coincidence processing (AC). The positron detector is composed of a plastic scintillator which is machined to fit the specimens and photo multi-amplifier tube. The positron source is sandwiched by the specimen and the positron detector. In this case half of positrons are annihilated in the plastic scintillator. When the scintillation light generated upon the passage of a positron through the plastic scintillator is coincident with positron lifetime events, these events are removed from the lifetime spectrum by anti-coincidence processing. Therefore the accuracy of measurement is largely improved even without specimen cutoff. Fig.3 shows the comparison of the positron lifetime spectrum with AC and without AC. It is obvious that the long lifetime component (attributed to noises) on the graph right side is almost removed by AC.

3. APPLICATION OF MEASUREMENT

3.1 The relationship between the positron annihilation lifetime and fatigue cycles[6]

Fig. 4 shows the relationship between the mean positron lifetime and fatigue life ratio. The mean positron lifetime increased monotonically with the fatigue life ratio. 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 just before fracture at *N/Nf* = 92%. The results shows generation and accumulation of lattice defects in fatigue process on the identical specimen.

3.2 Evaluation of shot peening effect

Fig. 5 shows the relationship between coverage and the positron annihilation lifetime at the peened Almen test strip.

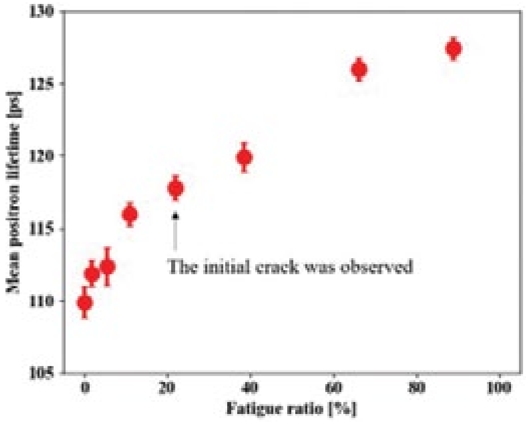

Fig.4 Relation between fatigue life ratio and positron lifetime

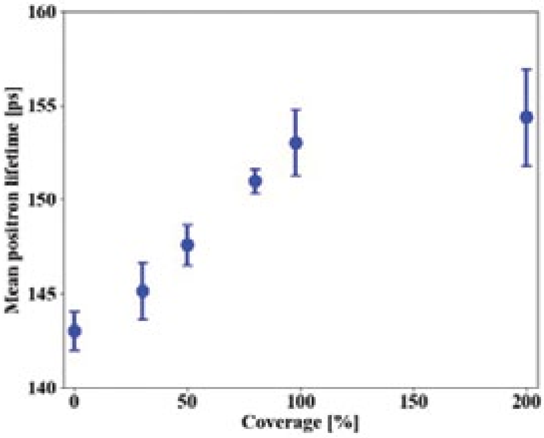

Fig.5 Relation between coverage and positron lifetime

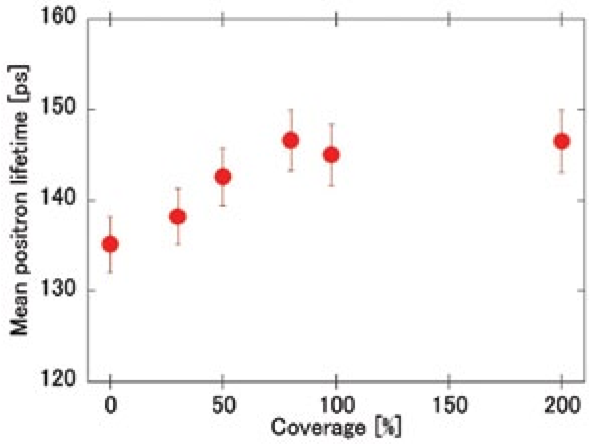

Fig.6 Relation between coverage and positron lifetime using portable PSA unit

The mean positron lifetime increased with the fatigue life ratio and saturated over 100% coverage. This tendency is very close to the saturation of residual stress profile at over 100%.

3.3 EVALUATION OF SHOT PEENING EFFECT USING PORTABLE PSA SYSTEMS

Fig. 6 shows the relationship between coverage and the positron annihilation lifetime at above peened test strip using PSA portable unit (b) at Fig.2. The mean positron lifetime increased with peening time (coverage) and saturated over 100% coverage. This tendency is very close to the results of stand-alone PSA. In conclusion, a portable PSA unit could be used for not only test specimens but also peened industrial products like coil springs and carburized gears.

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